From: Candy, John
Sent: Thursday, October 15, 2020 12:53 PM
To: Sullivan, Tarah
Subject: 30 min time slot for meeting next week with Carmel to discuss aquaculture issue

Hi Tarah
Lesley has asked to arrange a meeting including Carmel to discuss the possible emerging issues around mouth rot disease (Tanachbaculum maritimun)
Is there a 30 min time slot next week that she is free that I can try and arrange a meeting with others?

The group requested for this call would include:
Carmel Lowe
Stewart Johnson
Zac Waddington
Kristi Miller
Lesley McDougall
myself

John Candy
Section Head
Molecular Genetics Laboratory
Pacific Biological Station
Nanaimo BC V9T 6N7
(250) 756-7036
John.candy@dfo-mpo.gc.ca

From: MacDougall, Lesley
Sent: Wednesday, October 21, 2020 3:11 PM
To: Lowe, Carmel
Subject: Fwd: Shea paper
Attachments: Shea et al. 2020 (pathogen eDNA from salmon farms).pdf; ATT00001.htm

Sent from my iPhone

Begin forwarded message:

> **From:** Kristi
> **Date:** October 21, 2020 at 9:16:52 AM PDT
> **To:** "MacDougall, Lesley"
> **Subject: Shea paper**

No information has been removed or severed from this page

PROCEEDINGS B

royalsocietypublishing.org/journal/rspb

Environmental DNA from multiple pathogens is elevated near active Atlantic salmon farms

Dylan Shea[1], Andrew Bateman[1,2,3], Shaorong Li[4], Amy Tabata[4], Angela Schulze[4], Gideon Mordecai[5], Lindsey Ogston[1], John P. Volpe[6], L. Neil Frazer[7], Brendan Connors[8], Kristina M. Miller[4], Steven Short[1,9,†] and Martin Krkošek[1,2,†]

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Research

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Pages 4 to / à 12

are withheld pursuant to section

sont retenues en vertu de l'article

68(a)

of the Access to Information Act

de la Loi sur l'accès à l'information

From: Webb, Allison
Sent: Wednesday, October 21, 2020 3:59 PM
To: Thomson, Andrew; Dostal, Alexandra; Struthers, Alistair; Parsons, Jay; Lowe, Carmel; MacDougall, Lesley
Cc: Girouard, Louise; Waddington, Zac; Paylor, Adrienne
Subject: FW: DI Farm metrics report
Attachments: Discovery Islands Metrics FINAL 2020-10-15.pdf

Just FYI only. I thought that you might be interested in seeing this product. Our team has been working hard to start producing more of this proactive info. I would like to see this for all areas on the coast. It is really good work from my perspective that can be shared with FN and external partners rather than them going to our public reporting website and needing to try to extract things. Thanks to our staff for this work. We have shared with the DI FN for the licence renewals so that they have the best info that we can provide to them about the farms in the claimed territories. With our improvements to our fish health database moving forward and investments in our data team, we will be able to more easily produce this type of info that is accessible for those external to DFO or even for colleagues within DFO.

Please feel free to share if this is of interest to other colleagues.

Thanks,
Allison

From: Waddington, Zac
Sent: Thursday, October 15, 2020 12:35 PM
To: Johansson, Todd
Cc: Newcomb, Reagan ; Webb, Allison ; Sitter, Laura ; Sandberg, Krista ; Blasco, Nathan ; Price, Derek ; Manchester, Howie
Subject: DI Farm metrics report

Hi Todd,

We've got a final version of our DI farm metric comparison report for you to distribute in advance of our future consultations/meetings. A big thanks to all the folks who helped pull this together. I hope this will provide the context FNs may wish for.

Dr. Zac Waddington DVM, B.Env.Sc.(Hons)
Lead Veterinarian - Pacific Region
Fisheries and Oceans Canada | Pêches et Océans Canada
Aquaculture Environmental Operations - Fish Health
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Discovery Islands

2011-2019/2020 COMPLIANCE AND PERFORMANCE | MARINE FINFISH

Introduction

This report provides an overview of the environmental and fish health performance of marine finfish facilities in the geographical region of the Discovery Islands, based on industry-submitted Conditions of Licence reports. The data are summarized by year and compare the performance of facilities in the Discovery Islands to all other marine finfish facilities operating in British Columbia waters.

For the purposes of this report, the Discovery Islands facilities are the 18 farms identified in the Discovery Islands risk assessments and illustrated on the map (Figure 1). The two facilities culturing Chinook salmon (Yellow Island and Doctor Bay) and three farms that are currently licensed but inactive (Dunsterville, Read Island and Young Passage), and one decommissioned experimental Chinook farm (Middle Point Bay) are not included. Additionally, two farms that are no longer licensed but were active since 2012 (Far Side and Frederick Arm) are included. The farms producing Atlantic salmon in the Discovery Passage area are:

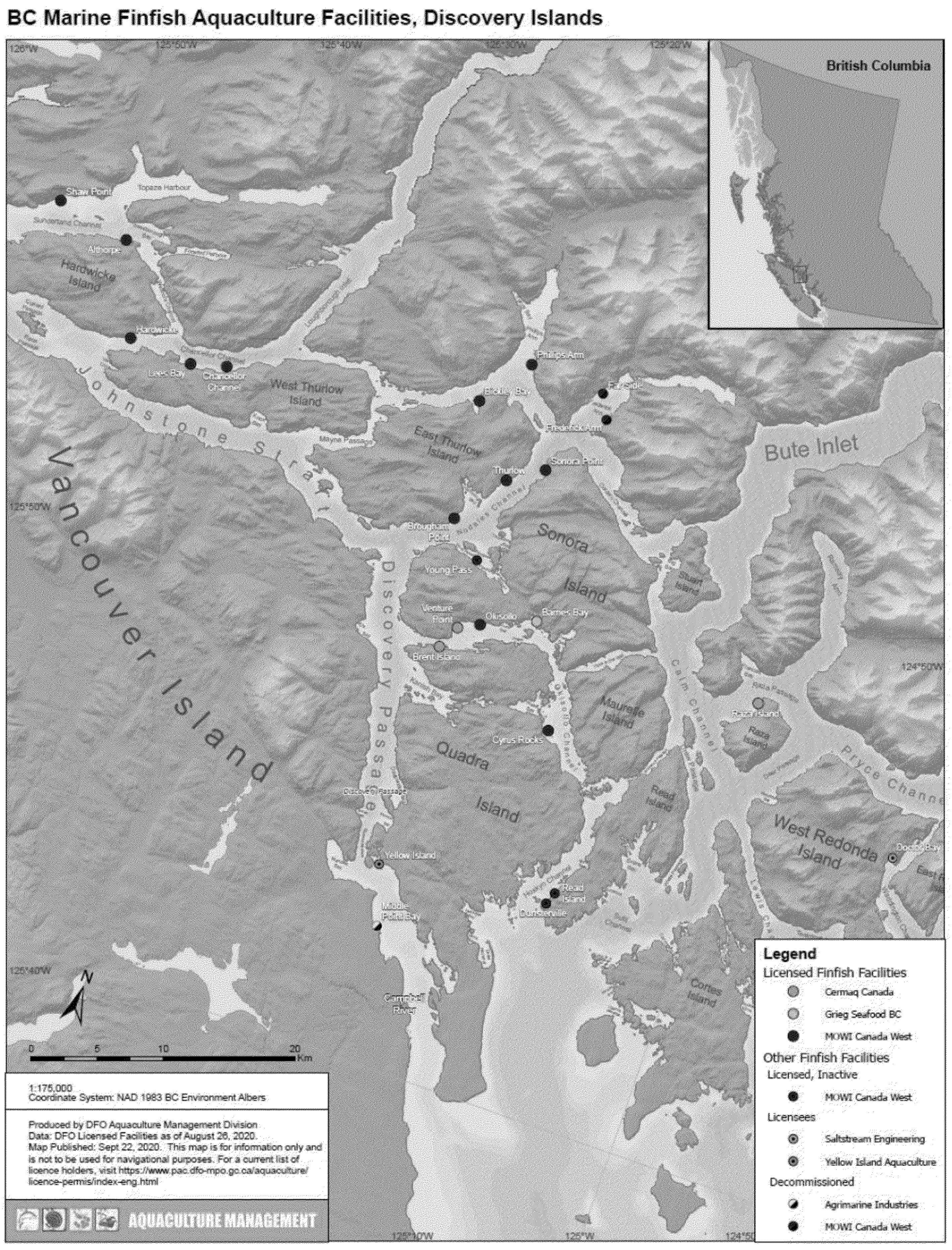
- Althorpe (MOWI Canada West)
- Barnes Bay (Grieg Seafood)
- Bickley Bay (MOWI Canada West)
- Brent Island (Cermaq Canada)
- Brougham Point (MOWI Canada West)
- Chancellor Channel (MOWI Canada West)
- Cyrus Rock (MOWI Canada West)
- Far Side (MOWI Canada West, no longer licensed)
- Frederick Arm (MOWI Canada West, no longer licensed)
- Hardwicke (MOWI Canada West)
- Lees Bay (MOWI Canada West)
- Okisollo (MOWI Canada West)
- Phillips Arm (MOWI Canada West)
- Raza Island (Cermaq Canada)
- Shaw Point (MOWI Canada West)
- Sonora Point (MOWI Canada West)
- Thurlow (MOWI Canada West)
- Venture Point (Cermaq Canada)

The **Discovery Islands** area is one of the main Atlantic salmon producing areas in BC with farms operated by MOWI Canada West, Cermaq Canada and Grieg Seafood BC. This area is generally quite good and consistent year-to-year with respect to environmental and fish health performance.

DFO conducts up to 120 randomized farm audits annually under the Fish Health Audit and Intelligence Program (FHAIP). These audits ensure the veracity of industry reported data, and compliance with Conditions of Licence (COL). DFO biologists and veterinarians collect samples to independently determine the fish health status of the farm at the time of audit, and ensure that any disease is being identified, mitigated and reported correctly by industry. Targeted audits have been added to the FHAIP in 2020 and are triggered at discretion of DFO biologists and veterinarians. These audits may or may not occur with advance warning to the company/facility.

Additional public information on the regulation and compliance of the marine finfish industry in British Columbia can be found through public reports on *DFO's Open Data Portal* or the *Pacific Region Aquaculture website* (Appendix I).

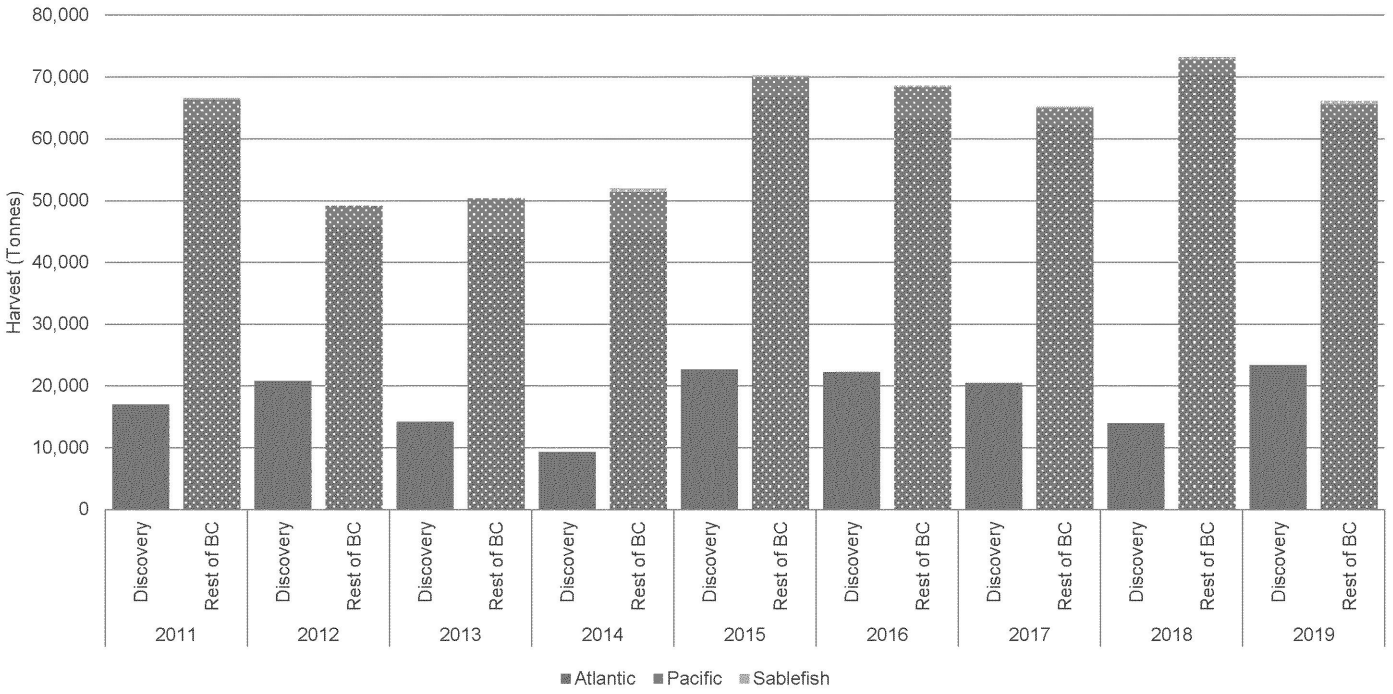
Figure 1. Marine fish farms in the Discovery Passage area (2020)



Production

Farms in the Discovery Islands account for approximately 20% of Atlantic Salmon Production in British Columbia. There are 18 licensed facilities in the Discovery Islands with an average of 11 active facilities in a calendar year.

