Regulatory Processes for Setting Sensitive-Period Sea-lice Thresholds in Major Salmon Producer Jurisdictions: An Evaluation

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Executive Summary

Regional variability in the complexity of conditions affecting farm / wild fish interactions calls for a regional approach to sea-lice management. To assist evaluation of whether and to what extent the ASC may rely on the regulatory regimes of major salmon-producing jurisdictions in setting regionally (or locally) relevant "sensitive periods" and sea-lice limits, this report assesses the robustness of regulatory processes for managing the risks to wild salmonids from farm sea lice.

Two of the jurisdictions included in this assessment, the Faroe Islands and Scotland, do not regulate on-farm sea-lice levels for the purpose of protecting wild salmonids. In the Faroe Islands this is due to the limited presence of wild populations. In Scotland, however, the government has recently committed to adopting a new management system for mitigating lice-induced risks to its wild populations, although considerable uncertainty remains as to how the currently lenient on-farm sea-lice thresholds will be updated. Among the jurisdictions assessed here, Norway has implemented the strictest limit-levels for sea lice in recent years; and has, to a larger extent than the other jurisdictions, incorporated the health of wild salmonids into its decision-making through its area-based, "traffic-light" system. In Canada's British Columbia, sensitive-period trigger levels for delousing actions have remained unchanged since 2004; however, recent updates to conditions of license have enhanced enforceability, and further revisions to improve the protection of wild populations are being considered. The Irish government has not updated its trigger level for treatment since 2008, nor are further revisions planned.

In Norway and more recently Scotland, scientific consensus anchored in a growing body of research that recognizes farm sea lice as a potential hazard to wild salmonids has emerged among government bodies and research institutes. This has underpinned ongoing efforts by the Scottish government to reform its regulatory system, as well as the implementation of gradually more stringent sea-lice regulation in Norway. In Canada and Ireland, on the other hand, scientific controversy around population-level impacts has been notable. Here, aquaculture managers have relied largely on scientific research from researchers in government institutions that argue the population-regulating effects of farm lice are low to negligeable. Thus, scientific research has also underpinned the positions of the Canadian and Irish governments: that existing sea-lice regulations continue to be precautionary in nature.

Wild-salmon stakeholders have not played a major role in setting on-farm thresholds or defining the length of sensitive periods in any of the jurisdictions examined here. However, a general trend towards increasing stakeholder involvement in regulatory processes is evident. In Canada, for example, independent biologists, NGOs and First Nation rights-holders are now consulted and included in efforts to develop multi-stakeholder, area-based management systems for aquaculture in British Columbia.

All the jurisdictions examined here publish farm sea-lice data on a regular basis. In Norway and the Faroes, arrangements promoting frequent data sharing between farms are also in place. In Ireland, and Canada in particular, however, the substantial time-lags between farm sampling and data compilation, and the official publication of such data, have given rise to concerns as regards real-time data transparency in these jurisdictions.

Introduction

Indicator 3.1.7. of the ASC Salmon Standard requires farms located in areas with wild salmonid populations to comply with a maximum on-farm lice abundance of average 0.1 mature female sea lice per fish in the period of wild salmonid out-migration. There is currently no scientific, evidence-based justification for setting a maximum 0.1 sea-lice limit: the ASC has taken a precautionary approach by requiring farms to keep lice levels close to zero.

However, there is a clear rationale for moving beyond a one-size-fits-all approach: Regional variation—in environmental and biological conditions, wild salmonid species, lice species and sub-species, host profiles, water temperatures, production-area biomass, and diversity around the length of sensitive periods—calls for regional, area-based approaches to farm sea-lice regulation. This leads to the important question of whether and to what extent the ASC may rely on regulatory regimes of national or local jurisdictions to determine regionally appropriate sea-lice levels and sensitive periods.

This report has been prepared to inform the work of the Sea Lice Technical Group on revised recommendations for Indicator 3.1.7 of the Salmon Standard,[1] by evaluating the "robustness" of regulatory approaches towards setting sensitive-period limit levels in major salmon producer jurisdictions: Scotland, the Faroe Islands, Norway, Ireland, and Canada (British Columbia). The evaluation is structured around the criteria defined in the Terms of Reference (ToR) investigation outline, focusing particularly on the role of science, stakeholders and data sharing in supporting the incorporation of concerns for the health of wild salmonids in regulatory decision-making.

As outlined in the ToR, the two main questions, and the set of sub-questions, are:

1. *Does the jurisdiction incorporate the health of wild salmonid populations into its regulatory decision-making?*
    - Does the jurisdiction provide a space of consultation and input from diverse stakeholders, including advocates of wild salmonids and rights-holders, indigenous peoples in particular? With what frequency?
    - In the face of uncertainties, does the jurisdiction seek out answers through research and analysis around the interactions between wild fish and farms?
    - Is there evidence that this research and public input have had an impact on decision-making by the jurisdiction?
    - How frequently are these regulations updated, and what triggers a revision?
2. *Does the jurisdiction actively promote and practice transparent data sharing from, with, and between farms?*

[1] See: Review - Salmon - 3.1.7 - ASC International (asc-aqua.org)

Methodology

This evaluation draws upon a range of sources, including peer-review literature, government reports and presentations, policy and legislative documents, and written correspondence and semi-structured interviews with a total of 25 key informants. Interviews were based on a common interview guide reflecting the ToR evaluation criteria, adjusted to local circumstances and the positions of the interview objects. Interviews generally lasted between 45 and 90 minutes; all were transcribed, to enable systematic analysis.

To provide some anonymity, this report does not refer directly to statements made or information provided by informants in interviews or through written correspondence.

The following persons participated as informants in interviews and through written correspondence:

