	Council	
NASCO	***Progress by ISFA to promote the international goals for sea lice and containment among its members and what more can be done to protect wild salmonids from the adverse impacts of salmon farming***	**CNL(21)53** **Agenda Item: 5(a)**

Progress by ISFA to promote the international goals for sea lice and containment among its members and what more can be done to protect wild salmonids from the adverse impacts of salmon farming

International Salmon Farmers Association

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Introduction

Sustainable development revolves around meeting the needs of people in today's world without destroying the possibility of future generations to meet their own needs. These goals reflect the three dimensions of sustainable development:

1. Climate and environment
2. Economy
3. Social conditions

ISFA endorses the UN Sustainable Development Goals. The UN has developed 17 goals and 169 sub-goals to provide global direction for countries, the business community and civil society.

Countries around the world were actively involved in establishing the goals and more than eight million people contributed to the process. In the Ocean Economy in 2030, the Food and Agriculture Organization of the United Nations (FAO) and the Organization for Economic Co-operation and Development (OECD) explain the significance of aquaculture for resolving many of our future global challenges.

ISFA aims to contribute to the UN achieving the following sustainability goals related to environmental sustainability:

- Sustainability goal 12: Ensure sustainable consumption and production patterns.
- Sustainability goal 13: Take urgent action to combat climate change and its impacts.
- Sustainability goal 14: Conserve and sustainably use the oceans, seas and marine resources.
- Sustainability goal 15: Sustainably manage forests, combat desertification, halt and reverse land degradation, halt biodiversity loss.

The aquaculture industry can contribute to solving many global challenges such as increased production of healthy food with low climate footprint, effective use of raw materials and reducing the need for increased exploration of areas of land for food production. But the industry also has a focus on local challenges such as control of sea lice and escapees.

Sea Lice

Sea lice are a naturally occurring parasite that in some circumstances attack farmed salmon. Without salmon farms the occurrence of and impacts on free range salmon populations would be largely unknow because sea lice typically drop off adult Atlantic salmon entering fresh water, the most common ecosystem in which anglers encounter salmon. Salmon farms, because farmers constantly monitor their fish, act as sentinel monitoring stations for lice and are an indirect measure of the infection pressure that occurs on free-range salmon populations.

Integrated Pest Management Plans

Integrated Pest Management Plans, which outline protocols for the management of sea lice and other pests, include overarching components such as prevention and control, monitoring and assessment and data collection and analysis. IPMs specify company measures and activities to manage pests including Area Management and coordinated treatment schemes, stocking strategies, fallowing strategies and therapeutant and non-therapeutant control regimes. IPMs are in place for many salmon farming jurisdictions.

Integrated Pest Management plans are in place in all salmon farming regions in Canada. In Newfoundland and Labrador the Department of Fisheries, Forestry and Agriculture has published an Introduction and Guiding Principles document for companies to use in the development and maintenance of their Sea Lice Integrated Pest Management Plans, which advocates for the utilization of a combination of management approaches. https://www.gov.nl.ca/ffa/files/Newfoundland-and-Labrador-Sea-Lice-Integrated-Pest-Mangement-Plan.pdf

The New Brunswick Integrated Pest Management Plan (IPMP) for Sea Lice was developed by the provincial and federal governments in 1998 and provides a comprehensive, strategic framework that promotes the health and welfare of cultured Atlantic salmon, while minimizing potential impacts to wild aquatic resources in the surrounding environment.

The IPMP includes prevention, research, monitoring (observation), and therapeutant and non-therapeutant control measures (intervention). It promotes access to a variety of management tools, as well as strategic and synchronized treatment plans to ensure optimal benefit of each treatment and minimize environmental exposure. This will not only reduce farm-level sea lice populations, but also result in an overall reduction of treatments and therapeutants used and their release into the aquatic ecosystem.

This plan encourages continuous improvements in management, the application of new technologies, and the introduction of new products as new information and science advances become available. This will ensure management tools remain effective while reducing potential impact to the environment and wild resources.

In New Brunswick in 2020, more than 90% of treatments were non-therapeutant. And in Nova Scotia, there has not been an application of therapeutant to treat sea lice for at least a decade.

The Department of Fisheries and Oceans Canada (DFO) advocates for IPMs saying…. *"An integrated, multi-facetted approach to managing sea lice in net-pen sites that is specific to the local area is recommended. Such an adaptive approach can permit customized management strategies to address area-specific issues. Such approaches do not rely on a single tool to control sea lice, but rather encompass several management strategies to improve the likelihood of success. A similar adaptive multilevel approach to pathogen control has been successfully used for bacterial and viral diseases."* Sea Lice Monitoring and Non-Chemical Measures - Canadian Science Advisory Secretariat July 2014 - https://waves-vagues.dfo-mpo.gc.ca/Library/363891.pdf

In Maine, USA, an Integrated Pest Management Plan, developed by salmon farmers, in cooperation with the United States Department of Agriculture and state resource agencies, for all marine salmon aquaculture sites has been in place since 2002. The plan outlines protocols for monitoring sea lice levels on farmed fish and includes best management practices for managing sea lice levels and for evaluating treatment efficacy. The plan includes single year class stocking, all-in all-out production plans, site rotation, fallowing and the use of non-chemical sea lice treatment strategies. https://www.tandfonline.com/doi/full/10.1080/03632415.2014.966818

https://nasco.int/wp-content/uploads/2020/11/Response-from-the-United-States-to-Letter-from-President_16-Nov_Redacted.pdf

Area Management (AKA Bay Management) and Coordinated Sea Lice Treatment

Area-based management approach to sea lice management, which are designed to facilitate local farm cooperation, are in place in all salmon aquaculture jurisdictions. These area management schemes apply to all salmon farming companies in the shared areas and are meant to achieve shared objectives including the maintenance of healthy stocks of farmed fish. Coordinated and strategic timing of sea lice control efforts are part of these approaches.