Figure 2: Annual production (harvest) from marine finfish farms in BC, by species, 2011-2019



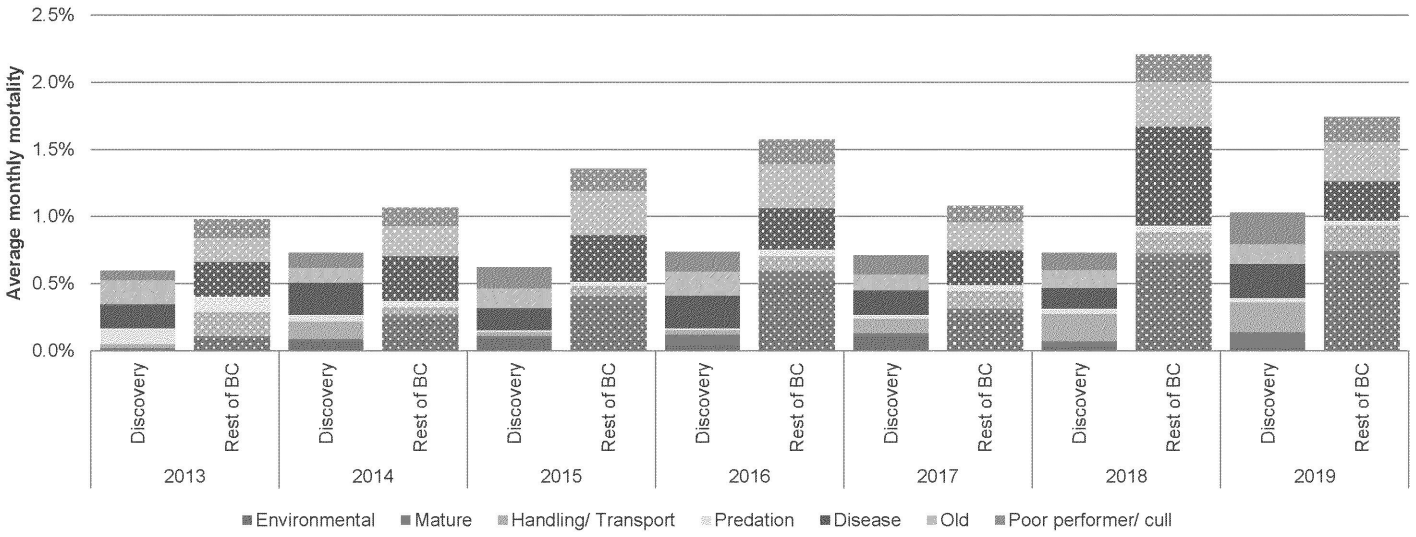
This graph shows the production farmed fish in the Discovery Islands (DI) compared to the rest of BC. The left vertical axis shows the amount (weight) of fish harvested from each area by species(illustrated by the coloured columns/bars). Annual production has ranged between 9000-23,000 tonnes between 2011-2019.

A large majority of production in the Discovery Islands is Atlantic salmon, and all facilities identified in the risk assessments produce Atlantic salmon. There are two small facilities, Yellow Island and Doctor Bay, which produce other species. Yellow Island is a very small facility, with its own hatchery on land, which focusses mainly on research and harvests only small numbers of large Chinook salmon each year. Doctor Bay also produces small amounts of Chinook salmon, and has historically cultured small numbers of sablefish (*Anoplopoma fimbria*). The production of Chinook salmon and sablefish in the Discovery Islands is so small that it is difficult to display on the graph

Fish Health - Mortality

The average monthly mortality at fish farms in the Discovery Islands is about half that of other farms in British Columbia.

Figure 3: Mortality at Atlantic salmon facilities in BC, by area



This graph shows the average percent monthly mortality in DI compared to other farming regions of BC. It also shows the causes of death. Mortality rates in DI are generally less than 1% per month Farms in the DI typically experience lower mortalities than other regions of BC. Generally water quality is good (few instances of low dissolved oxygen events and harmful algal blooms) and disease is less frequent given the area and production practices.

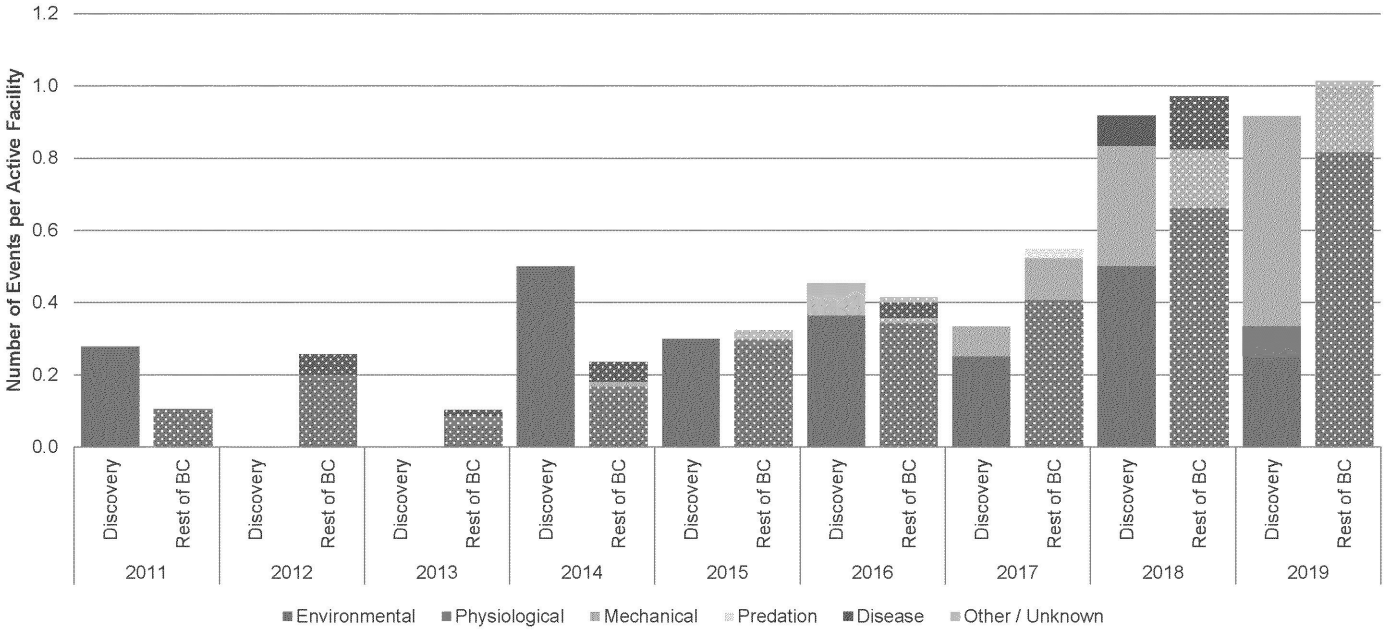
A production practice which is unique to the Discovery Islands is that salmon smolts are generally not entered into any of the DI farms directly from freshwater hatcheries. This practice is in place due to the Myxozoan parasite *Kudoa thyrsites. Kudoa* infects salmon (both farmed and wild) and creates intramuscular cysts without resulting disease or compromise in the salmon host. However, post-mortem enzyme degradation of the cysts results in muscular liquefaction and therefore significant fillet quality downgrades. This parasite is ubiquitous in BC marine waters, but the degree of infection pressure seems much higher in the Discovery Islands. Industry has learned that by introducing smolts to areas outside the DIs first, and then months later transferring those fish into DI farms results in lower levels of infection, reducing subsequent cyst formation, and resulting in substantially fewer fillet downgrades. The exact mechanism of this protective effect is unclear, and is the subject of ongoing research.

This production practice means that without smolt entries occurring in the DI there is very little of the early mortality and production disease which often occur in the first months when smolts are at sea. The primary production disease affecting farmed Atlantic salmon in BC is Mouthrot which is caused by the ubiquitous marine bacteria *Tenacibaculum maritimum.* Mouthrot does not occur in Pacific salmon species, and only occurs in Atlantic salmon within their first 6-8 months at sea. This disease is treated with in-feed antibiotics and is responsible for the vast majority of antibiotic use in BC aquaculture.

Mortality Events

The majority of mortality events in the Discovery Passage are caused by environmental conditions. In recent years, there has been more impact of handling and treatment, and improved auditing and reporting of events by industry.

Figure 4: Mortality events at marine finfish aquaculture facilities in BC, 2011-2019



A Mortality Event occurs when the number (or "biomass") of dead fish at a facility growing Atlantic or Pacific salmon exceeds the thresholds outlined by conditions of licence for 24hrs (4,000kg or 2% inventory) or five days (10,000kg or 5% inventory).

This graph shows the number of mortality events per active facility. Farms in the Discovery Islands typically experience a similar rate of mortality events to other areas of BC.

The increase in Mortality Events in 2018 is attributed mainly to unfavourable environmental conditions, but also to an increase in reporting due to increased compliance auditing efforts by DFO biologists beginning in 2016, which enforced reporting requirements. In 2012 and 2013, there were no reported Mortality events in DI. In 2011, 2014, 2015 there was a low number of mortality events reported and all were attributed to environmental conditions.

Mortality Events due to environmental factors are increased by the higher-than-normal presence of poor gill health issues which predispose fish to die when water conditions are adverse, such as during low dissolved oxygen or harmful algae bloom events.

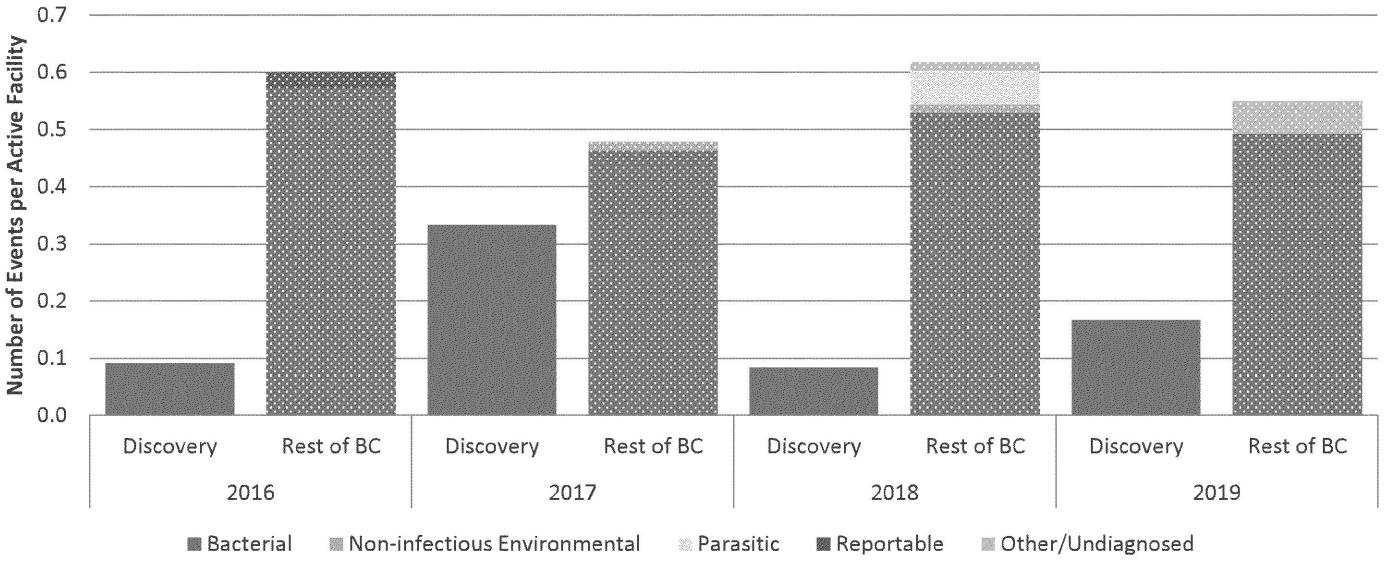
Table 1: Mortality events at marine finfish aquaculture facilities in BC, 2011-2019