- Kerra Shaw, Regional Manager, Aquaculture Management, Department of Fisheries and Oceans (DFO), Canada
- Laura Sitter, Veterinarian, Aquaculture Management, Department of Fisheries and Oceans (DFO), Canada
- Danny O'Farrell, Stewardship Biologist, Maaqutusiis Hahoulthee Stewardship Society (MHSS), Ucluelet, BC, Canada
- Sean Godwin, Dept. of Biology, Dalhousie University, Canada
- Mack Bartlett, Executive Director and Director of Research, Cedar Coast Field Station, BC, Canada
- Karen G. Wristen, Executive Director, Living Oceans Society, West Vancouver, BC, Canada
- Kelly Roebuk, Sustainable Food Campaigner, Living Oceans Society, Canada
- Jared Dick, Regional Fisheries Biologist, Uu-a-thluk Fisheries, Nuu-chah-nulth Tribal Council, BC, Canada
- Lance Stewardson, RPBio. CPESC, Mainstream Biological Consulting Inc., Campbell River, BC, Canada
- Marc LaBrie, Director of Development, West Coast Aquatic, Port Alberni, BC, Canada
- Paddy Gargan, Fishery Biologist and Senior Research Officer, Inland Fisheries Ireland, Dublin, Ireland
- Neil Ruane, FEAS Aquaculture Manager, the Marine Institute, Galway, Ireland
- Kristin Eliasen, Head of the Fish Health Department, Fiskaaling, the Faroe Islands
- Esbern Patursson, Biological Development, Hiddenfjord, Faroe Islands
- Else Marie Djupevåg, Senior Advisor, the Food Safety Authority (FSA), Norway
- Sigurd Hytterød, Chief Advisor, Norske Lakseelver (Norwegian Salmon Rivers), Norway
- Kari Helgesen, Veterinarian and Senior Researcher, the Veterinary Institute (VI), Norway
- Ørjan Karlsen, Senior Researcher, Institute for Marine Research (IMR), Norway
- Alan Wells, CEO, Fisheries Management Scotland, Edinburgh, UK
- Charlotte Middleton, Aquaculture Interactions Manager, Fisheries Management Scotland, UK
- Richard Beckett, Head of Standards, Scottish Salmon Producers' Organisation (SSPO), UK
- Simon Ryder-Burbidge, Marine Conservation, Nova Scotia, Canada

The following persons participated as informants through written correspondence:

- Roar Heini Olsen, Advisor, Food and Veterinary Authority, Faroe Islands
- Jill Barber, Head of Aquaculture Development, The Scottish Government, UK.
- Ron Smith, Technical Manager, Fish Health Inspectorate (FHI), Marine Scotland Science, UK.

Scotland

Does the jurisdiction incorporate the health of wild salmonid populations into its regulatory decision-making?

The existing regulatory regime governing salmon aquaculture in Scotland is not designed to address interactions between farms and wild fish. Farm sea lice has been primarily regulated, monitored, and enforced by the sea-lice policy of Marine Scotland's (MS) Fish Health Inspectorate (FHI), whose objective is to prevent, control, and reduce sea-lice parasites in aquaculture pens—not to protect the health of wild populations.[2] The regulation requires license holders to inform the FHI upon reaching or exceeding an average of 2.0 adult female *L. salmonis* per fish, which will then trigger increased FHI monitoring. If sea-lice levels reach or exceed an average of 6.0 adult females per fish, license holders are required to bring levels down to meet the Scottish Salmon Producer Organization's voluntary Code of Good Practices (CoGP), and the suggested criteria for treatment/management actions, set to 0.5 adult female *L. salmonis* per fish in the period February 1st to June 30th.[3] The MS and FHI policy does not delineate a sensitive period.

Trigger levels have been updated only once since their adoption in 2007. The notification threshold of 2.0 has remained unchanged, but the intervention limit was lowered from 8.0 to 6.0 in 2019. This was the result of concerns and debate around farmed fish welfare, and not the potential impacts on wild populations.

However, an ongoing process towards reforming Scottish aquaculture aims to establish a new management system for governing potentially hazardous impacts of farm sea lice on wild salmonid populations. The reform process was triggered by two parliamentary inquiries by the Environment, Climate Change and Land Reform Committee (ECCLR) and the Rural Economy and Connectivity (REC) committee in 2018, focusing on the environmental impacts of salmon aquaculture and the negative effects on wild salmonids. These inquiries concluded that the maintaining the status quo was no longer an option, and the government subsequently made a political commitment to reform the regulatory system. The Salmon Interactions Working Group (SIWG), established that year, included members from the aquaculture and wild fisheries sectors, Scottish Environment Link, Marine Scotland, the Scottish Environment Protection Agency and NatureScot. In April 2020, the SIWG published 40 recommendations on measures to address farm and wild fish interactions; in October 2021, the government published its formal response to the SIWG recommendations. Meanwhile, the ruling Scottish National Party (SNP) also pledged to reform salmon farming, and to determine a single, government authority

[2] The policy regime is anchored in the Aquaculture and Fisheries (Scotland) Act of 2007, in legislative requirements of The Fish Farming Businesses (Record Keeping) (Scotland) Order 2008, and more recently also in The Fish Farming Businesses (Reporting) (Scotland) Order 2020. Significant exceedance of thresholds set also requires farmers to follow the Scottish Salmon Producer Organization's voluntary Code of Good Practice (CoGP). See 'The Regulation of Sea Lice in Scotland', Marine Scotland, 2021. URL: 71+The+Regulation+of+Sea+Lice+in+Scotland+2021.pdf (www.gov.scot)

[3] If the farm does bring levels down but not below the CoGP criteria, an advisory letter will be issued to alert of the breech; after four more weeks, if levels do not continue to reduce below 2.0, an enforcement notice will be issued. If the farm does not reduce below 6.0 within four weeks, a warning letter will be issued, and after two more weeks, an enforcement notice will follow.

responsible for farm/wild interactions. For this purpose, they requested an independent review of the current regulatory framework.[4]

While it is difficult forecast the outcome of an ongoing reform process, a few key points may be identified: First, the government has acknowledged and concluded that farm sea lice represent a potential hazard to wild salmonid populations. Second, the government will assign responsibility for managing risks to wild salmonids from sea lice emitted from fish farms in Scotland to the Scottish Environmental Protection Agency (SEPA). In the current regime, SEPA is responsible for issuing licenses "to pollute" under the Water Environment (Controlled Activities) (Scotland) Regulations 2011. These "CAR licenses" set the limits for levels of pollutants that farms may discharge to the water environment, although they currently cover the use of sea-lice therapeutants, they do not regulate sea lice or emissions of sea-lice larvae into the wild. Third, SEPA is instructed to build on the work of the Regulators Technical Working Group in further developing proposals for an "adaptive, spatially-based risk assessment framework" to manage sea-lice interactions between farmed and wild salmonids. The framework will be applied through the CAR licensing regime, and SEPA will undertake public consultations on proposals. The framework is intended to create industry growth, including new farms and expansions of existing farms. It is intended to be adaptive: responsive to actions by salmon producers (e.g. to reduce lice levels), and the growing scientific evidence base on farm/wild interactions. The aim is to include tracking studies of wild salmonids, for better knowledge on smolt out-migration, and to invest in the development of lice-dispersion models.