In Canada, the designation of Aquaculture Bay Management Areas (BMA) is based on a three-year production cycle and is founded on the principle that, to foster and support a sustainable industry, the marine site production system framework must provide an operational environment which enables industry to operate on a year-round basis without compromising fish health management and biosecurity requirements.

In Norway, coordinated sea lice treatment is a successful strategy used to control sea lice and is under the authority of the Norwegian Food Safety Authorities (NFSA). The regulations set treatment thresholds lower in the spring (0.2 lice per fish) than other times and require salmon farming companies to perform coordinated sea lice control measures whenever the threshold is exceeded. At it's discretion, the NFSA can edict coordinated lice control measures when deemed necessary.

In Ireland, husbandry practices such as stocking, fallowing and lice treatment, are coordinated through Single Bay Management arrangements which promote farming best practices and ensure that all on-farm events are compatible with activities on neighbouring farms. Synergistic farm actions, which have beneficial effects on each bay as a whole, is the goal of these Single Bay Management arrangements.

The Marine Institute says that "The Single Bay Management process has proved very effective, since its introduction in 1997, in enhancing the efficacy of lice control and in reducing the overall incidence of disease in the stocks". https://www.marine.ie/Home/site-area/areas-activity/aquaculture/sea-lice/single-bay-management

In Canada, a software-based Sea Lice Decision Support System (SLDSS) developed by the Atlantic Veterinary College (AVC) is being used in New Brunswick and Newfoundland and Labrador to minimize on-farm sea lice numbers and the associated risks. The Decision Support System, called FishiTrends, collects and archives on-farm sea lice data, such as lice counts and lice treatments, and assists farming companies in making informed and coordinated farm management decisions, based on sea lice counts and historical treatment data.

Single year-class stocking

Single Year-class stocking is a strategy which is part of all salmon farming Area-based Management schemes and involves the rearing of only one year class of salmon in a defined management area and period of time in order to facilitate fish health management. It requires that all fish in the defined management area are stocked and then harvested within set timeframes, before the next year class of farmed fish is stocked in that area. This strategy is employed by the salmon farming sector in all salmon farming countries.

Fallowing

Farm fallowing is common salmon farming management approach in all countries where salmon is farmed. The approach involves the use of a temporary suspension in farming at a site or in an area, usually between production cycles, that is used together with other strategies to control parasites and diseases prior to introduction of new farmed stock.

Monitoring of Lice Levels on Sites

In all salmon farming countries farming companies are required to sample their salmon at regular intervals for prevalence and abundance of various stages of sea lice. This is a regulatory requirement in most or all jurisdictions and companies have also instituted their own sampling protocols either in line with compliance or in excess of regulatory requirements. New technologies, including AI and machine learning, are being developed and tested to make sea lice monitoring more automated and more precise.

In Atlantic Canada, depending on slightly variable provincial requirements, farms are required to count sea lice per fish every two weeks when temperatures are above 5^{o} C (typically May to December) and monthly when below this temperature. Some companies choose to count sea lice monthly even when temperatures are below the temperature threshold.

In Ireland the number of sea lice on farmed fish are determined from a monitoring process carried out by trained inspector from the Marine Institute, an independent organization. "*Farmed stocks of Atlantic salmon in Ireland are inspected on 14 occasions throughout the year to monitor sea lice levels as part of the national programme. Additional follow-up inspections may be carried out when it is deemed appropriate. Sea lice inspections take place twice per month in March, April and May (the spring period) and then monthly for the remainder of the year. December and January are combined and only one inspection is carried out*" https://www.marine.ie/Home/site-area/areas-activity/aquaculture/sea-lice

In Maine, USA, mandatory monitoring of sea lice levels occurs at least biweekly when water temperatures are greater than 8^{o} C and monthly when water temperatures are between 6^{o} C and 8^{o} C. https://nasco.int/wp-content/uploads/2020/11/Response-from-the-United-States-to-Letter-from-President_16-Nov_Redacted.pdf

In N**orway** sea lice levels on sites must be reported weekly for each farm if the sea temperature is above 4^{o} C. The data from these reports are available at the site level on the Lusedata (www.lusedata.no) and Barents Watch (https://www.barentswatch.no) websites.

The Norway aquaculture technology company Aquabyte is using machine learning technology with a robust underwater camera setup for automatic lice counting. However for now, Norwegian regulations state that farms still have to count salmon lice manually to remain in compliance.
https://thefishsite.com/articles/consigning-manual-lice-counting-to-history
https://www.aquabyte.ai/index.html

Treatment Trigger Levels

All salmon aquaculture jurisdictions have pre-defined numbers of sea lice on farmed fish that, when attained or exceeded, require an intervention by the farming company, in the form of therapeutant treatment or physical treatment such warm water or freshwater flushing to reduce the number of sea lice on the fish.

In Scotland, Government regulations contain mandatory reporting of sea lice to the Fish Health Inspectorate when average adult female lice counts are 2 per fish or above, and there is an intervention threshold set at 6 average adult female sea lice per fish. In addition, the industry-developed Code of Good Practice for Scottish Finfish Aquaculture (CoGP) suggested a sea lice management trigger of 0.5 adult female lice per fish between February and June, and 1.0 adult female lice per fish for the rest of the year. https://www.gov.scot/publications/understanding-relative-cost-effectiveness-sea-lice-management-measures-farmed-salmon-production-scotland/pages/5/

In Canada there are different approaches to thresholds across the provinces. In British Columbia 3 adult motile lice is the trigger, while in Nova Scotia it is set at 1.0. In Newfoundland and Labrador and New Brunswick the government requires salmon farming companies to divulge their own sea lice treatment thresholds for government approval. These company thresholds are based on a risk-management approach tailored to the particular region the company is operating in.