Date	Licence Holder	Facility	Species	Probable Cause or Diagnosis
21-Jun-11	Marine Harvest Canada	Conville Bay	Atlantic Salmon	Algae bloom
30-Jun-11	Cermaq Canada	Brent Island	Atlantic Salmon	Algae bloom
30-Jun-11	Marine Harvest Canada	Far Side	Atlantic Salmon	Algae bloom
30-Jun-11	Marine Harvest Canada	Frederick Arm	Atlantic Salmon	Algae bloom
04-Jul-11	Marine Harvest Canada	Brougham Point	Atlantic Salmon	Algae bloom
07-Jul-14	Cermaq Canada	Brent Island	Atlantic Salmon	Low Dissolved Oxygen
16-Sep-14	Cermaq Canada	Venture Point	Atlantic Salmon	Low Dissolved Oxygen
18-Sep-14	Cermaq Canada	Brent Island	Atlantic Salmon	Low Dissolved Oxygen
23-Sep-14	Marine Harvest Canada	Lees Bay	Atlantic Salmon	Algae bloom
16-Oct-14	Marine Harvest Canada	Okisollo	Atlantic Salmon	Low Dissolved Oxygen
24-Jul-15	Marine Harvest Canada	Lees Bay	Atlantic Salmon	Algae bloom
24-Jul-15	Marine Harvest Canada	Phillips Arm	Atlantic Salmon	Algae bloom
24-Jul-15	Marine Harvest Canada	Hardwicke	Atlantic Salmon	Algae bloom
3-Feb-16	Cermaq Canada	Brent Island	Atlantic Salmon	Other - explain
11-Sep-16	Cermaq Canada	Brent Island	Atlantic Salmon	Low Dissolved Oxygen
14-Sep-16	Grieg Seafood BC	Barnes Bay	Atlantic Salmon	Low Dissolved Oxygen
26-Sep-16	Cermaq Canada	Venture Point	Atlantic Salmon	Low Dissolved Oxygen
11-Oct-16	Marine Harvest Canada	Okisollo	Atlantic Salmon	Low Dissolved Oxygen
24-Aug-17	Marine Harvest Canada	Hardwicke	Atlantic Salmon	Algae bloom
31-Aug-17	Marine Harvest Canada	Althorpe	Atlantic Salmon	Handling
8-Sep-17	Marine Harvest Canada	Althorpe	Atlantic Salmon	Algae bloom
25-Sep-17	Marine Harvest Canada	Hardwicke	Atlantic Salmon	Low Dissolved Oxygen
9-Mar-18	Cermaq Canada	Raza Island	Atlantic Salmon	Algae bloom
1-Jun-18	Marine Harvest Canada	Phillips Arm	Atlantic Salmon	Treatment
6-Jun-18	Grieg Seafood BC	Barnes Bay	Atlantic Salmon	Non-infectious disease
6-Aug-18	Marine Harvest Canada	Okisollo	Atlantic Salmon	Low Dissolved Oxygen
22-Aug-18	Cermaq Canada	Venture Point	Atlantic Salmon	Low Dissolved Oxygen
28-Aug-18	Grieg Seafood BC	Barnes Bay	Atlantic Salmon	Low Dissolved Oxygen
06-Sep-18	Cermaq Canada	Brent Island	Atlantic Salmon	Handling
1-Oct-18	Cermaq Canada	Venture Point	Atlantic Salmon	Low Dissolved Oxygen
8-Oct-18	Grieg Seafood BC	Barnes Bay	Atlantic Salmon	Handling
9-Oct-18	Marine Harvest Canada	Lees Bay	Atlantic Salmon	Treatment
19-Nov-18	Grieg Seafood BC	Barnes Bay	Atlantic Salmon	Low Dissolved Oxygen
11-Jun-19	MOWI Canada West	Sonora Point	Atlantic Salmon	Handling
27-Jun-19	MOWI Canada West	Phillips Arm	Atlantic Salmon	Handling
08-Jul-19	MOWI Canada West	Sonora Point	Atlantic Salmon	Handling
12-Jul-19	MOWI Canada West	Chancellor Channel	Atlantic Salmon	Handling
16-Jul-19	MOWI Canada West	Phillips Arm	Atlantic Salmon	Handling
31-Jul-19	MOWI Canada West	Sonora Point	Atlantic Salmon	Handling
16-Aug-19	MOWI Canada West	Althorpe	Atlantic Salmon	Low Dissolved Oxygen
19-Aug-19	MOWI Canada West	Chancellor Channel	Atlantic Salmon	Maturation
28-Aug-19	MOWI Canada West	Lees Bay	Atlantic Salmon	Low Dissolved Oxygen
2-Sep-19	MOWI Canada West	Hardwicke	Atlantic Salmon	Low Dissolved Oxygen
30-Oct-19	MOWI Canada West	Okisollo	Atlantic Salmon	Treatment

Fish Health Events

The occurrence of fish health events at farms in the Discovery Islands is generally lower than in other areas of British Columbia.

Figure 5: Fish health events at marine finfish facilities in BC, 2016-2019



A Fish Health Event(FHE) occurs when veterinary intervention is required due to a suspected or diagnosed disease at a facility and mitigation is applied. Mitigation most often takes the form of antibiotic treatments, but could also be any of: culling, accelerated harvest, quarantine, enhanced biosecurity, disease investigation or reducing stress. Fish Health Events are sometimes, but not always, associated with a Mortality Event.

This graph shows the number of FHEs per active facility. Farms in the Discovery Islands typically experience a lower rate of FHEs than in other areas in BC. There have been eight treatment events since 2016 and most of these were attributed to mouthrot.

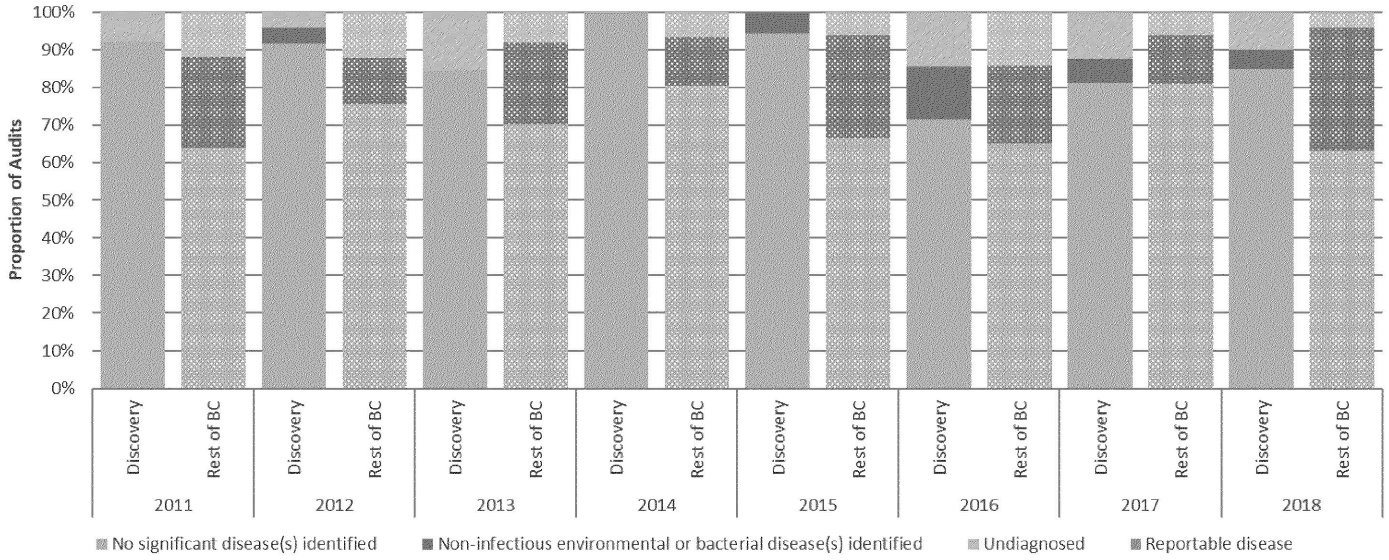
Table 2: Mortality events at marine finfish aquaculture facilities in BC, 2011-2019

Date	Licence Holder	Facility	Species	Veterinary Diagnosis
Jan-16	Cermaq Canada	Raza Island	Atlantic Salmon	Mouthrot
26-Jun-17	Grieg Seafood BC	Barnes Bay	Atlantic Salmon	Mouthrot
Jul-17	Cermaq Canada	Brent Island	Atlantic Salmon	Mouthrot
18-Oct-17	Marine Harvest Canada	Okisollo	Atlantic Salmon	Furunculosis
04-Nov-17	Cermaq Canada	Raza Island	Atlantic Salmon	Mouthrot
14-May-18	Marine Harvest Canada	Shaw Point	Atlantic Salmon	Mouthrot
13-Apr-19	MOWI Canada West	Shaw Point	Atlantic Salmon	Mouthrot
01-Nov-19	Cermaq Canada	Raza Island	Atlantic Salmon	Mouthrot

Fish Health Audits

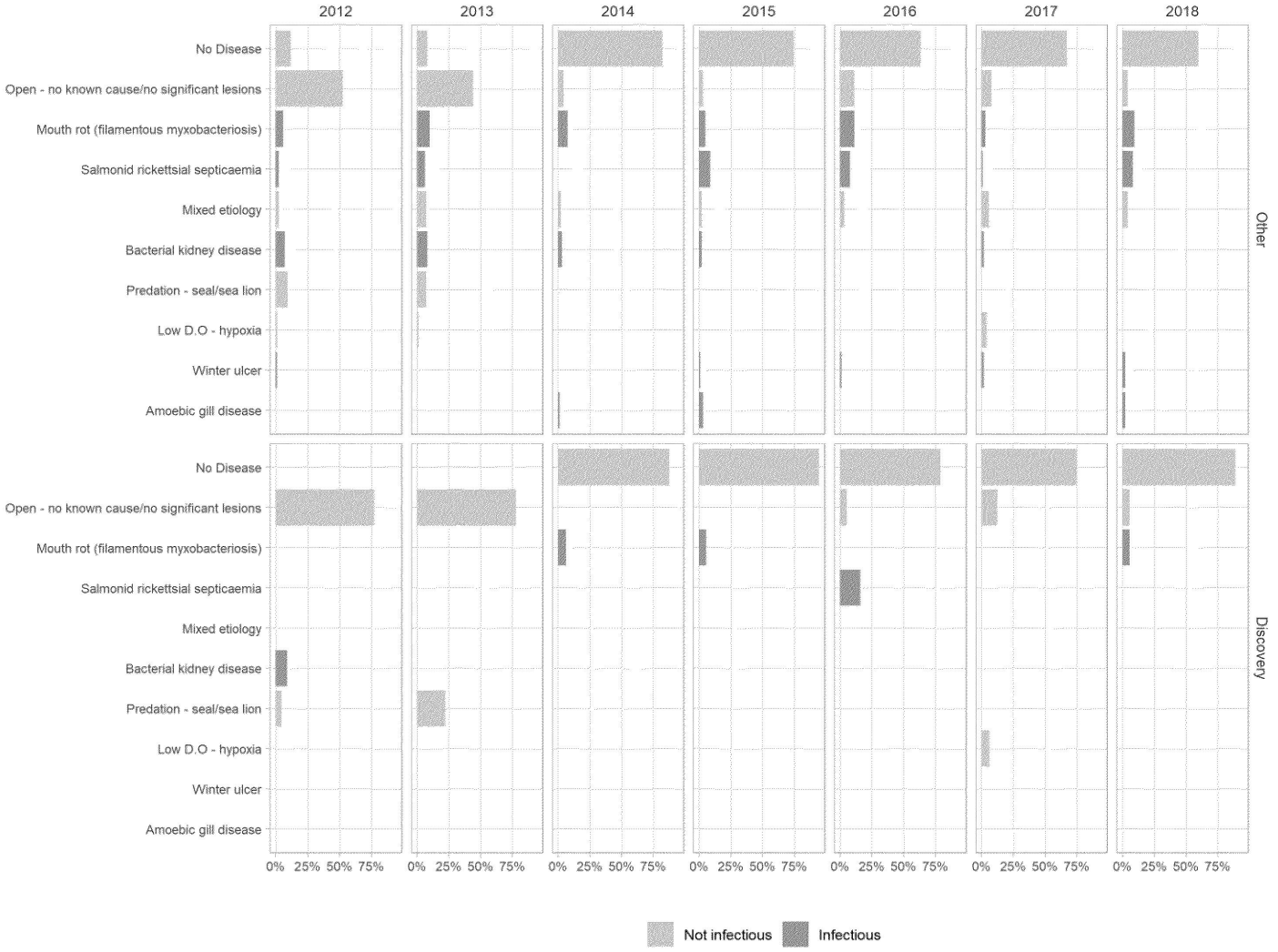
DFO conducts at least 120 marine farm audits annually under the Fish Health Audit and Intelligence Program (FHAIP). Approximately 850 fish are sampled and submitted for diagnostic testing annually. From 2011-2018 DFO conducted 118 audits at Atlantic salmon farms in the Discovery Islands. These farms generally have less disease diagnosed than the industry average.