Although scientific studies of interactions between wild fish and farms have been fewer in Scotland than in neighboring Norway and Ireland, the evidence-base relevant to assessing risks and effects of farm lice for Scottish wild salmonids has grown over the past decade.[5] In facing concerns and uncertainties related to the health of its wild salmonid populations, the Scottish government has increasingly sought out answers from such research and analysis. This is evident from the ongoing regulatory reform process. For example, Marine Scotland have conducted regular reviews of peer-review research on farm lice impacts for wild salmon and sea trout. In March 2021 they published a summary of science, which the government has referred to as the scientific basis for its official acknowledgement of the need to reform the regulatory system to deal effectively with hazards to Scottish wild salmonids.[6] Marine Scotland Science (MSS) has been a central actor in the development of the spatially-based sea-lice risk assessment framework, intended to govern Scottish aquaculture if reform proposals become operational. Thus, research and analysis on farm/wild interactions have increasingly begun to inform and impact government decision-making related to regulatory change.

This evidence-base has also empowered wild salmon stakeholders and NGOs, who have long argued for change. Wild salmon stakeholders have been involved with the MS, the FHI, SEPA and Scottish politicians, and the ongoing reform process accord them considerable space for providing inputs at multiple stages of deliberation and decision-making. The official request for an independent review of the regulatory regime includes a long list of stakeholders that should

[4]The first stage of the review process is to conclude by the end of November/mid-December 2021. See: URL: Aquaculture: external review of the current regulatory processes involved in fish farming - gov.scot (www.gov.scot)

[5] See e.g. Butler 2002, Butler and Watt 2003, McKibben and Hay 2004, Middlemas et al. 2013, Susdorf et al. 2018, and Impacts of lice from fish farms on wild Scottish sea trout and salmon: summary of science - gov.scot (www.gov.scot)

[6] Impacts of lice from fish farms on wild Scottish sea trout and salmon: summary of science - gov.scot (www.gov.scot)

be consulted in the evidence-gathering process.[7] Furthermore, SEPA will consult widely on their proposals for a new management framework.

Wild salmon stakeholders also played a role in the process for adopting a mandatory sea-lice sampling and reporting regime in 2020 (see details below). Reporting and data transparency were discussed in the negotiations for a revised Aquaculture and Fisheries (Scotland) Act in 2013; however, this resulted mainly in an SSPO commitment to and initiation of voluntary reporting.

Does the jurisdiction actively promote and practice transparent data sharing from, with and between farms?

The lack of robust and transparent sea-lice data has long been a major concern of wild salmon stakeholders in Scotland. Until 2020, the Marine Scotland/FHI only required license holders to report if the 2.0 trigger level were met or exceeded. However, the new Fish Farming Businesses (Reporting) order 2020 requires mandatory sea-lice reporting for *all* aquaculture-production businesses. After this order entered into force in 2021, sea-lice counts must be reported on a weekly basis, irrespective of the average levels per fish; if no count is conducted, a reason must be provided. Fish farmers must report the average number of adult female (gravid and non-gravid) *L. Salmonis* counted per fish per site in the reporting week.

The government publishes sea-lice data within two weeks of receiving the weekly reports.[8] Further, all sea-lice data are made publicly available through the Scotland Aquaculture Website.[9] In its response to the SIWG, the government has stated that it is unable to direct wild and farmed salmon interests to publish historical data. On the other hand, the Scottish regime has improved significantly with respect to data sharing.

The Faroe Islands

Does the jurisdiction incorporate the health of wild salmonid populations into its regulatory decision-making?

The Faroese regulatory system for salmon aquaculture does not incorporate concerns for the health of wild salmonids—primarily because there are no naturally spawning populations of Atlantic salmon in the Faroe Islands. Freshwater bodies are limited, with most streams being short, narrow and fallow. However, Faroese deep-sea waters are natural feeding grounds for wild Atlantic salmon, and the Island have a native sea-trout stock.

Sea-lice levels are managed by the Faroese Food and Veterinary Authority through conditions of license. The main purpose of setting lice limits for salmon farms is to reduce the distribution of sea lice and sea-lice larvae between aquaculture facilities. License-holders are required to keep levels below a maximum average of 0.5 adult female *L. salmonis* per fish from May 1 to

[7] Aquaculture: external review of the current regulatory processes involved in fish farming - gov.scot (www.gov.scot)
[8] Fish Health Inspectorate: sea lice information - gov.scot (www.gov.scot)
[9] Scotland's Aquaculture | Home

July 31, and below 1.0 per fish the rest of the year.[10] Thresholds have been updated several times since 2016: from an initial level of 2.0 to 1.5, then 1.0, and finally 0.5 for the spring period in 2021.[11]

These threshold updates were triggered by studies of optimal lice-treatment thresholds to mitigate the spread of sea lice between aquaculture facilities, and related industry pressure to lower thresholds to prevent costly, cross-farm lice infections.[12] Some companies want an even stricter, year-round threshold of 0.2 or 0.1, arguing that lice-levels close to zero most effectively prevent infectious sea-lice larvae from spreading with (tidal) currents around the Islands—enabling higher profits for farm networks, thanks to the diminishing need for delousing actions. Also, the adoption of a sensitive period in 2020 was triggered by industry pressure. As many ASC-certified aquaculture farms in the Faroes must comply with the Salmon Standard's sea-lice indicator, they asked the government to delineate a sensitive period—even if the purpose of regulation is not to protect *wild* salmonids. The duration of the sensitive period was based on initial research and data on sea-trout migration from 2019[13] related to a new research project aimed at increasing knowledge about Faroese sea trout, led by P/F Fiskaaling Ltd.—which is also responsible for sea-lice sampling and reporting (see below).

Whether regulators respond to research and analyses on wild/farm interactions, and incorporate the concerns of wild-salmon stakeholders in their decision-making, appears be of less relevance for the Faroese context. The main stakeholder and input provider is industry,[14] which has only recently begun to monitor the sea-trout stock, with Fiskaaling collecting new data on out-migration in rivers, sampling some 50 sea trout individuals annually since 2019.

Does the jurisdiction actively promote and practice transparent data sharing from, with and between farms?

In the Faroes, sea-lice sampling and counting are conducted by an independent third party, P/F Fiskaaling. Mature female *L. salmonis* must be counted from every cage at least once a fortnight. Fiskaaling reports its counts to the authorities the same day, or one day afterwards at the latest, as well as sharing sea-lice counts with other companies. Fiskaaling holds monthly meetings for aquaculture companies, where actors go through all sea-lice data collected during the past month and backwards, to discuss the evolving lice situation. Data are made public by

[10] For the current executive order on lice management from 2016, amended and tightened with lowering threshold the same year, and in 2019 and 2021, see:
https://www.logir.fo/Kunngerd/75-fra-28-06-2016-um-yvirvoku-og-talming-av-lusum-a-alifiski

[11] The enforcement regime involves requirements for fallowing and a complex system of penalty points for threshold exceedance and treatments. A farm that exceeds the maximum set threshold three times in a row, or four times in the same production cycle, must harvest its salmon within 11 weeks. However, if the salmon weigh <4 kg, an exemption may be requested.
Penalty points are accorded for each chemical treatment, where each type of chemical leads to one penalty point and a partial treatment of the site leads to partial penalty points. As regards breaches to the threshold limit, e.g. in the period where the threshold is 1.0 adult females per fish, one penalty point is given if the site on average has 1.0 adult females per fish, two penalty points are given if the site on average has 2.0 adults females per fish, and so on. If a farming site receives less than 8 penalty points in a production cycle it can apply for an increase in the number of salmon in the next production cycle; if it receives from 8 to 15 penalty points, it will not be allowed to increase the number of salmon in the next production cycle; and if it receives 16 or more penalty points it will be required to reduce the number of salmon in the next production cycle.