The Department of Fisheries and Oceans Canada says that "*Management and regulatory thresholds defining the level of on-farm sea lice per fish, that trigger the application of control measures for managing sea lice infestations, have been shown to be a useful management tool for reducing risk of transfer of sea lice from farmed to wild salmonids in some areas of British Columbia. A more flexible, dynamic and risk-based approach to setting thresholds than has been used in the past is recommended*." Sea Lice Monitoring and Non-Chemical Measures - Canadian Science Advisory Secretariat July 2014 - https://waves-vagues.dfo-mpo.gc.ca/Library/363891.pdf

In Ireland the number of sea lice on farmed fish are determined from a monitoring process carried out by trained inspector from the Marine Institute, an independent organization. Average spring lice numbers are viewed against treatment trigger levels of greater than 0.5 egg bearing females per fish. Farms are required to take action to reduce sea lice numbers if their number is above this threshold. *https://www.marine.ie/Home/site-area/areas-activity/aquaculture/sea-lice*

In Norway a standardised counting method is used to monitor lice levels on salmon farms and sea lice regulations specify 0.5 adult female lice per fish as the trigger for lice control measures. In the spring these trigger limits are set to 0.2 adult female lice per fish in order to reduce lice during timing of outmigration of smolt.

Codes of Practice

In Scotland, the aquaculture industry has developed a Code of Good Practice for Scottish Finfish Aquaculture (CoGP), which says that the build-up of preadult sea lice should guide farm management measures in order to prevent the development of gravid females. , and it includes a suggested sea lice management measure criteria of 0.5 adult female lice per fish between 1st February to 30th June inclusive, and 1.0 adult female lice per fish between 1st July to 31st January inclusive.

https://www.gov.scot/publications/understanding-relative-cost-effectiveness-sea-lice-management-measures-farmed-salmon-production-scotland/pages/5/

In Canada, the National Farm Animal Council and the aquaculture industry are developing a Code of Practice for the Care and Handling of Farmed Salmonids. The Code identifies the impact of sea lice on fish welfare as a priority welfare issue and outlines monitoring, control and treatment options. https://www.nfacc.ca/codes-of-practice/farmed-salmonids

Use of Cleanerfish

The use of cleaner fish to control sea lice as an environmentally friendly biological control is recognised as one of the key tools to control sea lice on fish farms. This is now in common use in Norway, Scotland, Canada, etc. Several different species of wrasse are being used, like the ballan wrasse (*Labrus bergylta Ascanius*), corkwing wrasses (*Symphodus melops*), gold-sinny (*Ctenolabrus rupestris*) as well as the Atlantic lumpfish (*Cyclopterus lumpus*) are used for this specific purpose.

In Atlantic Canada there are two species with potential as cleanerfish; namely the cunner (*Tautogolabrus adspersus*) and the lumpfish (*Cyclopterus lumpus*). Both have shown good potential in reducing sea lice abundances and are being bred in pre-commercial quantities. The development of commercial cleanerfish hatcheries are underway in Maine and Newfoundland and Labrador.

Research is being done into closing the breeding loop on some wrasse species to be bred in captivity for use in salmon farms. "*Mowi Scotland now cultures 100% of our lumpfish deployed as cleaner fish, and are into our second production year of cultured Ballan Wrasse production in the UK. Eggs are produced at our dedicated Wrasse Broodstock facility at Machrihanish and on-growing is done at the Anglesey RAS hatchery. The first deployments of cultured wrasse will be deployed into our saltwater farms this autumn and we expect to supply around 20% of the requirement from this source. With our current production operations we are targeting 100% use of cultured wrasse in 2022 with additional production offered to external producers*." (Dougie Hunter, Technical Director: Mowi Scotland).

Alternative Sea Lice Control Methods

In recent years, the salmon farming industry has been developing and testing new technologies and approaches to improve the management of sea lice in an environmentally responsible manner. These new approaches include non-medicinal control methods such as physical lice removal systems and physical barriers placed between the lice and the salmon.

The Global Salmon Initiative outlines many of the new approaches being developed and implemented, some of which are in the development or testing phases. https://globalsalmoninitiative.org/en/our-work/biosecurity/non-medicinal-approaches-to-sea-lice-management/

Physical Sea Lice Removal Systems

Physical sea lice removal methods such as Optilicers and Thermolicers take advantage of the sea lice's low tolerance for sudden changes in water temperature and salinity to physically remove the lice from salmon. These systems make use of well boats or barges to treat the fish, which are pumped onboard and briefly passed through either warm seawater of fresh water before being added back to the pen. These systems filter the treatment water and collect the sea lice for disposal, as some can survive the treatment.

Similar treatment systems operated on boats or barges, known as Hydrolicers (AKA Flushers), pass salmon quickly through the system where they are flushed with water from a set of water jets which dislodge the sea lice from the surface of the salmon. Again, the salmon are returned back to the cage and the sea lice are collected for disposal.

Another physical sea lice removal method, which takes advantage of the sea lice's low tolerance for low salinity is the freshwater bath method. This method can be done using a tarpaulin wrapped around the salmon cage to hold the fresh water in or can be done by pumping the salmon into a wellboat filled with freshwater. In either case the salmon can be held in the fresh water for up to 8 hours. Some approaches for this treatment employ a tow bag to deliver the fresh water to the cages or a desalination system to make fresh water on site. https://thefishsite.com/articles/a-new-tool-in-the-battle-against-sea-lice-and-agd https://www.sciencedirect.com/science/article/pii/S0044848619307616

Physical Barrier Sea Lice Restraint Devices

Sea lice larvae generally live in the top few meters of the water column. Sea lice skirts consist a sheet of material that is impervious to sea lice larvae which can be wrapped around the top portion of salmon cages and act as a shield, preventing sea lice from entering the cage and reducing attachment to the farmed salmon. https://globalsalmoninitiative.org/en/our-work/biosecurity/non-medicinal-approaches-to-sea-lice-management/

Controlling Salmon Swimming Depth

New net cage systems have been developed to keep farmed salmon at a depth where they are exposed to less sea lice infection pressure, reducing attachment of lice.