Figure 6: Fish health audits at marine finfish facilities in BC, 2011-2018



DFO biologists and veterinarians conduct randomized routine audits of marine salmon farms. In 2020, targeted audits were also added to the FHAIP which are triggered at the discretion of DFO veterinarians when there may be elevated risk, or suspected/confirmed non-compliance. During these audits, all aspects of fish health and husbandry are reviewed, as well as compliance with the conditions of licence and Health Management Plan (HMP). Samples of moribund and/or recently dead fish are taken by DFO auditors on site and sent to a certified diagnostic laboratory for analysis including: bacteriology, virology, PCR, and histopathology. Additional molecular diagnostics and special staining (for histopathology) may be used at the discretion of the veterinarian and veterinary pathologist(s). DFO veterinarians review the results of the diagnostic testing; along with the field notes on fish behavior and appearance, recent mortality, handling and treatment events, and gross necropsy notes, to make a farm-level diagnosis.

Figure 7: Fish health audits at marine finfish facilities in BC, 2012-2018



This graph displays the farm-level diagnoses made by DFO veterinarians from 2012- 2018. The bar charts on the top half show data from all salmon farming regions in BC except for Discovery Islands. The bottom half shows the data from Discovery Islands only.

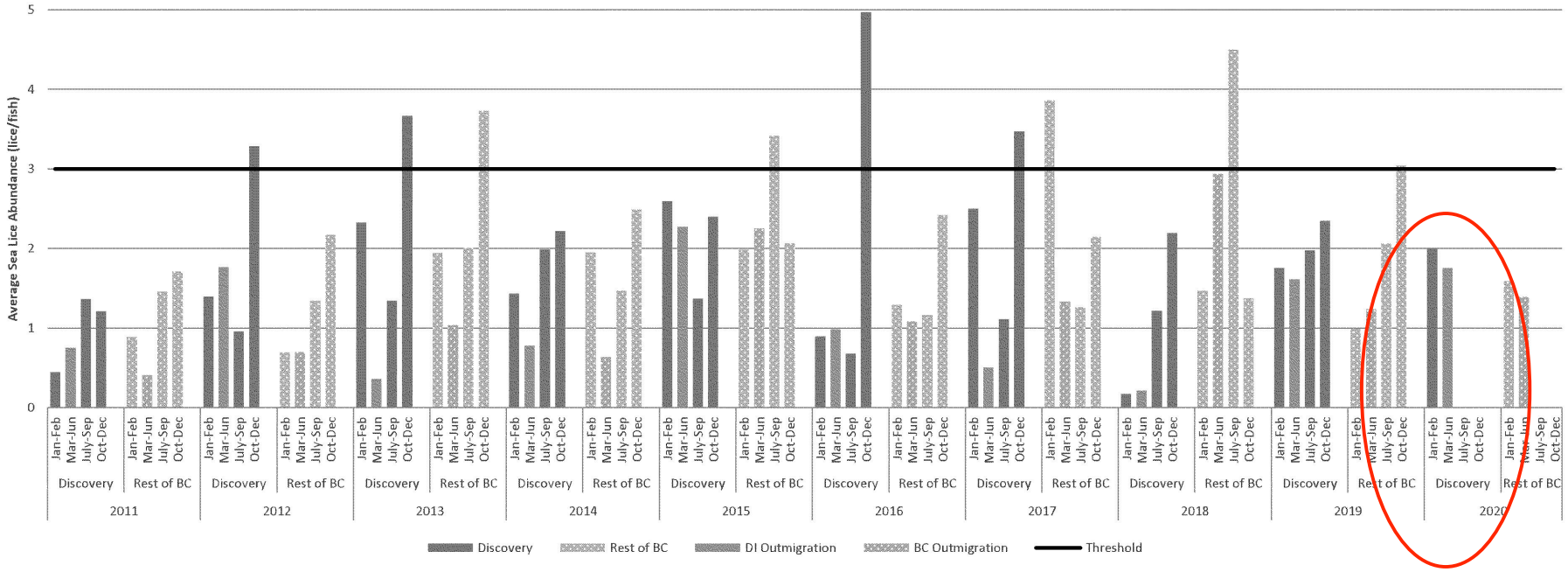
The left axis lists the different diagnoses that have been made during this period. The light-blue bars indicate that the diagnosis was not an infectious disease, and the dark blue bars indicate where an infectious disease was present.

In all areas of BC (including Discovery Islands), the majority of farm-level diagnoses are "open" or "no disease". An "open" diagnosis indicates that there is no know or obvious disease present. Between 2013 and 2014, a change in reporting categories saw a change in language from "open" to "no disease".

Sea Lice

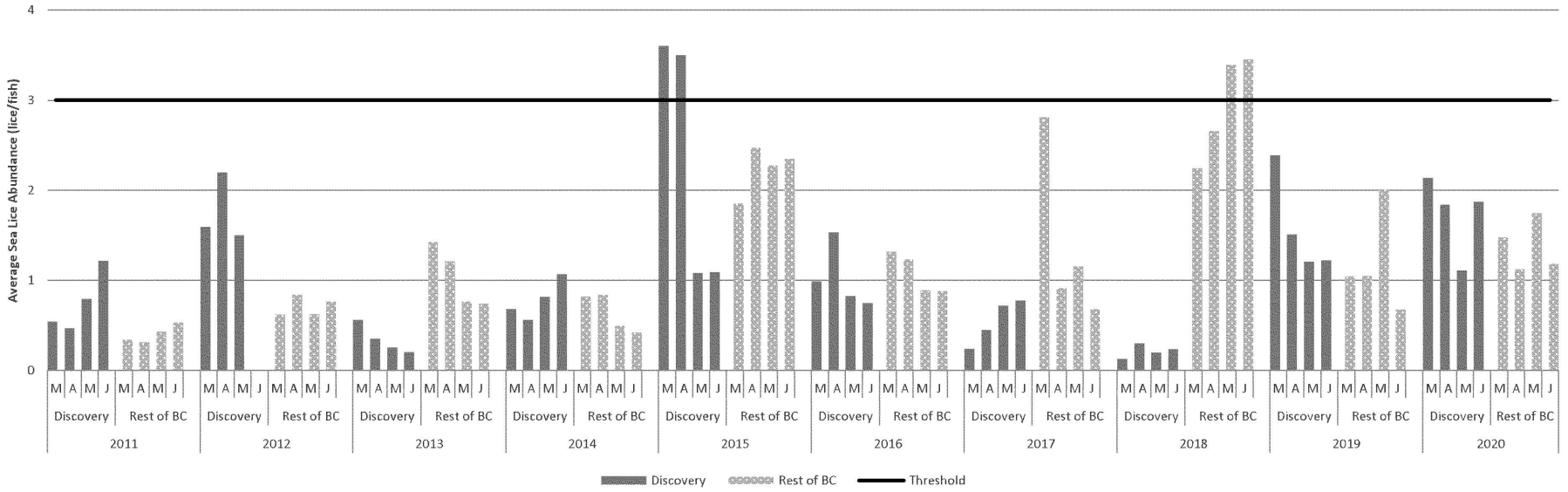
Since 2011 there have been 14 incidents of sea lice threshold exceedances during the juvenile salmon outmigration period (March- June) in the Discovery Islands.

Figure 8: Average abundance of motile *L.salmonis* sea lice at marine finfish aquaculture facilities in BC, 2011- 2020



This graph shows the average monthly sea lice abundance in the Discovery Islands and in the rest of BC. The bold, black horizontal line indicates the sea lice threshold as set out in the Conditions of Licence (i.e. 3 motile *L. salmonis* per fish). The coloured bars are grouped by sets of months, with the bright green bars indicating the juvenile salmon outmigration period in the Discovery Islands, and the bright yellow bars indicating the outmigration for the other farming regions of BC. Additional details on the abundance during the juvenile salmon outmigration period are shown in Figure 9.

Figure 9: Average abundance of motile *L.salmonis* sea lice, during the juvenile salmon outmigration period, at marine finfish aquaculture facilities in BC, 2011- 2020



This graph shows the average monthly sea lice abundance, during the juvenile salmon outmigration period, in the Discovery Islands and in the rest of BC. The bold, black horizontal line indicates the sea lice threshold as set out in the Conditions of Licence (i.e. 3 motile *L. salmonis* per fish).

As a condition of licence (COL), all farms have been required to regularly sample and report sea lice numbers on farms. The licence also sets out a threshold of three motile lice per fish as a precautionary management threshold to trigger mitigation and/or increased sampling/reporting depending on the time of year. This licence requirement ensures that sea lice numbers are at their lowest during the outmigration period of wild juvenile salmon (March 1st –June 30th annually).

DFO audits 50% of all active facilities during the outmigration period, and approximately 15% of active facilities per quarter during the remainder of the year. These sea lice audits involve a comprehensive review of sea lice sampling technique, counting methodology and sea lice classification. DFO auditor counts are compared to industry counts statistically to identify any error in the counting and classification methodology.

New licence conditions came into effect in March 2020 which increased sampling and reporting requirements around sea lice management on farms. These changes were made with contributions and feedback from First Nations, non-government environmental groups, industry and stakeholders.

With the new licence conditions, there is mandatory reporting of pre- and post-treatment sea lice numbers to allow DFO to monitor treatment efficacy and thereby detect and mitigate emerging resistance to sea lice treatments. There is a requirement for all lice removed mechanically to be captured, and the language of the licence has been improved to increase enforceability.

Farms in the Discovery Islands typically experience high lice infections in the fall as wild adult salmon return to spawn and carry with them high lice loads. Generally DI farms have performed better than industry average for sea lice management during the critical outmigration period. The number of facilities which have an exceedance, and the time spent in exceedance of the threshold are typically fewer and shorter than other farming areas. The DI farms have not had widespread occurrence of SLICE resistance, which have been seen in other farming areas resulting in significant sea lice management challenges. On the farms, sea lice mitigation efforts have generally resulted in reducing lice loads prior to the juvenile salmon outmigration period.

Details on the mitigation treatments can be found in the Therapeutants section below.

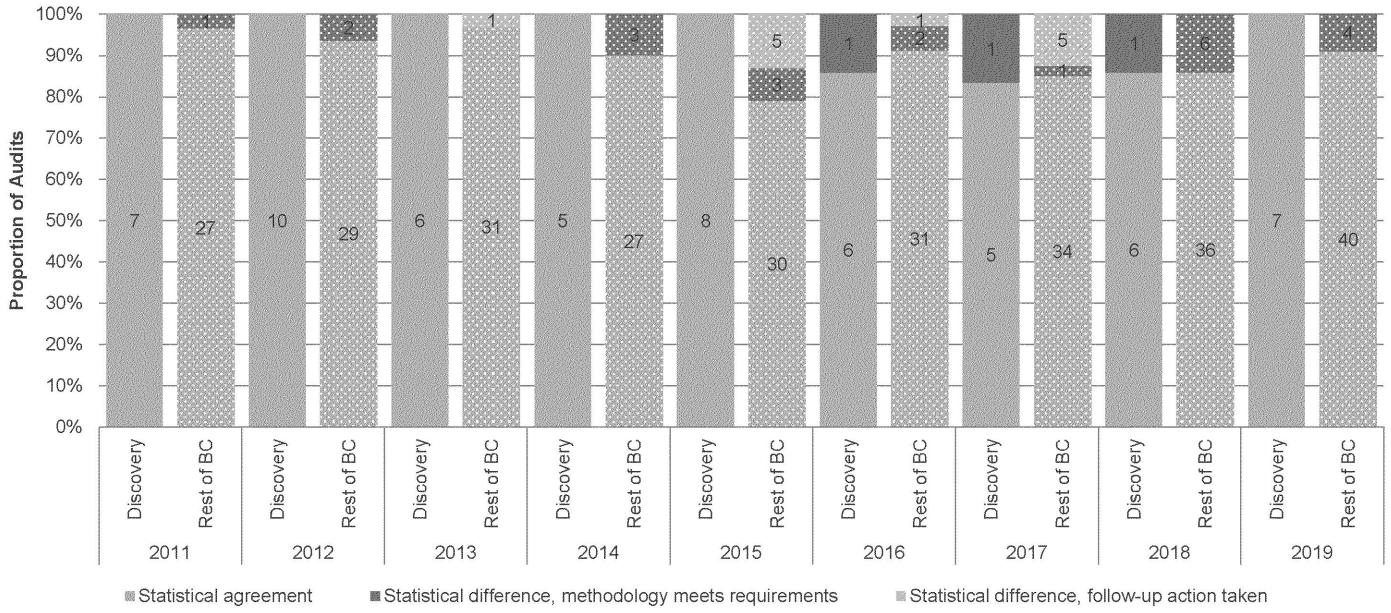
Table 3: Sea Lice exceedances during juvenile salmon outmigration period at marine finfish aquaculture facilities in the Discovery Islands, 2011-2019

Year/Month	Licence Holder	Facility	Maximum Sea Lice Abundance	Number of months over threshold
June 2011	Marine Harvest Canada	Chancellor Channel	4.0	1
March 2012	Marine Harvest Canada	Hardwicke	9.2	1
April 2012	Marine Harvest Canada	Brougham Point	5.9	1
April 2012	Marine Harvest Canada	Okisollo	4.4	1
April 2012	Marine Harvest Canada	Sonora Point	4.2	1
May 2012	Marine Harvest Canada	Thurlow	4.9	1
May 2014	Marine Harvest Canada	Sonora Point	3.5	2
March 2015	Marine Harvest Canada	Hardwicke	10.1	2
March 2015	Marine Harvest Canada	Lees Bay	15.8	1
June 2015	Cermaq Canada	Brent Island	4.9	1
April 2016	Marine Harvest Canada	Okisollo	4.0	1
March 2019	MOWI Canada West	Hardwicke	7.9	2
March 2019	MOWI Canada West	Shaw Point	5.7	3
June 2019	MOWI Canada West	Chancellor Channel	3.1	1
March 2020	MOWI Canada West	Lees Bay	13.8	2
March 2020	MOWI Canada West	Shaw Point	20.9	4
April 2020	Grieg Seafood BC	Barnes Bay	3.3	1
April 2020	Cermaq Canada	Brent Island	5.4	1
June 2020	MOWI Canada West	Lees Bay	6.8	1
June 2020	MOWI Canada West	Okisollo	7.0	1
June 2020	Cermaq Canada	Venture Point	3.2	1

Sea Lice Audits

Within the 120 marine farm audits conducted annually; 50% of all active facilities will be subject to a sea lice audit during the outmigration period, and approximately 25% of facilities will be audited during the remainder of the year for a total of approximately 40 sea lice audits annually. From 2011-2019 DFO conduced 60 sea lice audits at DI farms.