[12] E.g. Patursson et al. 2017, Kragesteen, et al. 2019, 2021.

[13] Research Projects (fiskaaling.fo)

[14] There is only one NGO working in collaboration with industry to collect wild sea trout and salmons, taking roe and sperm to fertilize and release smolts.

the Faroese Food and Veterinary Authority.[15] Information is updated daily, and must appear on the website no later than 7 days after it becomes available to the Faroese Food and Veterinary Authority.

Norway

Does the jurisdiction incorporate the health of wild salmonid populations into its regulatory decision-making?

The Norwegian regulatory regime for salmon aquaculture addresses potential hazards to wild salmonid populations from farm sea-lice through several types of regulations. First, the Food Safety Authority is responsible for enforcing maximum levels of average sea lice per fish in aquaculture pens.[16] Since 2013, all license-holders have been required to keep lice levels below a maximum average of 0.5 adult female *L.salmonis* per fish, which replaced a 0.5 trigger level for treatment. In 2017, the regulation was further updated, introducing the requirement to maintain lice levels below 0.2 in the period of salmonid out-migration, which was set to weeks 16–21 in the southern part of Norway, and weeks 21–26 in the northern part of Norway.[17] The absolute sea-lice limits in the sensitive period replaced the previous requirement to conduct "spring delousing."

The updates were triggered by a combination of growing political concerns and scientific consensus on the potentially hazardous impacts of farm sea lice on the health of wild salmonid populations in Norway.[18] The 0.2 limit was intended to be precautionary, but the decision-making process prior to its adoption was also partly anchored in research. The Institute for Marine Research (IMR)—a "neutral" knowledge-provider and advisor on farm and wild fish interactions associated with the Ministry of Trade, Industry and Fisheries—ran models simulating the effects of different thresholds. However, setting the limit at 0.2 (and not 0.1) was also a decision based on farm data, where consideration was given to what was possible, given existing sampling/counting techniques, and without having to undertake excessive delousing, to minimize welfare concerns.[19] The lengths of the sensitive periods were based on out-migration data. However, only some rivers had been monitored; others were modelled. Based on input from the IMR, where researchers now include more rivers in the monitoring program, the FSA is seeking to extend the length of the sensitive periods from 6 to 8 weeks, aiming to be more precautionary by covering early as well as late migration. Thus, new evidence and research have been central in decision-making related to regulatory updates.

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[15] Lúsatøl (hfs.fo)

[16] Until 2012, the government set a trigger level for treatment at 0.5 average mature female lice per fish. The maximum limit was established with the regulation on combating sea lice in aquaculture facilities, implemented in 2013, and amended in 2017/2018.
Forskrift om bekjempelse av lakselus i akvakulturanlegg - Lovdata

[17] Certain licenses have stricter sea lice limits, such as "green licenses" (limits between 0.1 and 0.25), and for sites that were granted capacity increases in 2015, conditional on keeping sea-lice levels below 0.2

[18] E.g. Finstad et al. 2000, Heuch and Mo 2001, Skilbrei and Wennevik 2006, Forseth et al. 2010, Bjørn et al. 2011, see also the Office of the Auditor General's Investigation of Aquaculture Management, dok 3:9, 2011-2012: Riksrevisjonens undersøkelse av havbruksforvaltningen - PDF Free Download (docplayer.me)

[19] Due to increasing resistance to therapeutants, farmers must rely primarily on mechanical delousing methods, which often cause increased farm-fish mortality. Therefore, FSA is currently considering how better to incorporate farm-fish welfare into the lice regulation.

Moreover, Norway has gone further than setting sea-lice thresholds for fish farms, by adopting a new, area-based management system in 2017 that regulates aquaculture biomass based on sea-lice infestation levels in the wild (the "Traffic Light System"). This system is based on risk assessments of wild salmon mortality for 13t production areas (PAs) in Norway. Risk levels are set by an expert group composed of scientists from the IMR, the Veterinary Institute (VI) and the Norwegian Institute of Nature Research (NINA).[20] Mortality risk assessments are based on a combination of hydrodynamic dispersion models, which predict the spread of lice larvae from production sites, on the basis of reported lice levels, sea temperature, and water currents; and data from the national surveillance program for salmon lice on wild salmon (NALO), which are used to verify the models.[21] The conclusions of the expert group are considered by a steering group, who advise the Ministry of Trade, Industry and Fisheries on their decision to allow growth, freeze growth or request a reduction of farm biomass in the various PAs.[22] License-holders within a "high-risk," "red" PA requested to reduce biomass may apply for an increase in site biomass if they can demonstrate compliance with maximum average of 0.1 mature female lice per fish.

Norway's traffic light system provides an example of how uncertainties related to farm and wild fish interactions, and the growth of related research and analysis, have been drivers behind the new forms of aquaculture and sea-lice regulation. Moreover, national research institutes have become key knowledge providers in decision-making. Research conducted by scientists at institutes involved in government decision-making has acknowledged the persistence of uncertainties regarding the scale of population-level impacts, but a consensus has now emerged: farm lice have hazardous, sub-lethal and potentially lethal effects on wild salmonids.[23] This scientific consensus has served to enable, underpin, and justify the increasingly precautionary approach adopted by the Norwegian government.[24]

The FSA, which does not have its own, in-house science branch, also meets and consults regularly with these research institutes. For example, the FSA may approach the IMR with questions and ask for advice on how to manage new problems and uncertainties. In turn, the IMR may also approach the FSA with new, and important evidence or knowledge, providing inputs when regulatory proposals are drafted—i.e. in advance of formal, stakeholder consultation rounds. As part of the current process to update the sea-lice regulation,[25] the IMR

[20] The VI is a public-sector research institute that conducts monitoring and risk assessment related to fish health, associated with the Ministry of Agriculture and Food, and provides advice to the Ministry of Industry and Fisheries. NINA is an independent research institution that conducts research related to coastal marine environments.