The AKVA Tubenet™ invented and patented by Egersund Net (https://www.akvagroup.com/pen-based-aquaculture/tubenet-) and the Snorkel Cage developed by the Institute of Marine Research (https://thefishsite.com/articles/how-to-reduce-lice-levels-by-75-percent) are innovative designs featuring a horizontal net across the net cage which keep the salmon out of surface waters, with a large tube at the centre of the cage, which is impervious to sea lice larvae, through which the salmon can swim to refill their swim bladders without being exposed to sea lice larvae.

Mowi Scotland has recently installed the new Tubenets which are designed to reduce sea lice numbers, at a salmon farm in Argyll. Mowi Scotland's farm at Port na Cro, is the first farm in the UK to install AKVA's Tubenets, in a project that follows successful trials carried out at Mowi's research centre in Norway. https://thefishsite.com/articles/mowi-invests-in-novel-lice-reducing-nets

Physical Removal Using Lasers

An innovative system developed in Norway used a laser to automatically target and kill sea lice while salmon swim by it in the cage. The Stingray system is suspended in salmon cages and uses stereo camera vision and advanced software to target the lice while operating 24 hours a day. The operation of the Stingray system is monitored from the company's office and data on lice numbers and laser beams fired is collected. https://www.stingray.no/delousing-with-laser/?lang=en

Genetics, Breeding and Gene Editing

A new innovative, selective breeding method is being developed to improve the resistance of farmed Atlantic salmon to sea lice. Breeding programs in Norway, Iceland and the USA are selecting for families of Atlantic Salmon that show high resistance to sea lice attack. Since Atlantic salmon are more susceptible to sea lice than other salmon species, such as coho or pink salmon, researchers in Scotland and Norway are trying to identify differences in the genetic code which make these other species less susceptible to sea lice, with the possibility of using CRISPR-Cas9 to make targeted changes to the genetic code of farmed fish.

https://thefishsite.com/articles/cutting-the-costs-of-sea-lice-resistance-in-salmon

https://thefishsite.com/articles/can-crispr-edit-sea-lice-out-of-salmon-aquaculture

Therapeutants

Even though therapeutants have been essential components in Integrated Pest Management Plans for sea lice, they are seen as the least preferred method for sea lice control. Research continues in all jurisdictions on new therapeutants that have minimal environmental impacts.

There are 5 therapeutant groups currently used for the control of sea lice in salmon aquaculture. These include pyrethroid compounds (pyrethrum, cypermethrin, deltamethrin); organophosphates (dichlorvos and azamethiphos); avermectins (ivermectin, emamectin and doramectin), benzoylphenyl ureas (teflubenzuron and diflubenzuron) and an oxidizing agent (hydrogen peroxide).

Of these compounds, there is a large variation in the number which are available for use in the various salmon farming countries. Norway has 9 of these available for use, there are 6 available in the United Kingdom, 4 in Canada and only 2 are available for use in the United States. Some of these are approved in these countries while others are only available under extra-label (aka off-label) veterinary prescription or emergency use or special research permits.

Recently the neonicotinoid Imidacloprid has been trialed as a sea lice therapeutant. The UK-based biotechnology firm which developed this treatment is also pioneering a water purification system called CleanTreat which can remove the compound for treatment water.
https://thefishsite.com/articles/novel-sea-lice-treatment-gains-medical-approval

In New Brunswick in 2020, greater than 90% of treatments were non-therapeutant. And in Nova Scotia, there has not been an application of therapeutants to treat sea lice in Nova Scotia for at least a decade.

Post - smolts

In recent years, salmon farming companies have been keeping smolts on land, or in another containment facility, to grow them to a larger size than with previous industry stocking standards, to minimize time at sea limiting exposure to sea lice and reducing costly sea lice control methods.

Salmon smolt companies and farming companies such as Cooke Aquaculture, Mowi, Grieg, Lerøy, Salmar, Firda Seafood, Helgeland Smolt, Vikan Settefisk and others are using Recirculating Aquaculture Systems (RAS) in Norway, Canada, and UK to produce post-smolt to be stocked into marine cage sites at sizes between 500 and 1200 g. Virtually all other jurisdictions have plans for, or are in construction of, Post-smolt facilities.

Closed Containment Systems

There are several closed containment systems designed to reduce the exposure of smolt and post-smolt to larval sea lice. Most of these are either in the design, testing or pre-commercial phases of development.

Neptune tanks are solid-panel tanks which are deployed at sea to grow salmon from the freshwater phase to the post-smolt stage before being transferred to sea cages for their final growth phase. Built by Aquafarm Equipment, these 40m diameter tanks will enable fish farmers to grow post-smolt to 800 or 1000 grams which will reduce the time the salmon will be grown in net cages by about eight months. The water supply is pumped in from below the tank to avoiding harmful algae blooms and larval stages of sea lice. https://salmonbusiness.com/mowi-aiming-to-install-closed-containment-systems-in-scotland/

The FishGLOBE company in Norway has developed and has tested an innovative fully-closed floating closed-containment system for salmon aquaculture which is also being tested in growing post-smolt to larges sizes before they are transferred to marine net cages. The system is composed of high density polyethylene with 6 water intake pipes which draw in water from depths where harmful algae and larval sea lice are not concentrated. https://www.fishglobe.no/home

The Starfish, another innovative floating closed-containment salmon farming system, produced by Nekkar, also has it's water inlets deep under the cage to avoid sea lice larvae. Starfish is being tested in Norway by Lerøy Seafood and is due to be stocked in 2021. https://thefishsite.com/articles/novel-closed-containment-salmon-farm-launched-in-norway

The Preline raceway system is a floating semi-closed raceway-based system used to grow salmon post-smolt up to 1000 grams before being transferred to sea cages. The system is built mostly of high density polyethylene and has a raceway just under the surface with water intake pipes which extend to 25 to 30 meters deep to avoid sea lice larvae.