Figure 10: Fish health and sea lice treatment events and finfish aquaculture facilities in BC by area, 2013-2019

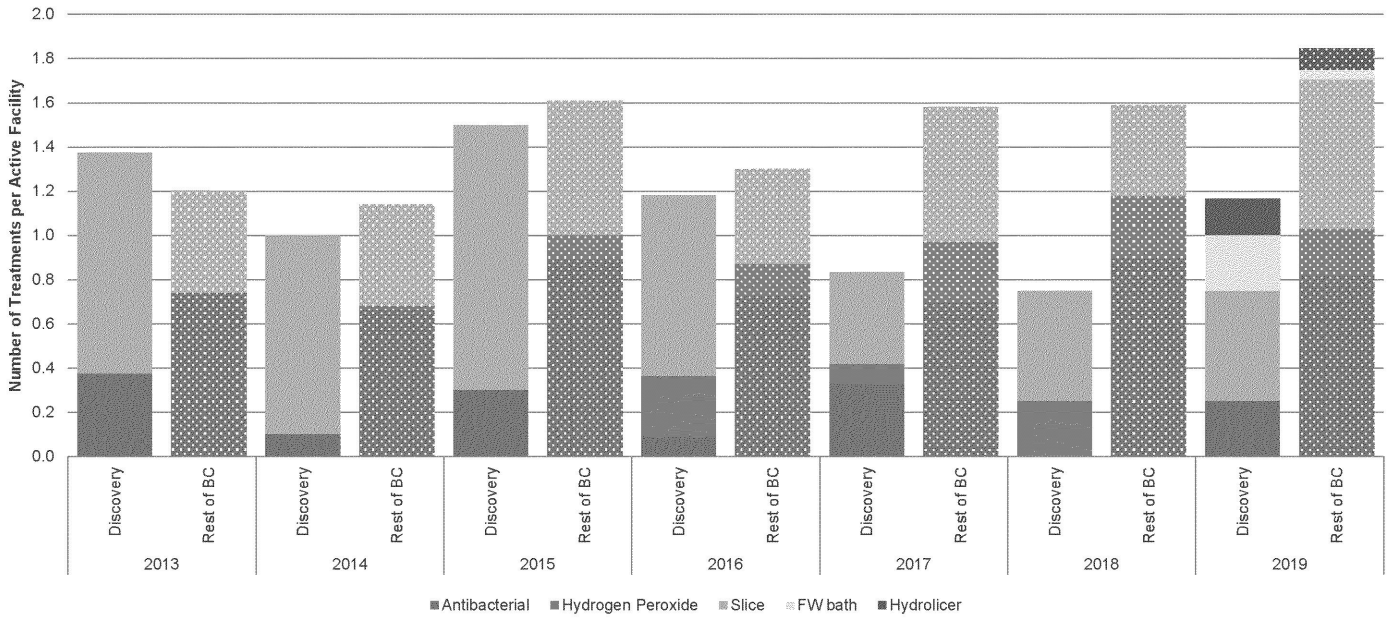


During a sea lice audit, DFO auditors conduct a comprehensive review of sea lice sampling technique, counting methodology and sea lice classification. Farm staff count sea lice on 10 fish from at least three pens (at least 30 fish total), which is the minimum required for a "counting event" as defined in the licence. DFO auditors observe the counting technique and lice identification, and conduct an independent count of 10 fish from each of the same pens. DFO auditor counts are compared to industry counts statistically to identify any error in the counting and classification methodology. If a deficiency in sampling technique, counting rigor, sea lice life stage or species ID is identified, the company is issued a deficiency letter and this is deficiency is noted and checked for resolution at the next audit. A repeated deficiency may be classified as a non-compliance, and referred to DFO Conservation and Protection for possible prosecution.

Fish Health and Sea Lice Treatments

Farms in the Discovery Islands perform about ¼ of the antibacterial treatments compared to the rest of BC. Mechanical and bath treatments for sea lice are on par with the rest of the province and SLICE© treatments are slightly higher than other regions.

Figure 11: Fish health and sea lice treatment events and finfish aquaculture facilities in BC by area, 2013-2019



This graph shows the number of treatments per active facility in the Discovery Islands and in the rest of BC. A tabular summary of the treatments in the Discovery Islands can be found below.

"Antibacterial" indicates a treatment with antibiotics for a specific reason (infection). Antibiotics are always prescribed by a licensed veterinarian. Fish are usually medicated by adding the antibiotic to the fish food and feeding it to the fish. The rate of antibacterial treatments is generally lower than in other regions, as farms in this area tend to have much less Mouthrot due to the production practice of not stocking smolts into the area directly from the hatchery.

"Hydrogen peroxide" refers to a sea lice bath treatment, where fish are taken from their sea pens and placed into a large boat filled with a special type of hydrogen peroxide compound for a few hours. This kills the sea lice so they fall off the fish. The fish are then placed back into their sea pens, and the lice are captured and composted in land-based facilities. Hydrogen Peroxide treatments have been successfully utilized in the Discovery Islands since 2015. No hydrogen peroxide treatments were applied in 2019.

"SLICE" refers to a medication given to fish that kills sea lice and prevents them from reattaching for some period of time. Like antibiotic treatments, the medication is added to the fish feed. This medication can only be prescribed by a licensed veterinarian.

"FW bath" refers to a sea lice bath treatment, where fish are taken from their sea pens and placed into a large boat filled with freshwater for a few hours. This causes the sea lice to then fall off the fish. The fish are placed back into their sea pens and the lice are captured and composted in a land-based facility. The use of freshwater baths were first implemented in the Discovery Islands in 2019.

"Hydrolicer" refers to a mechanical sea lice treatment, where fish are removed from their sea pens and travel through a system on a boat that sprays pressurized water at the fish, and removes the lice. The fish are then placed back into their sea pens and the lice are captured and composted in a land-based facility. Hydrolicer treatments are a new method of sea lice mitigation in BC and were implemented in 2019. These treatments have been applied in the Discovery Islands farms as a successful method of lice removal.

Many novel techniques (e.g. hydrolicer, hydrogen peroxide, freshwater) to manage sea lice have been implemented in the Discovery Islands and elsewhere beginning in 2015. The adoption of alternative methods for sea lice control, and their rotational use is part of an Integrated Pest Management approach which helps to prevent the development of medication resistance and allows for improved control.

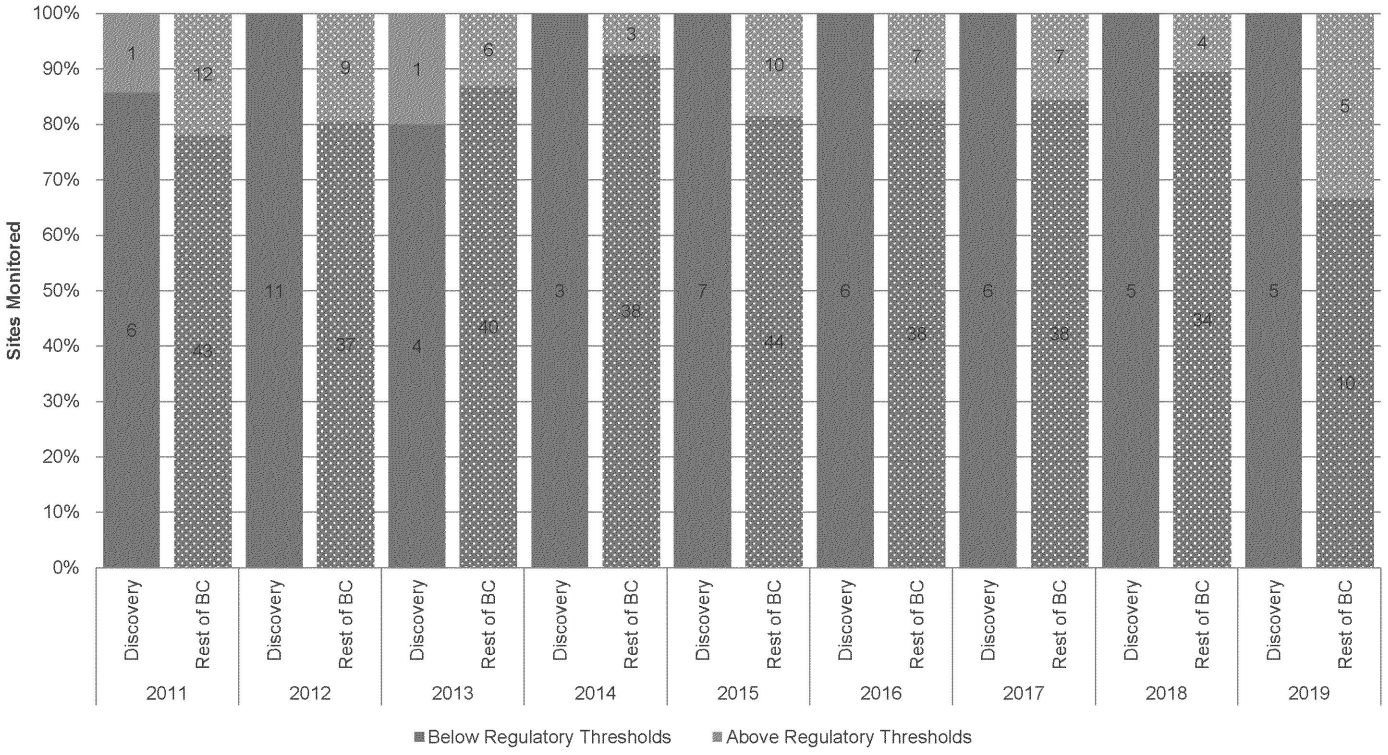
Table 4: Antibiotic and Sea Lice treatments in the Discovery Islands, 2013-2019

Year	Treatment	# of Treatments
2013	SLICE ©	8
	Florfenicol	3
2014	SLICE ©	9
	Florfenicol	1
2015	SLICE ©	12
	Florfenicol	3
2016	SLICE ©	9
	Florfenicol	1
	Hydrogen Peroxide	3
2017	SLICE ©	5
	Florfenicol	4
	Hydrogen Peroxide	4
2018	SLICE ©	6
	Hydrogen Peroxide	3
2019	SLICE ©	6
	Florfenicol	3
	FW bath treatment	3
	Hydrogen Peroxide	2

Benthic performance

Since 2011, 96% of marine finfish aquaculture sites monitored in the Discovery Islands were below regulatory thresholds, compared to 84% in other areas of BC.

Figure 12: Benthic performance and marine finfish facilities in BC, 2011-2018



Conditions of Licence require industry to conduct monitoring of the sea floor at peak production to ensure that thresholds for indication of harm are not exceeded. The presence of free sulphides in sediments are monitored for soft bottom sites, and the presence of sulphide oxidizing bacteria (e.g. *Beggiatoa sp.*) and OPC (polychaetes) are monitored for hard bottom sites. If thresholds are exceeded, the facility may not be stocked again until further monitoring indicates that the sea floor has adequately recovered. Overall, benthic impact at farms has been decreasing, likely due to better food conversion and digestibility of feed, decreased stocking densities, and moving containment arrays further offshore in deeper water and faster currents.