[21] NALO is conducted by IMR on behalf of the Norwegian Food Safety Authority The aim of the program is to obtain robust data on salmon-lice infestation on wild salmonids in all production areas. Field surveys are conducted from late April till early August; quality assured data are published annually. See: https://www.hi.no/hi/nettrapporter?query=&fast_serie=overvaking-lakselus

[22] License-holders within a PA deemed to have an "acceptable" impact on wild salmon ("green light") may buy a set percentage increase in production volume at a fixed price from the government (2% in 2018 and 1% in 2020). They may also participate in auctions where allowances to increase production volumes by up to 6% are sold, after added volumes bought at fixed price have been deducted. License-holders within a PA deemed to have a "moderate" impact ("yellow light") are allowed to maintain current production volumes; license-holders within a PA deemed to have an "unacceptable" impact will be required to reduce production volumes by 6%.

[23] E.g. Thorstad et al. 2012, Skilbrei et al. 2013, Torrissen et al. 2013, Vollset et al. 2016, Vollset et al. 2018, Bøhn et al. 2020, Johnsen et al. 2021

[24] Of course, politics also permeate what is intended to be a science- and knowledge-based regulatory system. In several cases, the government has set a different traffic light (allowing growth or freezing growth) than recommended by the expert group

[25] See Ny lakselusforskrift | Mattilsynet

requested the FSA to propose that sea-lice counts and reports on treatments be dated. That is now included in the proposal regulation.

Moreover, the FSA are required to consult a wide range of stakeholders prior to any regulatory amendment. In formal consultation rounds, stakeholders provide written inputs and comments on proposals. For example, the FSA received a total of 40 comments on the most recent proposal for updating the sea-lice regulation. Wild-salmon interest organizations also meet regularly with politicians, the Ministry, the FSA, and other agencies. It is beyond the scope of this report to assess the weight given to the concerns of major stakeholders, such as wild-salmon interests and industry associations; however, the FSA holds that the inputs of research institutes are prioritized, given the goal of a knowledge-based regulatory system.

Does the jurisdiction actively promote and practice transparent data sharing from, with and between farms?

Since 2012, aquaculture license-holders have been required to conduct weekly counts and file weekly reports to the FSA that include the average number of motile lice, mature female lice and sedentary stages of *L. Salmonis* per fish in all production cages.[26] In addition, they must report the type of delousing measures used to keep levels below the set limits. The FSA publishes lice data close to real time, and shares the data on a weekly basis with the industry and NGOs. Full public access is provided through two sites, lakselus.no and Barentswatch.no. Every week the IMR, on behalf of the FSA, also compiles a sea-lice and biomass report from each Norwegian production area, which is shared with the industry. These reports include scenario models predicting the lice situation in the next weeks, so that farmers may plan future delousing measures. Today, license-holders are not required to report the time and day of sampling, which in theory enables a farmer to undertake a count *after* a delousing treatment.

Ireland

Does the jurisdiction incorporate the health of wild salmonid populations into its regulatory decision-making?

The Irish regulatory regime is aimed at mitigating potential risks to wild salmonids from farm sea lice by setting treatment thresholds for aquaculture pens, mainly through conditions of license. These are managed by the Aquaculture Foreshore Management Division (AFMD) of the Department of Agriculture, Food and the Marine (AFM).[27] Since 2008, license-holders have been required to instigate treatment or management action to reduce sea-lice levels when these reach or exceed an average level of 0.5 ovigerous (egg-bearing) *L. salmonis* per fish in the sensitive period from March 1 to May 31. This requirement was added to an existing year-round trigger level for treatment set at an average of 2.0 lice per fish.[28]

[26] With water temperatures below 4°C, they may report every other week.

[27] License conditions are anchored in the Fisheries (Amendment) Act of 1997. Moreover, several associated regulations have been amended to give effect to various EU environment protection Directives. See gov.ie - Aquaculture & Foreshore Management (www.gov.ie)

[28] The Single Bay Management also facilitates coordinated lice management, with synergistical stocking, fallowing and treatment regimes for neighboring farms. See https://www.marine.ie/Home/site-area/areas-activity/aquaculture/sea-lice/single-bay-management

This update was the result of a processes instigated by the government, which requested an examination and review of the existing system for sea-lice control in marine finfish farms. For this purpose, the government established a Sea Lice Monitoring and Control Working Group comprised of representatives from the Department of Communications, Marine and Natural Resources (then responsible for aquaculture), the Marine Institute (the state agency responsible for marine research), the Fisheries Boards, and the Bord Iascaigh Mhara (Irish Seafood Federation). However, the group was unable to reach consensus on recommendations for moving forward. Responsibility for aquaculture licensing was then transferred to the Department of Agriculture, Fisheries and Food (now AFM). In 2008, they developed a pest-control strategy,[29] and worked closely with the Marine Institute (MI) on updating the treatment trigger level in the out-migration period. The 0.5 trigger level for treatment was intended to be precautionary, to ensure mitigation of potentially negative effects of farm sea lice. However, setting the level at 0.5 was also a pragmatic decision anchored in farm data, taking into consideration what was achievable. In other words, there was no scientific evidence-base or analysis conducted to justify the threshold level. The duration of the sensitive period was based on data collected from rivers which had fish counters/trap data regarding the out-migration of Atlantic salmon smolts. In Ireland, migration generally picks up in April and peaks around early May; most of the fish have migrated by the end of May. A start date of March 1 was decided, to ensure that sea-lice levels would be low on all farms before the start of out-migration. Stakeholders were not involved in the process of setting thresholds and defining the length of the sensitive period; there has been no updating since then.

In 2016, the Department of Agriculture, Fisheries and the Marine requested a review of the complex, aquaculture licensing process.[30] That also led to discussions between the Department and the Marine Institute (MI) about a potential revision of the sea-lice control strategy. According to MI, there is no new research or analysis on optimal sea-lice thresholds that would call for such a revision: thus, any future update of the threshold would be a political decision.

The MI appears to be the main provider of knowledge-based advice to the Department. There exists a substantial body of research from MI scientists on farm / wild fish interactions.[31] MI researchers find that farm sea lice represent a small and irregular component of wild salmon marine mortality, and argue that it is unlikely to have significant, population-level impacts.[32] However, researchers at the Inland Fisheries Ireland (IFI)—a state agency under the Department of Environment, Climate and Communications, responsible for protecting wild salmonid populations—argue that sea-lice induced mortality does have significant effects on Atlantic salmon returns, and that farm lice represents a serious hazard for sea-trout populations.[33] MI studies have also been rebutted by other, non-IFI scientists.[34] The diverging positions of MI and IFI demonstrate the existence of significant scientific controversy in Ireland on the issue of population-level effects from farm lice.