Sea Lice Reporting Programs

Sea lice reporting programs and portals are now in place and accessible in all salmon farming jurisdictions.

In western Canada… *"Fisheries and Oceans Canada's (DFO's) conditions of licence for marine finfish aquaculture contain monitoring and intervention requirements to minimize the potential exposure of wild and farmed fish to sea lice. The Industry Sea Lice Abundance Counts report is updated monthly. It shows which Atlantic salmon farms were actively raising fish during the month and the results of industry's monthly sea lice monitoring". https://open.canada.ca/data/en/dataset/3cafbe89-c98b-4b44-88f1-594e8d28838d*

The Marine Institute in Ireland operates a program which surveys and determines the number of sea lice on farmed fish each year and report the results in the Marine Institute Annual Sea Lice Reports. The results for all inspections performed can be found here: https://www.marine.ie/Home/site-area/areas-activity/aquaculture/sea-lice

Barents Watch is a portal, developed in Norway by government agencies and research institutes, which develops and shares information for both public and industry use. Shared data includes, among other things, weekly overviews of sea lice levels on salmon farms and both medicinal and mechanical lice treatments. The sea lice numbers that are shown on Barents Watch are those reported to the Norwegian Food Safety Authority by the salmon farming companies. https://www.barentswatch.no/en/

Sea lice data is also available on the Lusedata website www.lusedata.no

In Scotland, the government states that "*To ensure the Scottish aquaculture industry continue to demonstrate satisfactory measures are in place for the prevention, control and reduction of sea lice on farm sites, Aquaculture Production Businesses (APB) are required to report the weekly average adult female sea lice numbers per fish on farm sites, under the Fish Farming Businesses (Reporting) (Scotland) Order 2020*". https://www.gov.scot/publications/fish-health-inspectorate-sea-lice-information/

Scotland's sea lice data can be found here: https://sepaweb.maps.arcgis.com/apps/webappviewer/index.html?id=f1527f9cf8cc43acad27dee61d8597de

Monitoring of sea lice on wild salmonids

Mowi Canada West and Cermaq Canada have contracted a biological consultant company to perform sampling to monitor sea lice abundance, prevalence and intensity on juvenile wild pink, Coho and sockeye salmon and stickleback in British Columbia since 2015. https://mowi.com/caw/sustainability/wild-salmonid-lice-monitoring/

In addition, the Department of Fisheries and Oceans Canada surveys sea lice on wild salmon on both the Atlantic and Pacific coasts. According to DFO…. "*The level of sea lice infestation is regularly monitored on farmed salmon on the Atlantic and Pacific coasts. In addition, surveys to monitor sea lice infestations on wild fish hosts have been conducted on both coasts, although the number of surveys conducted is much higher on the Pacific coast*". Sea Lice Monitoring and Non-Chemical Measures - Canadian Science Advisory Secretariat July 2014 - https://waves-vagues.dfo-mpo.gc.ca/Library/363891.pdf

Escape Management

Mandatory reporting of escape and suspected escape events

Government regulations in all salmon aquaculture jurisdictions include the requirement for reporting of escape events and suspected escape events to the government. In some regions these events are required to be reported publicly by either the government or by the aquaculture company. Third-party eco standards such as the Aquaculture Stewardship Council's Salmon Standard and the Best Aquaculture Practices' Salmon Farms standard, to which many salmon farms conform, also have specific clauses about reporting of escape and suspected escape events, investigation of causes of loss and avoiding recurrence.

In Norway, according to the Ministry of Trade, Industry and Fisheries: "*Fish farmers are required to immediately report any suspicion of escapes to the Norwegian Directorate of Fisheries. They are also* *required to take steps to capture escaped fish. Failing to report suspected escapes is a criminal offence. The Norwegian Directorate of Fisheries publishes all information on its website*."

https://www.regjeringen.no/en/topics/food-fisheries-and-agriculture/fishing-and-aquaculture/1/farmed-salmon/escaped-fish/id730685/

Norway has also established a body for which the main task is to reduce the number of escapees in rivers. This includes the planning and implementation of measures to reduce the occurrence of escaped farmed salmon, trout and rainbow trout in rivers where the presence of escaped fish is unacceptable. The body covers expenses for the work being done to solve the problem of escapes in rivers. It is mandatory for holders of salmon, trout and rainbow trout aquaculture licenses to participate in the body.

Marine Scotland says that: "*It is a legal requirement to notify the Scottish Ministers of any incident which has caused an escape of aquaculture animals or may have given rise to a significant risk of an escape of aquaculture animals*."
http://aquaculture.scotland.gov.uk/resources/datasets/data_details/fish_escapes_data.aspx

Their guidance document on reporting an escape or suspected escape event outlines the relevant legislation involved and delineates notification and publication procedures.
https://www.gov.scot/binaries/content/documents/govscot/publications/advice-and-guidance/2018/10/what-to-do-in-the-event-of-a-fish-farm-ecape/documents/what-to-do-in-the-event-of-a-fish-farm-escape-guidance/what-to-do-in-the-event-of-a-fish-farm-escape-guidance/govscot%3Adocument/What%2Bto%2BDo%2Bin%2Bthe%2BEvent%2Bof%2Ba%2BFish%2BFarm%2BEscape.pdf

This data represents all the reports of fish escapes and potential fish escapes which have been reported to Scottish Government since 2002 when this became a mandatory requirement. Some data is also available prior to 2002 however this was provided on a voluntary basis and may not be comprehensive."
http://aquaculture.scotland.gov.uk/data/data.aspx

In Atlantic Canada, each province has a Code of Containment / Standard and requirements are outlined in their respective policies regarding breach reporting. In all provinces fish farms are required to report any suspected or confirmed escape event to the Government and to the public within 24 hours of the event occurring.