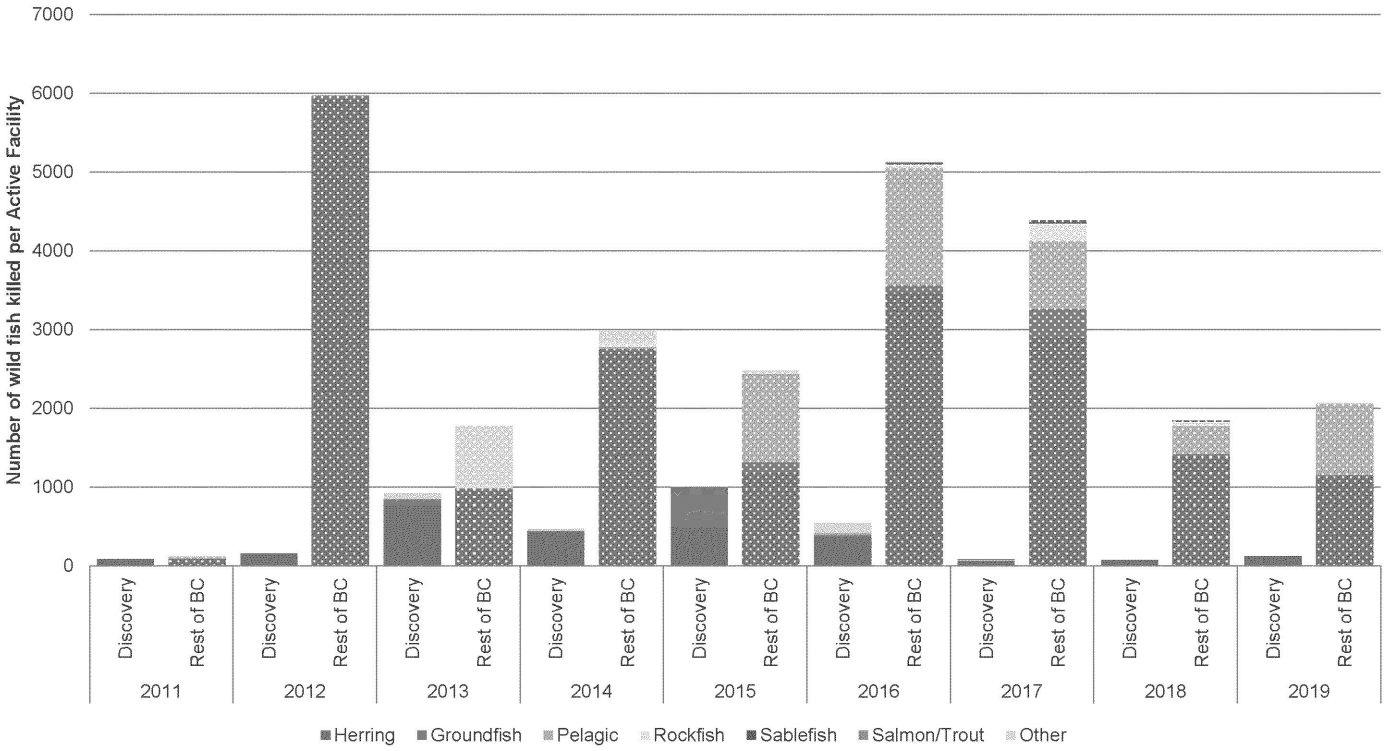
Table 5: Benthic threshold exceedances at marine finfish aquaculture facilities in the Discovery Islands, 2011-2019

Date	Licence Holder	Facility	Sea Bed Type	Survey Results
28-Mar-11	Marine Harvest Canada	Shaw Point	Soft Substrate	1 of 8 sediment sampling stations had chemical changes to the seabed which require additional monitoring
28-Mar-13	Marine Harvest Canada	Phillips Arm	Soft Substrate	1 of 4 sediment sampling stations had chemical changes to the seabed which require additional monitoring

Incidental Catch and Wild Mortalities

The number of wild fish killed at fish farms in the Discovery Islands is significantly lower than in other areas of British Columbia, accounting for only 2% of all dead wild fish captured at marine fish farms since 2011.

Figure 13: Incidental Catch and Wild Mortalities captured at finfish facilities in BC, 2013-2019



"Incidental catch" are any wild fish that are captured as a result of aquaculture activities including harvest, transfer or net removal. Licence holders are required to report both dead and released incidental catch, but only dead fish are publicly reported.

Wild mortalities are any wild fish that died or were captured within an aquaculture facility, where the cause of death or capture cannot be directly attributed to aquaculture activities. These are fish that are brought up in routine mortality uplifts, or scooped out of pens when harvest or transfer activities are not being performed.

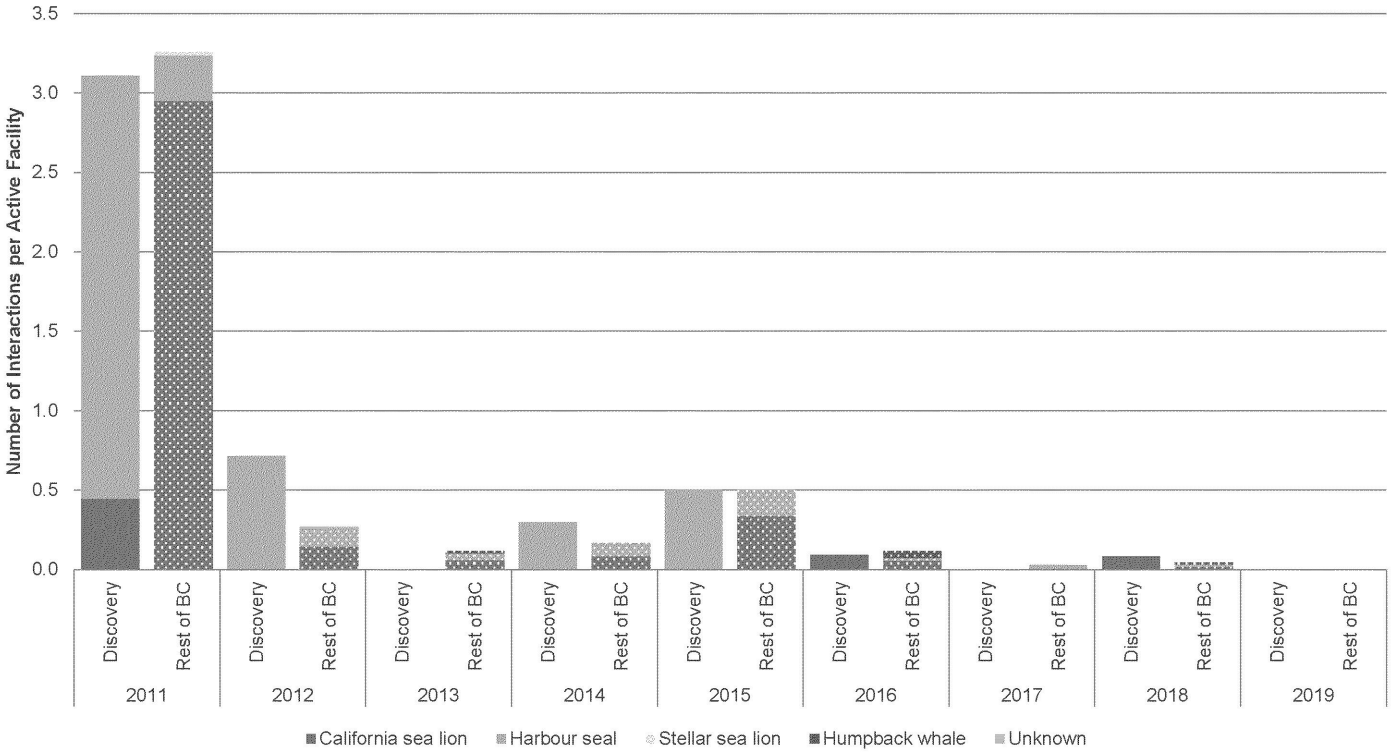
Licence holders are required to release all fish with least harm whenever possible. More than 70% of wild fish that are captured in aquaculture facilities are released back into the surrounding environment without harm.

DFO conducts inspections of harvest and transfer events at farm sites on an opportunistic basis. In addition, in 2018 and 2019, inspections occurred at fish processing plants to observe wild fish presence. This work ensures mitigation is followed at farms, and that wild fish are properly identified, recorded and reported to DFO.

Marine Mammals

Since 2011, there have been 17 accidental drownings of marine mammals at fish farms in the Discovery Islands. Authorized fatalities are no longer allowed.

Figure 14: Marine mammal fatalities at marine finfish facilities in BC by species, 1990-2019



Marine mammal deaths at marine fish farms have declined. Anti-predator netting, above water fencing and electric wires are effective when properly employed and maintained. As marine mammal populations grow in BC, new strategies to manage interactions with fish farms will be particularly important. These new technologies include improved net materials, non-harmful acoustic tools, and olfactory deterrents.

This graph shows the number of marine mammal fatalities per active facility at farms in the Discovery Islands and in other areas in BC.

The decrease in mortalities since 2012 coincides with the use of a new net material and with public reporting of marine mammal kills. Recently, the marine finfish aquaculture industry adopted a no-kill policy and DFO has retracted the authorization to dispatch pinnipeds.

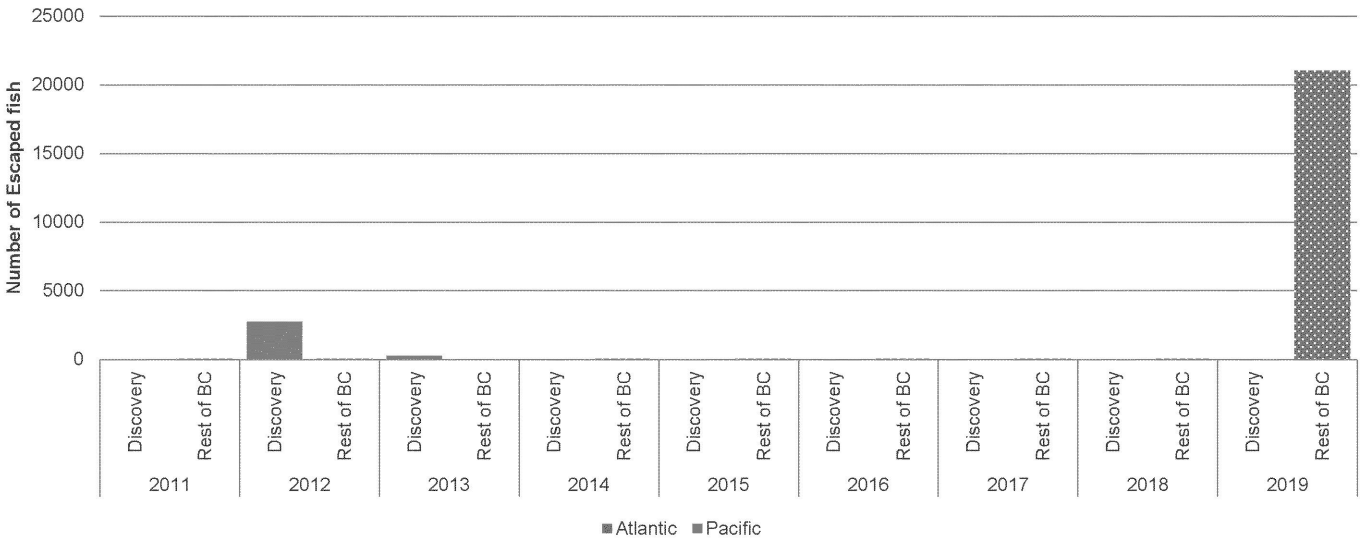
Table 6: Marine Mammal fatalities at marine finfish aquaculture facilities in the Discovery Islands, 2011-2019

Facility	Licence Holder	Year	Marine Mammal	Interaction
Barnes Bay	Grieg Seafood	2012	Harbour seal	1 accidental drowning
		2014	Harbour seal	3 accidental drowning
		2015	Harbour seal	3 accidental drowning
		2016	California sea lion	1 authorized fatality
		2018	California sea lion	1 accidental drowning
Bickley Bay	Marine Harvest Canada	2011	Harbour seal	6 authorized fatalities
Brent Island	Cermaq Canada	2011	Harbour seal	3 authorized fatalities
		2012	Harbour seal	1 authorized fatality
Brougham Point	Marine Harvest Canada	2012	Harbour seal	4 accidental drowning
Chancellor Channel	Marine Harvest Canada	2011	Harbour seal	9 authorized fatalities
Far Side	Marine Harvest Canada	2011	California sea lion	3 authorized fatalities
Frederick Arm	Marine Harvest Canada	2011	California sea lion	2 authorized fatalities
			Harbour seal	1 authorized fatality
Hardwicke	Marine Harvest Canada	2011	California sea lion	1 authorized fatality
			Harbour seal	7 authorized fatality
Lees Bay	Marine Harvest Canada	2011	California sea lion	2 authorized fatalities
			Harbour seal	11 authorized fatalities
Okisollo	Marine Harvest Canada	2015	Harbour seal	2 accidental drownings
Phillips Arm	Marine Harvest Canada	2011	Harbour seal	11 authorized fatalities
Raza Island	Mainstream Canada	2012	Harbour seal	1 authorized fatality
Sonora Point	Marine Harvest Canada	2012	Harbour seal	2 accidental drowning
Thurlow	Marine Harvest Canada	2012	Harbour seal	1 accidental drowning

Escapes

Between 2011- 2019, there has been only one major escape of Atlantic salmon from facilities in the Discovery Islands

Figure 15: Escapes of cultured salmon from marine finfish facilities in BC, 2011-2019



This graph shows the number of escaped salmon in the Discovery Islands since 2011. There have been two significant escape events of Chinook salmon in this area. The first occurred in 2012 at an experimental semi-closed containment facility, Middle Bay, that capsized in a storm event. The second occurred during a transfer of fish from a transport truck to a vessel at Discovery Harbour. Approximately 200-300 small fish spilled off the deck of the transport vessel.