The controversy also appears to affect government decision-making. The IFI does not have a formal or informal role as knowledge provider for the Department of Agriculture Food and the Marine. To date, IFI concerns and suggestions for regulatory reform have not been incorporated

[29] Strategy for improved pest control on Irish salmon farms, Department of Agriculture, Fisheries and Food, 2008. 98907_1fb6f9a3-10f9-4115-888a-ae03f6d07c61.pdf
[30] See: http://www.fishingnet.ie/media/fishingnet/content/ReviewoftheAquacultureLicensingProcess310517.pdf
[31] See Sea Lice | Marine Institute
[32] Jackson et al. 2011, Jackson et al. 2013 and 2013b,. See also Sea Lice | Marine Institute
[33] Gargan et al. 2012, Shepard and Gargan 2017, 2021
[34] Krkosek et al. 2013

in regulatory decision-making. For example, the IFI have continually stressed the need for sea-lice levels close to zero, arguing that the current 0.5 trigger level leads to inadequate protection of wild salmonids. They hold that sea-lice conditions should include absolute enforcement levels for both mobile *L. salmonis* and *Caligus Elongatus*. In addition, they have been pushing for a 'total bay cap': setting a total lice load limit in aquaculture bays during spring migration.

The position and key role of the MI as knowledge-provider in decision-making related to sea-lice regulation show that the Irish government has sought out answers to uncertainties regarding farm and wild fish interactions by relying largely on research that represents only one side of the scientific debate. The fact that the sea-lice regulation has remained the same since 2008 also shows that the department has thus far disregarded input from IFI—a public research institution responsible for wild salmonid protection.

Wild-salmon stakeholders and advocates have not been consulted regularly, and their role in regulatory-decision making within the Department of AFM appears limited. However, stakeholders frequently utilize an alternative and potentially powerful channel of influence: the independent Aquaculture License Appeals Board (ALAB).[35] When a new license or license renewal is granted, stakeholders can file an appeal within one month of publication (in the case of a decision) or notification (in the case of revocation/amendment). NGO activists, wild-salmon advocates and the IFI have often lodged appeals related to negative environmental impacts and farm sea lice. Appeals have put a halt to license approval or renewal processes, and have resulted in significant changes in license conditions. For example, in the 1990s, appeals made by the IFI and environmental NGOs resulting in stricter sea-lice trigger levels for treatment (0.3) and for the licenses subject to appeal.

Does the jurisdiction actively promote and practice transparent data sharing from, with and between farms?

Independent inspectors from the Marine Institute (MI) are responsible for monitoring sea-lice levels in salmon farms, and for enforcing the treatment threshold. Bi-weekly sampling is conducted in the sensitive period; for the rest of the year, sampling is conducted on a monthly basis. The MI compiles monthly reports of farm sea-lice levels, which include counts of the average level of ovigerous and mobile *L. salmonis* and *Caligus Elongatus* per fish.[36] These reports are shared with the Department of Agriculture, Food and the Marine, and a range of other stakeholders, including the IFI and the regional fisheries board. However, live, real-time data are not publicly available. Results are reported back to farms within five days of inspection; if a fish farm exceeds the 0.5 threshold, the MI will aim to report back to the farm as soon as possible.

[35] The Board was established in 1998 under section 22 of the Fisheries (Amendment) Act of 1997. See: ALAB - Home

[36] Irish Fisheries Bulletin, Nr 52, 2020: 125853 Marine Institute Irish Fisheries Bulletin 52.indd

British Columbia, Canada

Does the jurisdiction incorporate the health of wild salmonid populations into its regulatory decision-making?

The Department of Fisheries and Oceans (DFO), Canada, which is responsible for both the protection of wild salmonids and for managing salmon aquaculture in British Columbia (BC), regulates risks to the health of wild populations mainly through conditions of license. When the responsibility for aquaculture was transferred from the province level to the federal government in 2010,[37] the DFO adopted the BC jurisdiction's existing sea-lice conditions (from 2004), requiring license holders to undertake delousing actions when an average of 3.0 motile *L. salmonis* per fish in the sensitive period from March 1 to June 30 was reached or exceeded. For the rest of the year, license-holders were required to notify the DFO upon exceeding the 3.0 threshold. These conditions apply to farmers of Atlantic salmon; farmers of Pacific salmon (chinook and coho), are to notify the DFO upon exceeding 3.0 in the sensitive period.

A literature review was conducted prior to setting the 3.0 threshold; however, the figure arrived at was not based on research or BC-specific knowledge, but was a 'best guess' of what might be precautionary at the time. The out-migration window was largely evidence-based, drawing on migration data that covered all salmonid species in BC. The intention behind setting sea-lice conditions of license was to mitigate risks for wild populations. External stakeholders did not play a role in setting the threshold or defining the length of the sensitive period. The 3.0 trigger level for treatment and the duration of the sensitive period have not been updated since, and the DFO believes that the current threshold and out-migration window remains precautionary in nature.

However, in 2020 the Department made a series of updates to the sea-lice conditions, aimed at increasing the enforceability of the threshold. First, license holders were required to bring sea-lice levels down below 3.0 motile lice per fish within 42 days upon exceeding the threshold.[38] Second, a pre-migration window from February 1 to 29, was added, requiring farmers to notify the DFO of planned delousing measures to ensure they will be under the threshold by the first day of out-migration. Third, the sampling and reporting requirements were tightened (see section on data transparency).

These revisions were triggered by political attention in 2018 to reports of a sea-lice outbreak in Clayoquot Sound on the west coast of Vancouver Island following the emergence of resistance to SLICE (a treatment for all parasitic stages of sea lice) and the lack of alternative chemotherapeutics or mechanical delousing equipment.[39] After independent biologists and wild-salmon NGOs had alerted the media, bringing the issue to the DFO Minister's attention, the aquaculture management division was requested to update the conditions of license to improve the enforceability of the threshold.

[37] In 2008, a federal court case challenging the authority of the provincial government to be the lead regulator of salmon aquaculture led the court to appoint the federal government as lead regulator

[38] Previously, there had been no set deadline for when farmers were required to get back under the threshold limit.

[39] See, for example Sea lice outbreak threatens Clayoquot salmon – Today In BC

The DFO is considering another update of sea-lice conditions in 2022 when many licenses will be up for renewal.[40] This time the DFO has consulted stakeholders more widely than in previous rounds of license renewals, to get initial inputs on the type of changes to aquaculture management that may be needed. First, the DFO is considering shortening the period of 42 days required to bring sea-lice levels back below the 3.0 threshold. The independent research community and wild-salmon NGOs have long argued that license-holders should not be allowed to stay above 3.0 for as long as six weeks, as that could result in volatile sea-lice levels in the sensitive period.[41] Second, they have advocated for setting farm-level thresholds related to the total lice load in a farm or farming area. As the size and thus biomass of many farms has grown over time, so has the abundance of sea lice—irrespective of the license-holders' ability to keep average levels per fish below 3.0. In response to this argument, the DFO is exploring how to link farms size to lice thresholds. Thirdly, researchers and wild-salmon stakeholders have pressed for the adoption of a management system for farms based on monitoring of salmonids and sea-lice levels in the wild. However, the DFO remains skeptical of regulating farms on the basis of wild salmonid monitoring or modeling of risks based on sea-lice infestation levels.