In New Brunswick, the Code of Containment was updated (April 2021) and will be referenced in the new aquaculture regulations due late 2021.

In Nova Scotia, a Farm Management Plan for a holder of an aquaculture licence for finfish in a marine aquaculture site must include information and procedures related to containment including operating procedures that limit the risk of a breach, processes for installing and maintaining infrastructure in place to limit the risk of a breach, and responses to breaches.

In Newfoundland and Labrador, fish farms are required to report any suspected or confirmed escape event to the Government and to the public within 24 hours of the event occurring. For confirmed escaped, the number of fish that escaped, the cause of the event and the plan for recapturing the escaped fish must also be reported. Furthermore, any event which impairs the function of equipment used to prevent fish from escaping, such as cage equipment or nets, must be reported under the same criteria. Public reporting must be done on the company's corporate website or on an industry association website.

The NL Government's Aquaculture Policy and Procedures Manual can be found here: https://www.gov.nl.ca/ffa/files/licensing-pdf-aquaculture-policy-procedures-manual.pdf

More information about escape prevention in salmon aquaculture in Canada can be found here:

https://www.dfo-mpo.gc.ca/aquaculture/protect-protege/escape-prevention-evasions-eng.html

In the United States all escapes and suspected escapes are required to be reported to both State and federal authorities. In the early 90's U.S. salmon farmers in cooperation with ENGOs and regulators developed the first, third party audited, containment management and escape response system (CMS). Since that time no significant escapes have occurred. The Maine CMS has formed the basis for all CMS requirements in the large international seafood sustainability certification programs such as ASC, Global Gap and BAP.

The ASC Salmon Standard states that farms must report all escapes and the standard sets the total number of escapees allowed per production cycle under ASC certification. It has clauses that require the farm to calculate unexplained losses (stocked fish minus harvest count, minus mortalities minus known escapes) and make this number publicly available.

Furthermore, the standard requires evidence of escape prevention planning and worker training on escape prevention. The plan and training must include information on net strength testing, suitable net mesh sizing, net traceability, and reporting of events which may present a risk of escapes. (e.g. infrastructure damage, human errors). https://www.asc-aqua.org/wp-content/uploads/2019/12/ASC-Salmon-Standard_v1.3_Final.pdf

The BAP salmon standard contains clauses that require companies to report all escape events immediately to the regulator and also notify the BAP and the certifying body. It also contains clauses that require companies to maintain recapture equipment and written procedures for its use, investigate escape events and corrective actions, and to maintain records on number of fish stocked and harvested from all sites. https://www.bapcertification.org/Downloadables/pdf/standards/PI%20-%20Standard%20-%20Salmon%20Farms%20-%20Issue%202.3%20-%2013-October-2016.pdf

Containment Systems (physical)

The salmon farming industry is continually investing in research. As a result, cage designs are continually being enhanced. As a result of ongoing research, there are several closed containment systems designed for the prevention of escapes of farmed salmon into the freshwater and marine environments. Most of these are designed to hold post-smolt to reduce their time in sea cages and reduce their exposure to larval sea lice. Most of these are either in the design, testing or pre-commercial phases of development.

Neptune tanks are solid-panel tanks which are deployed at sea to grow salmon from the freshwater phase to the post-smolt stage before being transferred to sea cages for their final growth phase. Built by Aquafarm Equipment, these 40m diameter tanks will enable fish farmers to grow post-smolt to 800 or 1000 grams which will reduce the time the salmon will be grown in net cages by about eight months. The water supply is pumped in from below the tank to avoiding harmful algae blooms and larval stages of sea lice. https://salmonbusiness.com/mowi-aiming-to-install-closed-containment-systems-in-scotland/

The FishGLOBE company in Norway has developed and is tested an innovative fully-closed floating closed-containment system for salmon aquaculture which is also being tested in growing post-smolt to larges sizes before they are transferred to marine net cages. The system is composed of high density polyethylene with 6 water intake pipes which draw in water from depths where harmful algae and larval sea lice are not concentrated.

The Starfish, another innovative floating closed-containment salmon farming system, is produced by Nekkar and also has it's water inlets deep under the cage to avoid sea lice larvae. Starfish is being tested in Norway by Lerøy Seafood and is due to be stocked in 2021. https://thefishsite.com/articles/novel-closed-containment-salmon-farm-launched-in-norway

The Preline raceway system is a floating semi-closed raceway-based system used to grow salmon post-smolt up to 1000 grams before being transferred to sea cages. The system is built mostly of high density polyethylene and has a raceway just under the surface with water intake pipes which extend to 25 to 30 meters deep to avoid sea lice larvae.

Codes of Containment

A Code of Containment is set of guidelines applying to the salmon farming industry with the intention of preventing escapes of farmed salmon into the freshwater and marine environments. This can include codes of practice, standards, regulations or all of these.

In Canada, the Code of Containment for the Culture of Salmonids in Newfoundland and Labrador (March 2020) is a management strategy applied to marine cage culture of salmonids to minimize the risk of escape events. The development and ongoing maintenance of the Code is a collaborative initiative between industry and provincial and federal governments. The Code is based on a risk management approach and is consistent with the Oslo Resolutions, passed in 1994 by the North Atlantic Salmon Conservation. The main objective of the Code of Containment is to minimize escapes of farmed salmon by setting appropriate guidelines for cage design and construction, nets mesh size and net strength testing, mooring design and installation, predator control devices, fish handling practices, documentation and reporting, inspections, inventory reconciliations and the establishment of recapture plans. https://www.gov.nl.ca/ffa/files/Salmonid-Code-of-Containment-Updated-March-2020.pdf

A similar management strategy, The Code of Containment for the Culture of Atlantic Salmon in Marine Net Pens in New Brunswick applied to salmon aquaculture in New Brunswick, was recently updated and will be referenced in the new provincial aquaculture regulations due late 2021.