Technological improvements in containment material and anchoring systems along with more diligent inspections and maintenance of infrastructure have decreased escape events from marine finfish facilities in BC. Additionally, improvements and deployments of anti-predator technologies have reduced marine mammal interactions, which can cause damage to infrastructure leading to escapes. DFO conducts opportunistic inspections of marine finfish facilities to ensure compliance with conditions of licence aimed at preventing escapes including having and complying with an Escape Prevention and Response Plan and review of net maintenance records.

Table 7: Escapes from marine finfish aquaculture facilities in the Discovery Islands, 2011-2020

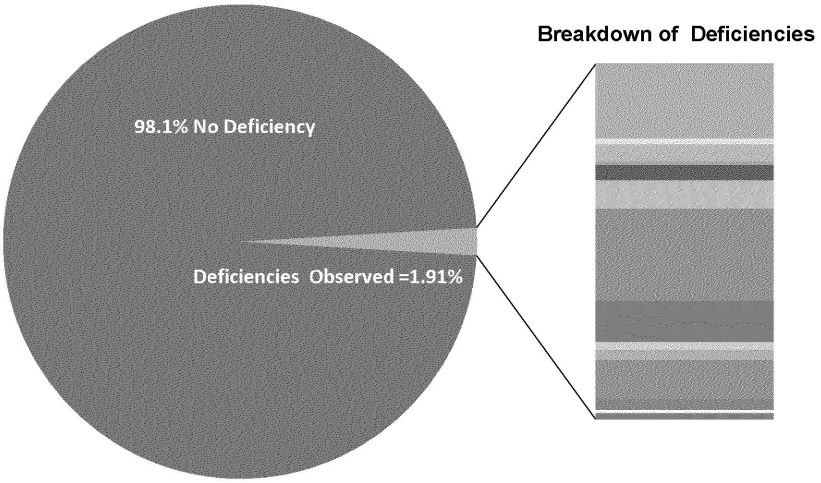
Date	Licence Holder	Facility	Species	Number of fish	Cause of Escape
12-Mar-12	Agrimarine Industries	Middle Bay	Chinook salmon	2745 alive	Extreme weather event, equipment failure
13-Jan-13	Grieg Seafood	n/a	Coho salmon	250 live	Equipment failure
15-Sept-17	Cermaq Canada	Venture Point	Atlantic salmon	5 dead	Equipment failure
24-May-20	MOWI Canada West	Shaw Point	Atlantic salmon	1066 alive	Hole in net caused by equipment; Unexplained inventory discrepancy

Health Management Plan (HMP) Compliance

A Health Management Plan is a requirement in the marine aquaculture licence. The HMP outlines fish health and biosecurity principles which the licence holder must meet. The company develops Standard Operating Procedures (SOPs) which specify how they will meet the principles of the HMP. An review of compliance with HMP principles is conducted at every site audit, and company SOPs are reviewed annually. DI farms have slightly above industry average HMP compliance.

Figure 16: Fish Health Management Plan Inspections at Salmon Aquaculture Sites in BC, 2011-2019

A total of 1034 HMP site inspections were completed between 2011-2019. All facilities are in compliance with the licence in that they have implemented an HMP; however, there may be need for improvement. The FH team performs audits on site to assess adherence to the HMP and DFO communicates any need for improvement (deficiencies) to the facility. A total number of 30,788 HMP elements were scored between 2011-2019, of these 587 deficiencies were noted. During 670 of those facility visits, no deficiencies were observed.



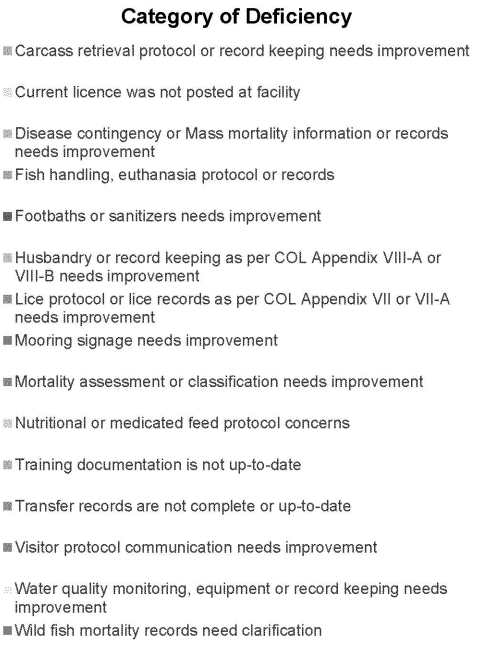
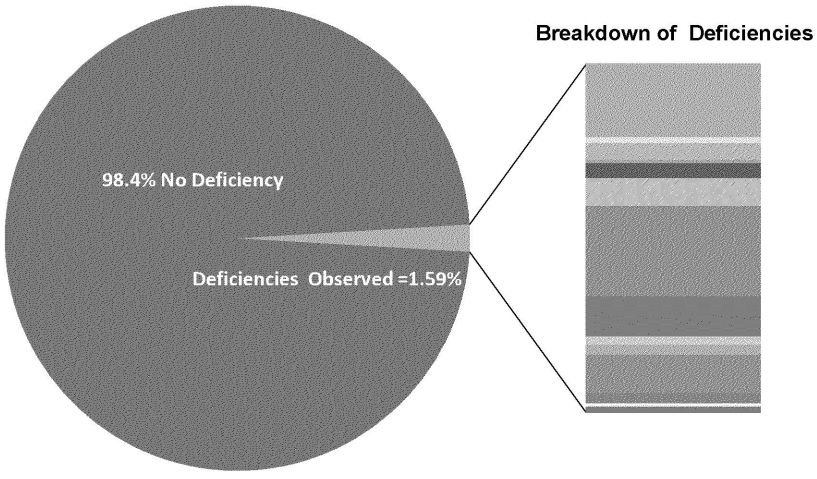
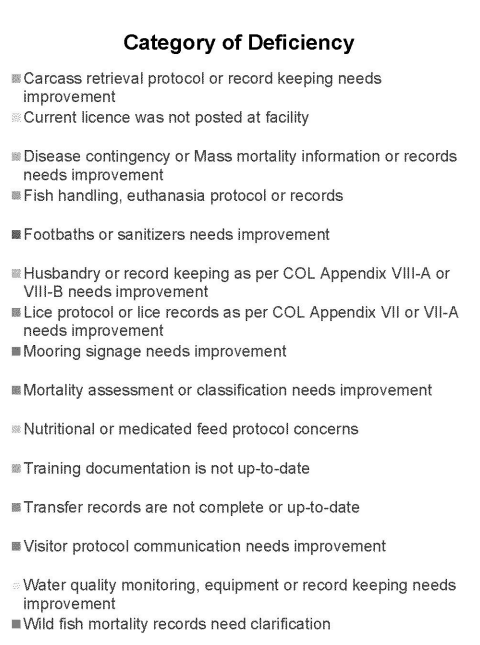


Figure 17: Fish Health Management Plan Inspections at Salmon Aquaculture Sites in the Discovery Islands, 2011-2019

A total of 154 HMP site inspections were completed between 2011-2019 in the Discovery Islands area. All facilities are in compliance with the licence in that they have implemented an HMP; however, there may be need for improvement. The FH team performs audits on site to assess adherence to the HMP and DFO communicates any need for improvement (deficiencies) to the facility. A total number of 4903 HMP elements were scored between 2011-2019, of these 78 deficiencies were noted. During 100 of those facility visits, no deficiencies were observed.





The Health Management Plan (HMP) is a section of the licence which outlines broadly fish health management principles and practices which are necessary to ensure optimal fish health and welfare. The Licence Holders (LHs) are then required to develop and implement Standard Operating Procedures (SOPs) which will dictate how the elements of the HMP are practically met by the LH on site. The LH may choose to meet a given condition of the HMP in any way they choose provided which is reasonable and biologically sound. The SOPs are submitted to DFO annually, along with any changes for review by fish health staff.

During a fish health audit, DFO biologists and veterinarians assess over 60 HMP elements using a standardized checklist. This is in addition to many other aspects of fish health and husbandry which are part of the licence conditions. Any deficiencies noted are recorded and relayed to site staff with an expectation for timely resolution. Past HMP deficiencies are noted during future audits of that facility to ensure they have been resolved. A letter is issued quarterly to each LH outlining the results of these HMP inspections. Any non-compliance with a licence condition identified during an audit will be recorded and relayed to DFO veterinary staff. DFO veterinarians will assess the risk posed by the non-compliance and determine if referral to Conservation and Protection branch for possible prosecution is warranted. At minimum, a letter of non-compliance will be issued with a timeline provided for resolving the non-compliance. These non-compliance letters are legally enforceable and inform the compliance history of the facility and LH. This has significant implications for third party sustainability certifications, and any request for production increases by the facility and/or LH.

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Conclusion

The farms in the Discovery Islands are generally very well performing across almost every metric. The area appears to be very conducive to growing fish well, with minimal inputs and interventions as are seen in some other growing areas. The good fish health and sea lice management seen on the DI farms ensures that the risk of disease and pest transfer to wild fish is minimized.

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Appendix I

Marine Finfish Aquaculture Public Reporting in British Columbia

1. Aquaculture Activities Regulations (AAR) Drugs and Pesticides
https://open.canada.ca/data/en/dataset/288b6dc4-16dc-43cc-80a4-2a45b1f93383

2. Monthly mortality by category, by facility (open data)
https://open.canada.ca/data/en/dataset/0a8c5505-ecb3-4d8b-8120-462bd7def6bb

3. Quarterly Average mortality by category, by zone (figure)
http://www.pac.dfo-mpo.gc.ca/aquaculture/reporting-rapports/carcass-health-zone-sante/2017/index-eng.html

4. Fish Health monitoring activities, number of carcasses sampled
https://open.canada.ca/data/en/dataset/4dc95665-3d44-428c-bb26-12f981c57060

5. Fish health, sea lice and benthic audits (figures)
http://www.pac.dfo-mpo.gc.ca/aquaculture/reporting-rapports/mer-mar-audit-verif/index-eng.html

6. Fish health events, by facility, 2016-ongoing (open data)
https://open.canada.ca/data/en/dataset/deefd1d7-7184-44c7-83aa-ec0db91aad27

7. Fish health events, 2016-ongoing (figures)
http://www.pac.dfo-mpo.gc.ca/aquaculture/reporting-rapports/health-events-sante/index-eng.html

8. Mortality events, by facility, 2011-ongoing (open data)
https://open.canada.ca/data/en/dataset/7fbb2662-391a-4df7-99b4-3343fa68fc93

9. Mortality events, 2016-ongoing (figures)
http://www.pac.dfo-mpo.gc.ca/aquaculture/reporting-rapports/episodes-mort-events/index-eng.html

10. Fish Health audits, by facility, 2011-ongoing (open data)
https://open.canada.ca/data/en/dataset/6c891715-317c-4d4d-9fe8-ea425e01d9d2

11. Monthly sea lice abundance, by facility (open data)
https://open.canada.ca/data/en/dataset/3cafbe89-c98b-4b44-88f1-594e8d28838d

12. DFO sea lice audits, by facility (open data)
https://open.canada.ca/data/en/dataset/5cfd93bd-b3ee-4b0b-8816-33d388f6811d

13. Average sea lice abundance, by zone (graph)
http://www.pac.dfo-mpo.gc.ca/aquaculture/reporting-rapports/lice-ab-pou/index-eng.html

14. Use of Antibacterials (graph)
http://www.pac.dfo-mpo.gc.ca/aquaculture/reporting-rapports/therapeut/index-eng.html#antibacterials

15. Use of Anti-lice Therapeutants (graph)
http://www.pac.dfo-mpo.gc.ca/aquaculture/reporting-rapports/therapeut/index-eng.html#slice

16. DFO benthic audits, by facility (open data)
https://open.canada.ca/data/en/dataset/c1a54a0c-4eb0-4b50-be1f-01aee632527e

17. Industry benthic monitoring, by facility (open data)
https://open.canada.ca/data/en/dataset/7e76fdc8-c36a-491a-9afb-4f9280c929e8