Reluctance towards such reform relates to the lack of scientific consensus on farm / wild fish interactions in the BC context, and the position of researchers within the DFO's in-house "science branch" on population-level impacts. DFO scientists have conducted considerable research and analysis on the effects of farm sea lice, and provide regular input and advice to the DFO aquaculture management division. Although there are opposing views within the DFO science branch, and some DFO studies show that the physiological impact of *L. salmonis* on Pacific salmon species, particularly sockeye salmon, may be greater than for Atlantic salmon,[42] most DFO researchers have argued that risks associated with farm lice have been exaggerated[43]. The position of the DFO aquaculture management division echoes this view: that farm lice do not represent a significant threat to the abundance and population productivity of wild salmonids.[44] However, a substantial body of research developed by independent scientists concludes otherwise, stressing the importance sub-lethal and indirect effects of farm lice on the health of wild populations,[45] and demonstrating the existence of significant population-level impacts, albeit through correlational studies.[46]

While the DFO has sought out answers to uncertainties related to farm / wild fish interactions from research and analysis, they have mainly drawn on the work and arguments of in-house scientists arguing that population-level effects of farm lice are low to negligible. However, in the latest round of consultations related to future license renewals, the DFO is considering two out of three reform proposals advocated by the independent research community.

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[40] Under the National Fisheries Act, the DFO may issue multi-year licenses of up to nine years; in practice, however, salmon aquaculture licenses are issued for six years at a time. In line with the principle of adaptive management, the DFO considers a reassessment of license conditions upon renewal.

[41] The 42 days was originally based on an estimate of how much time was needed for therapeutants such as SLICE or other delousing measures to be effective. However, the DFO is considering whether it can be shortened based on data of treatment time using other delousing technologies.

[42] Long et al. 2019

[43] For example, Brooks and Jones 2008

[44] One example is the DFO's response to Recommendation 19 of the 2012 Cohen Commission, on the impact of pathogens from Atlantic salmon farms on the health of Fraser River sockeye salmon. After completing nine risk assessments, the DFO concluded that no pathogens, including sea lice, posed more than a minimal risk to the abundance and diversity of Fraser River sockeye salmon under current regulatory practices. See Response to Cohen Commission (dfo-mpo.gc.ca)

[45] See, for example, Mages and Dill 2010, Godwin et al. 2017

[46] Krkosek et al. 2011, Connors et al. 2012

With any amendment to existing conditions of license, or conditions of license reviews, the DFO will solicit feedback through written responses, working groups and advisory forums, or bilateral meetings with a diverse set of stakeholders, including NGOs. That being said, the DFO has struggled frequently to have constructive interaction with the NGO community, particularly those organizations advocating for the complete elimination of salmon farming in BC, a position the DFO is not able to respond to without change in legislation. For their part, several NGOs also said they view the DFO relationship as challenging or adversarial, arguing that consultations have been a way for the DFO to *inform* stakeholders of their plans, rather than listening to or incorporating feedback.

Concerns were raised about the historic lack of decision-making power by First Nations regarding salmon aquaculture in BC. However, over the past five years, greater recognition of Canada's First Nations as rights-holders in their territories has translated into a more influential role. After a historic Supreme Court decision in 2014, ruling that the Tsilhqot'in First Nation (and in turn all other First Nations in Canada) have indigenous land rights and thus legal powers over their territories, the political winds have shifted towards reconciliation and inclusion in salmon aquaculture management. In 2018 the province-level government of British Columbia—which has authority over land and foreshore use, and thereby responsibility for the issuing of aquaculture tenures—announced a new policy to be implemented from 2022, requiring that agreements with First Nations must be in place. This has given First Nations new powers to request a removal of salmon farms from their territories and withhold consent for renewal of tenures in 2022.[47] As the province and the DFO are committed to aligning decisions despite having separate regulations, the DFO would revoke an aquaculture license after site decommissioning.

One the one hand, this has empowered certain First Nations, who favor salmon farming in their territories due to the economic benefits, in negotiations with industry for setting specific conditions of license. As a result, at some sites, aquaculture companies have agreed to lowering the sea-lice thresholds to 2.0 or 1.5. However, as the DFO is not involved in, or even has legal powers to enforce, such private agreements, there may be no real consequences in the event of non-compliance. On the other hand, the shift towards politics of reconciliation appears to have underpinned the BC Minister's 2018 call for a new, area-based management approach to aquaculture management, whereupon the DFO Minister announced that Canada would work with provinces/territories, industry, Indigenous partners, environmental groups, and others to ensure an area-based and sustainable path forward. First Nations and wild-salmon stakeholders are incorporated into the decision-making process towards an ABAM (as in the 2019 Indigenous and Multi-stakeholder Advisory Body (IMAB) and the Area-Based Management Technical Working Group tabling a draft framework for the adoption of ABAM in BC). The DFO is seeking to pilot an ABAM, within which consideration may be given to setting local sea-lice thresholds related to farm or site size, and defining the duration of the out-migration window related more precisely to the given set of species, while taking account of other potential influences, including water temperature and salinity conditions.

[47] Prior to this policy change, First Nations from Broughton Archipelago first went to the DFO to request that farms be closed down in their territories. However, the DFO did not believe that these concerns infringed their constitutional rights, which led the same Nations to apply pressure on the provincial government to change the tenuring policy. Meanwhile, many farms had already been shut down in Broughton Archipelago; and in 2021, the DFO Minister decided to stop issuing licenses to farms in Discovery Island by 2022, ultimately shutting down aquaculture in that area.

Does the jurisdiction actively promote and practice transparent data sharing from, with and between farms?

License holders for Atlantic salmon farms are required to conduct bi-weekly sampling in the pre-migration and out-migration windows, and to report the average level of motile, chalimus-stage and adult female *L. salmonis,* as well as the average level of adult and preadult *Caligus clemensi* per fish. For the rest of the year, license-holders are to report monthly. For Pacific salmon farmers, quarterly sampling is required.

The DFO publishes an Industry Sea Lice Abundance Counts report (per farm), updated on a monthly basis.[48] However, there is a significant time-lag between reporting and publication. Although they must perform bi-weekly counting, license-holders are required to submit the counts to the DFO only on a monthly basis. The DFO receives the reports on the 15th of the following month, upon which they conduct a quality control, including a comparison of data with DFO-performed audits, which may take between two and four weeks. In practice, the reviews of reports are often bundled together quarterly. Thus, although consistent and correct reporting is ensured, there is a significant time-lag of up to several months in data publication.