Escape Monitoring Planning

In recent years research has been done regarding the possible use of SNP analysis to trace salmon back to the farm of origin and there is interest among regulators in having escape monitoring facilitated through national systems.

A SNP (single nucleotide polymorphism) is a variation in the DNA sequence occurring when a single nucleotide in the genome of an individual is different than in other members of a species. A SNP genetic marker is a combination of a number of SNPs in the genome and can be used to discover parentage of an individual with a high level of certainty. This type of DNA tracking can be done to trace escaped salmon back to the site of origin if tissue samples of the female and male brood fish are taken and archived. The combination of SNPs and geo elements, elemental analysis from fish scales, can further improve the accuracy of tracing.

In 2019 Sporbarhet AS was established as a collaboration between salmon companies Mowi Norway AS, Lerøy Seafood Group ASA, Salmar Farming AS and , Cermaq Norway AS, to develop and operate a system for tracking escaped farmed fish in Norway in collaboration with relevant authorities. Sporbarhet uses a combination of SNP chips and geo element analysis to determine parentage on any captured fish which is suspected to be on farm origin. The service will provide fish farming companies with information on escape events, helping to reducing escapes and associated financial losses as well as preventing damage to their reputation as a result of suspected escaped fish with no known origin. It is hoped that other fish farming companies will join Sporbarhet as users of the service in the future to further enhance the overall effectiveness of the service. https://sporbarhet.com/

In Maine, USA, DNA tracking of farmed salmon has been made possible. Maine regulators have made it mandatory that salmon companies must archive DNA profiles of all broodstock fish which are used in breeding programs to enable possible identification and tracking of escaped fish back to the originating company.

Recapture Planning

It is generally accepted that recapturing escaped salmon in the marine environment is challenging, especially during unfavorable weather conditions and preventing escapes is the preferred approach. However, in many aquaculture jurisdictions recapture efforts, where permitted, are encouraged.

In Canada, recapture of escaped farmed salmon requires a permit from Fisheries and Oceans Canada and done so on a case-by-case basis depending on the provincial / federal jurisdiction. For example, the Code of Containment for the Culture of Salmonids in Newfoundland and Labrador (March 2020) sets out appropriate guidelines for the recapture of escaped salmon. Under the Code, each salmon farming company are required to have access to at lease two sets of gear to be used to recapture escaped salmon and at least one set of gear for every two active aquaculture sites. According to the Code recapture activity will be permitted using gillnets, seines, traps or angling gear. If necessary, the Code allows for collaborative recapture efforts by multiple farming companies.
https://www.gov.nl.ca/ffa/files/Salmonid-Code-of-Containment-Updated-March-2020.pdf

The BAP salmon standard, to which many salmon farms conform and are certified, contains requirements for companies to maintain equipment for attempted recapture and have written procedures for its use.

Third Party Eco-Standards

Third-party eco standards such as the Aquaculture Stewardship Council's Salmon Standard and the Best Aquaculture Practices' Salmon Farms standard, to which most salmon farms conform and are certified, also have specific clauses about reporting of escape and suspected escape events, investigation of causes of loss and avoiding recurrence.

The ASC Salmon Standard has clauses requiring reporting of escapes to regulators and public reporting of unexplained losses and requires evidence of escape prevention planning and worker training on escape prevention. The plan and training must include information on net strength testing, suitable net mesh sizing, net traceability, and reporting of events which may present a risk of escapes. (e.g. infrastructure damage, human errors). https://www.asc-aqua.org/wp-content/uploads/2019/12/ASC-Salmon-Standard_v1.3_Final.pdf

The BAP standard includes a section called "Control of Escapes" under which it is specified that: "Salmon farms shall take all practical steps to prevent escapes and minimize possible adverse effects on aquatic wildlife if escapes occur." Under the standard, certified companies must maintain a Fish Containment Plan which includes separate sections for escape prevention, dealing with escapes and inventory accounting procedures.

Under the principle of Escape Prevention, companies must characterize expected oceanographic conditions of farm sites and confirm that farm structure design and installation are appropriate. They must conduct risk analyses of potential causes of fish escapes and maintain protocols designed to reduce and respond to them. Companies must have procedures for surface and sub-surface inspections, net inventory management, predator deterrence, handling live fish to prevent "spillage" and training of staff on procedures in their Fish Containment Plan.

Under the premise of dealing with escapes, certified companies are required to maintain equipment and procedures for recapture, to immediately investigate known or suspected escape events with assessment of the cause and corrective actions and to report all escape events immediately to the regulator and to notify BAP and the certifying body. Furthermore, BAP outlines numbers of events and total numbers of escapees that if exceeded would result in suspension of certification.

With respect to inventory accounting procedures, farming companies must maintain records that certify numbers of fish stocked, record the number of farm mortalities and the number of fish harvested and account for any differences in the final numbers within each year class. Variances greater than set limits trigger a secondary audit investigation and possible loss of BAP certification. https://www.bapcertification.org/Downloadables/pdf/standards/PI%20-%20Standard%20-%20Salmon%20Farms%20-%20Issue%202.3%20-%2013-October-2016.pdf

Technical standards

Aquaculture equipment technical standards are developed and implemented to ensure that marine aquaculture cage sites are adequately designed, constructed, and maintained such that they are robust enough to meet the predicted conditions encountered in the marine environment in which they will be operated. As such, technical standards are effective at preventing escapes during normal every day operations and atypical conditions. These standards are intended to be applied on each farm site by the farm operators in consideration of the local conditions. The standards are equally to be referenced by equipment manufacturers and installers so that cage sites operators can ensure that their sites conform to the standards.