[48] https://open.canada.ca/data/en/dataset/3cafbe89-c98b-4b44-88f1-594e8d28838d

Comparative Discussion and Conclusions

The regulatory regimes governing sea-lice levels in periods of wild salmonid out-migration vary significantly among the five jurisdictions assessed in this report. With two jurisdictions—the Faroe Islands and Scotland—the regulations have not been designed for the purpose of mitigating impacts of farm lice on wild populations. In the case of the Faroe Islands, there are no naturally spawning populations of Atlantic salmon, which has justified the government's alternative focus of sea-lice regulation: to prevent the costly spread of lice and lice larvae between aquaculture facilities around the Islands. Thus, the government enforces an absolute sea-lice limit of average 0.5 adult females per fish in the spring. Perhaps paradoxically, a "sensitive period" requirement was introduced primarily to facilitate farm compliance with the ASC Salmon Standard. These updates to the Faroese sea-lice regulation may nevertheless contribute to greater protection of wild salmonids. The Scottish sea-lice regulation, which is designed to protect farmed-fish welfare, sets significantly more lenient trigger levels for treatment (2.0 and 6.0 adult females), and the government has not defined a sensitive period. This calls into question the regime's ability to, "by default," protect the health of wild populations.

By contrast, Norway, Ireland, and Canada (British Columbia), regulate sea-lice levels in salmon farms for the stated purpose of minimizing potential hazards to wild salmonids. Norway enforces the most stringent, absolute sea-lice limit, requiring farms to remain below an average of 0.2 mature female lice per fish in the sensitive period. Ireland has taken a somewhat more lenient approach, setting a sensitive-period trigger level for treatment at 0.5 ovigerous lice per fish. Canada (BC) also sets a trigger level for delousing actions at 3.0 motile lice per fish (equaling ca. 0.64-1.65 adult females).[49] However, a recent update requires farms to be below this threshold on the first day of out-migration, and to bring sea lice back below the threshold within 42 days in case of exceedance.

A thorough-going, comparative evaluation of absolute and trigger-level thresholds across jurisdictions to assess their robustness or effectiveness in protecting the health of wild salmonids is beyond the scope of this assessment. The various threshold levels are not directly comparable: the regions examined here have varying ecological and biological conditions, different wild salmonid species, lice species and sub-species, as well as highly varying aquaculture production outputs and farm-area densities. For instance, Norway has set the strictest absolute thresholds: but is also the by far largest producer of farmed salmon. Ireland's trigger levels are less stringent, but Ireland has a comparatively small-scale fish-farming industry. Canada's BC threshold is set to protect wild populations of Pacific salmon, which are genetically distinct from Atlantic salmon.

Beyond the regulation of sensitive period, on-farm sea-lice thresholds per fish, Norway stands out as the only jurisdiction that has begun to regulate farm biomass—and thus, indirectly, the total lice load of production areas based on sea-lice infestation-levels in the wild. The adoption of an aquaculture management system anchored in risk assessments of lice-induced mortality for wild populations demonstrates that Norway has incorporated the health of wild salmonids into its regulatory decision-making to a larger degree than the other jurisdictions studied here.

[49] Aquaculture Management Division, DFO. "Technical report: Sea lice threshold equivalency assessment for policy change".

The Scottish government is now moving in the same direction, working to develop a spatially based, risk-assessment framework modelled on Norway's red/yellow/green "traffic light" system. Although the political commitment to implementing such a system shows that Scotland has begun to incorporate the health of wild populations in regulatory decision-making, major uncertainties remain as to whether and how the existing, fish-health centered regime for regulating farm lice levels will be updated.

All the jurisdictions assessed have sought out answers to uncertainties around farm / wild fish interactions by turning to research and analysis, albeit in very different ways. In Norway, the research institutes and knowledge providers involved in regulatory decision-making largely agree that farm lice represent a major threat to the health of wild salmonids. This scientific consensus has underpinned the government's increasingly precautionary approach, aimed at minimizing the risks for wild populations. A similar consensus appears to be emerging in Scotland, where knowledge providers and the government have recently concluded that farm sea lice represent a potential hazard for wild salmonids and must be regulated accordingly. In Ireland and Canada, on the other hand, scientific controversy around farm / wild fish interactions persists. The deviating positions of the various national research institutes and independent scientists on both the sub-lethal and the population-level effects of farm sea lice also appear to affect how aquaculture is regulated. In both Ireland and Canada, the governmental departments responsible for aquaculture management have relied largely on research, analysis and advice from scientists who represent one side of the scientific debate, and conclude that population-level effects are small to negligible. Other research institutes or scientists have reached other conclusions, and stress the need to incorporate sub-lethal effects of lice on salmonids to a greater extent—but this research has not had a significant impact on government decision-making. This is clearly seen in Ireland, where sea-lice regulations have not been updated since 2008, despite considerable pressure from wild salmonid knowledge-providers. In Canada, recent regulatory updates and potential revisions indicate that consideration is now being given to a growing evidence-base and the arguments of independent scientists.

Stakeholders have not played a major role in setting sensitive-period sea-lice thresholds in any of the jurisdictions, except in the Faroe Islands, where industry has pushed for lowering thresholds, to reduce the transmission of sea lice between facilities. However, most jurisdictions formally consult with stakeholders prior to any regulatory revision, and stakeholders appear to have been more widely included in decision-making related to aquaculture and sea-lice management over the past five years. In Scotland, stakeholders have been central to the adoption of public reporting requirements, and are also deeply engaged in the ongoing reform process. In Canada's British Columbia, stakeholders—in particular, First Nations, who have become rights-holders in their territories—are consulted more frequently and genuinely, for example playing a key role in ongoing efforts towards developing multi-stakeholder, area-based management systems for salmon aquaculture in BC. The exception is Ireland, where there is little evidence of stakeholders being integrated in government decision-making: they rely on petitions made through the independent Aquaculture Licenses Appeals Board to impact aquaculture regulation.

Finally, although all the jurisdictions examined here have mandatory reporting requirements, they differ considerably as regards between-farm data-sharing arrangements and the timing of publication. In Scotland, sea-lice data are published no later than two weeks after recording, and in the Faroe Islands and Norway, the data are published close to real time. In the latter two jurisdictions, the government arranges regular industry data-sharing through meetings and

report distribution. Also, in Ireland and Canada, sea-lice reports are shared with industry and stakeholders, but the considerable time-lags in publication give rise to concerns about real-time data transparency.

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