In Scotland, the Marine Scotland standard "A Technical Standard for Scottish Finfish Aquaculture" sets technical requirements for fish farm equipment and is applied to all finfish aquaculture licenses and all species of finfish farmed in Scotland. All operations were expected to meet the requirements under this standard by 2020. It is expected that the standard is to be used in conjunction with company operational procedures, codes of practice and other industry processes to ensure the appropriate use and maintenance of aquaculture equipment. https://www.gov.scot/binaries/content/documents/govscot/publications/advice-and-guidance/2015/06/technical-standard-scottish-finfish-aquaculture/documents/00479005-pdf/00479005-pdf/govscot%3Adocument/00479005.pdf

The Norwegian Standards for sea-based aquaculture facilities (NS 9415:2009) is a technical standard that guides the design, production, installation, and operation of marine aquaculture facilities. It defines technical requirements for each of the components of a fish farm including net cages, cage collars, mooring equipment and any other equipment needed to run the operation effectively. Engineering equipment and constructing aquaculture sites to this standard provides extra protection against environmental damage, reducing the risk of failure and escape of farmed fish.

Since 2006, when this standard was implemented, equipment failures and site damage in Norway have continued to decline, leading to decreasing incidents of escaped fish, despite increasing numbers of farmed fish being held in marine cages. https://www.standard.no/en/nyheter/news-in-english/2012/marine-fish-farms/#.YICVnpBKgnI

ISO 16488:2015(en) - Marine finfish farms — Open net cage — Design and Operation is an International Standard which offers general methods for analysing the design of components of marine finfish cage farms, such as cages, nets and mooring systems for a given set of environmental conditions.

The standard is designed to be used by the operator of a marine farm and is intended to reduce the risk of equipment failure and resulting fish escape. As such, the Standard also provides guidelines for the development of documented procedures for the proper maintenance and operation of the farm.

Research into Wild Salmon Populations

Collaborative Initiatives

The Atlantic Salmon Trust is a charitable conglomerate in Scotland, bringing together individuals and organisations to do research on wild salmon populations. It is organising a West Coast Tracking Project, placing trackers in out-migrating smolts to study at-sea behaviour and marine survival. The Scottish farmed salmon sector is putting in £540,000 over three years (£240k in year one, £180k in year two and £120k in year three). https://atlanticsalmontrust.org/

The Scottish farmed salmon sector, led by the SSPO, has set up the Wild Salmonid Support Fund. Money given to the fund by salmon farming companies will be allocated, as directed by a collaborative Board, to projects which improve the chances of wild salmon survival. This fund will receive £360k over three years (£60k in year one, £120k in year two and £180k in year three). https://www.foundationscotland.org.uk/apply-for-funding/funding-available/wild-salmonid-support-fund#:~:text=The%20Wild%20Salmonid%20Support%20Fund,and%20%C2%A325%2C000%20are%20available.

In the United States the Maine Department of Marine Resources (DMR) will employ a novel approach to rearing Atlantic salmon for restoring native populations on the East Branch of the Penobscot River. The project, funded through a NOAA Section 6 Species Recovery Grant, will involve a partnership between DMR, Cooke Aquaculture USA, US Fish and Wildlife Service, NOAA Fisheries, and the Penobscot Indian Nation to grow juvenile Atlantic salmon to adult size in aquaculture pens located near Cutler Maine. The adult salmon will then be released into the East Branch of the Penobscot to spawn, a river with large amounts of high-quality salmon habitat. DMR and Cooke are additionally cooperating on an identical project focusing on the Machias River Watershed. Fish with Machias River genetics will be reared in isolated pens near Cutler Maine and released when mature into the Machias Watershed.

In Atlantic Canada, a large collaborative Atlantic salmon conservation project, Fundy Salmon Recovery (FSR), has been ongoing for two decades. It includes the salmon aquaculture industry, municipal, provincial and federal governments, law enforcement, researchers, Parks Canada and a First Nation partner. The goal of the FSR project is to increase the number of spawning wild salmon in four rivers of the inner Bay of Fundy system.

Research and experience have shown that Atlantic salmon that spend their early lives in rivers or streams are much better equipped to survive and reproduce in the wild, and the best strategy to maximize the recovery of wild salmon to Inner Bay of Fundy rivers is to minimize captive exposure early in their life cycle. So, the project collects smolt which have spend the critical early life stages in the wild, and then cares for them in an ocean environment at dedicated modified aquaculture sea cages at the world's first Marine Conservation Farm on the Island of Grand Manan managed by Cooke Aquaculture and the Atlantic Canada Fish Farmers Association.

When the salmon have grown to adult size and are ready to spawn, they are released back into their home rivers. Since 2014 the project has released close to 5,000 mature wild adults, documented increased smolt runs in certain years relative previous stocking numbers, and has seen adult returns that represented a 30 year high in one river. Research, conducted by the University of New Brunswick is also showing increased river productivity, increased fry densities, larger salmon smolt, and that the returning adults contribute proportionally more offspring.

Additional research that partners with salmon aquaculture and Fisheries and Oceans Canada (Marc Trudel) is the pilot wild salmon telemetry project to study juvenile migration:

Atlantic salmon have been extirpated from several of their native rivers and often fail to meet conservation requirements, particularly in the Bay of Fundy and Northeast United States. Although multiple factors likely contributed to these declines such has habitat destruction, overfishing, and climate change, the cumulative effects of multiple stressors on the survival of Atlantic salmon is poorly understood. The results of an acoustic telemetry project to assess the population response of Atlantic salmon to multiple stressors during a critical period of their life cycle, including passage through a hydropower system and bycatch mortality associated with in-river fisheries were presented. Also assessed in this project was the salmon migration routes and rates during their early marine life and whether there are any interactions with aquaculture.

A pilot wild salmon telemetry project to study juvenile migration and their interactions with aquaculture in Passamaquoddy Bay was undertaken in 2018, with a larger project, Assessing the effects of multiple stressors on the estuarine and early marine survival of Atlantic salmon post smolts, commencing in 2019 that will run through 2021. Another project starting in 2021 will study the migration and survival of Atlantic salmon post smolts in the Bay of Fundy.