18. Benthic performance (graph)
http://www.pac.dfo-mpo.gc.ca/aquaculture/reporting-rapports/benth/index-eng.html

19. Incidental catch, by facility (open data)
https://open.canada.ca/data/en/dataset/0bf04c4e-d2b0-4188-9053-08dc4a7a2b03

20. Marine mammal fatalities, by year (graph)
http://www.pac.dfo-mpo.gc.ca/aquaculture/reporting-rapports/mar-mam/index-eng.html

21. Marine mammal interactions, by facility (open data)
https://open.canada.ca/data/en/dataset/a7b3fdfb-5917-4ca6-b29c-093e3f65d6ba

21. Escapes, by facility, 2011-ongoing (open data)
https://open.canada.ca/data/en/dataset/691dd994-4911-433d-b3b6-00349ba9f24e

22. Escapes, by year (graph)
http://www.pac.dfo-mpo.gc.ca/aquaculture/reporting-rapports/escapes-evasions/index-eng.html

23. Atlantic Salmon Watch Program (open data)
https://open.canada.ca/data/en/dataset/f0299fb3-73b9-4977-b96a-c83bd84ebdc4

24. Salmon transfers, 2015-ongoing (open data)
https://open.canada.ca/data/en/dataset/700fe290-7653-49e1-b961-741dc1ead924

From: [redacted]
Sent: Thursday, October 22, 2020 4:59 PM
To: Lowe, Carmel; Waddington, Zac; Miller-Saunders, Kristi; Price, Derek
Subject: Re: FW: Emerging issues around mouth rot disease (Tanachbaculum maritimun)
Attachments: Tenacibaculum in sockeye 2020 10 22.pptx

Hi all,
I'm not sure who is going to be in the call today, but here's the presentation I put together to quickly go over my modelling work (and a couple other relevant results).
MS Teams doesn't work well for me, so I'll have to talk via my phone and have everyone follow along in the slides, assuming we get to this.
Thanks,
[redacted]

On Fri, 16 Oct 2020 at 09:16, Lowe, Carmel <Carmel.Lowe@dfo-mpo.gc.ca> wrote:

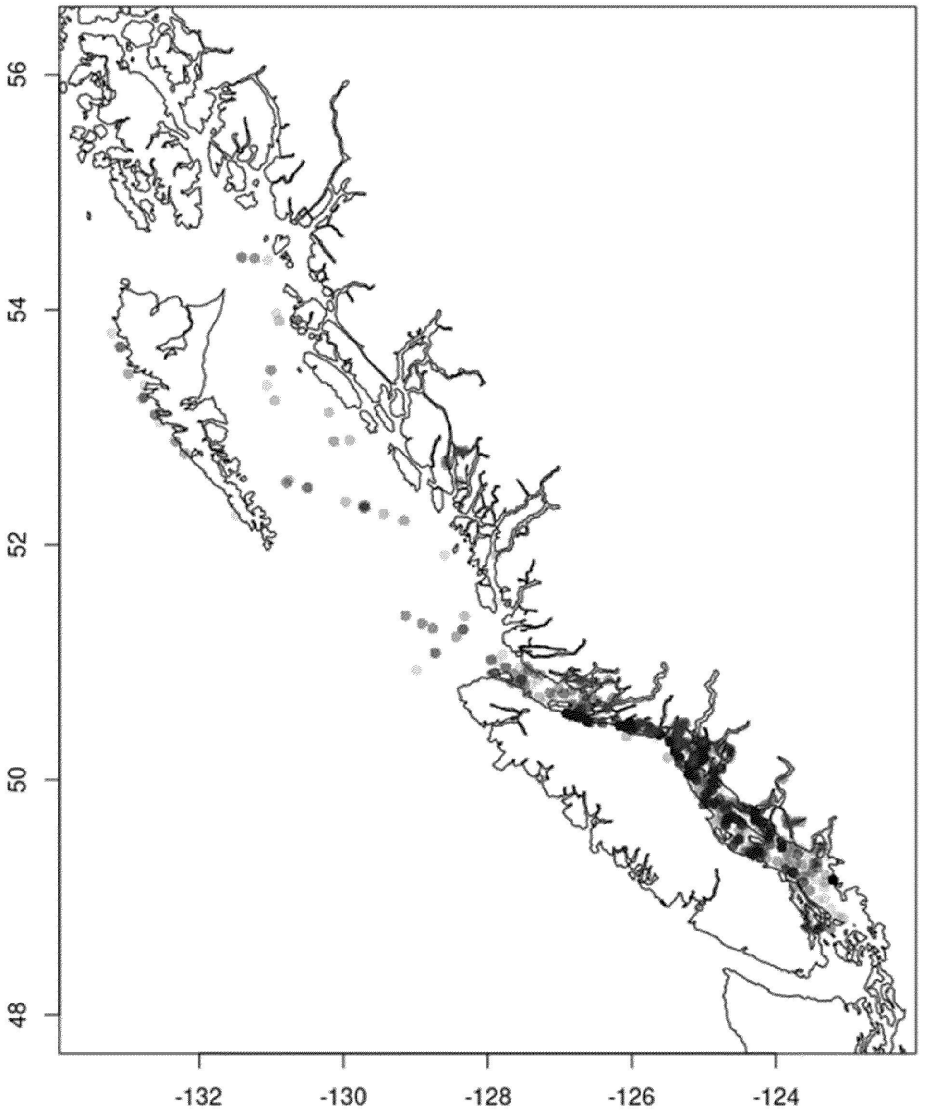
> Here's the follow-up conversation to our short one yesterday, [redacted]
> I've extended the invite to Derek since he's our resident model and modeler, so he will likely get more out of your presentation than I will.
> Look forward to chatting next week, [redacted]
> Zac
> -----Original Appointment-----
> **From:** Lowe, Carmel
> **Sent:** Friday, October 16, 2020 9:07 AM
> **To:** Lowe, Carmel; Candy, John; Johnson, Stewart; Waddington, Zac; Miller-Saunders, Kristi; MacDougall, Lesley
> **Subject:** Emerging issues around mouth rot disease (Tanachbaculum maritimun)
> **When:** Thursday, October 22, 2020 2:30 PM-3:00 PM (UTC-08:00) Pacific Time (US & Canada).
> **Where:** TEAMs
> Join Microsoft Teams Meeting
> +1 647-484-5913 Canada, Toronto (Toll)
> Conference ID: [redacted]
> Local numbers | Reset PIN | Learn more about Teams | Meeting options

s.16(2)(c)
s.19(1)

Spatio-epidemiological modelling of *Tenacibaculum maritimum* in Fraser-River sockeye smolts

[redacted]
Strategic Salmon Health Initiative
October 22 2020

s.19(1)

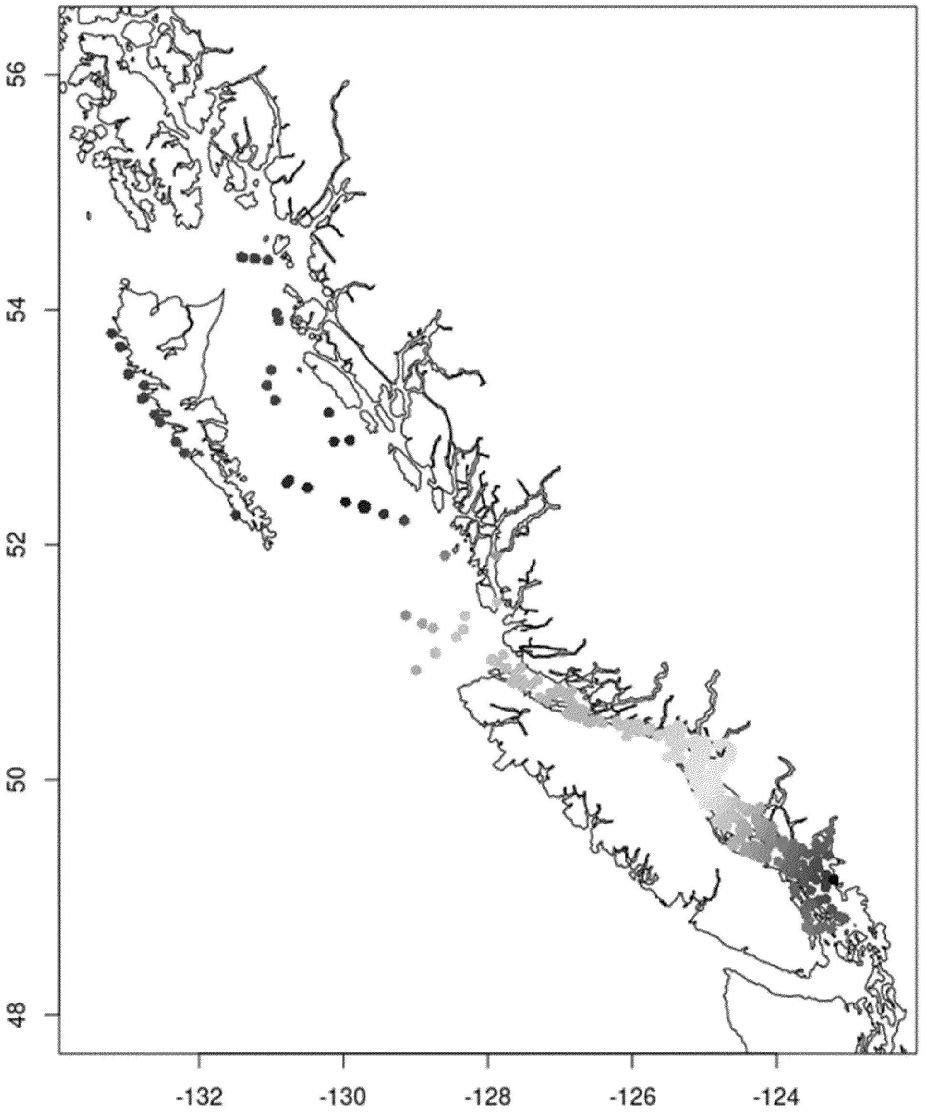


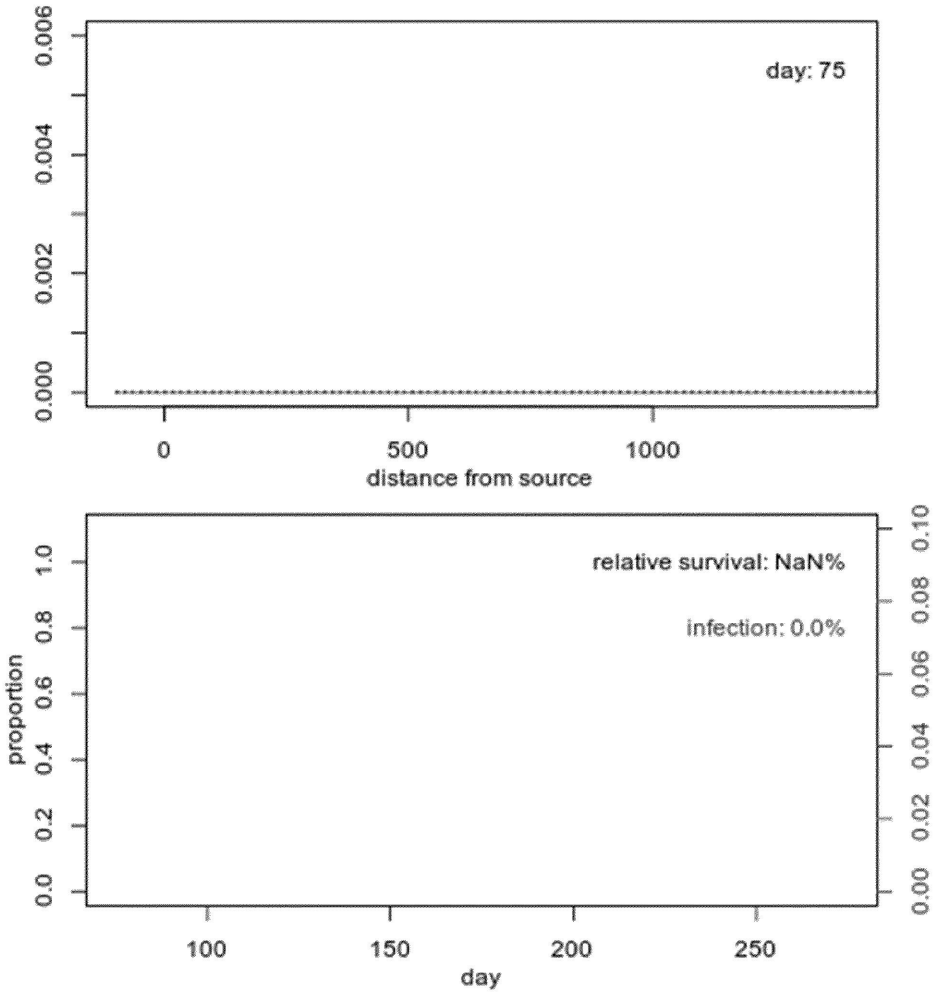
Migration (spatial) model

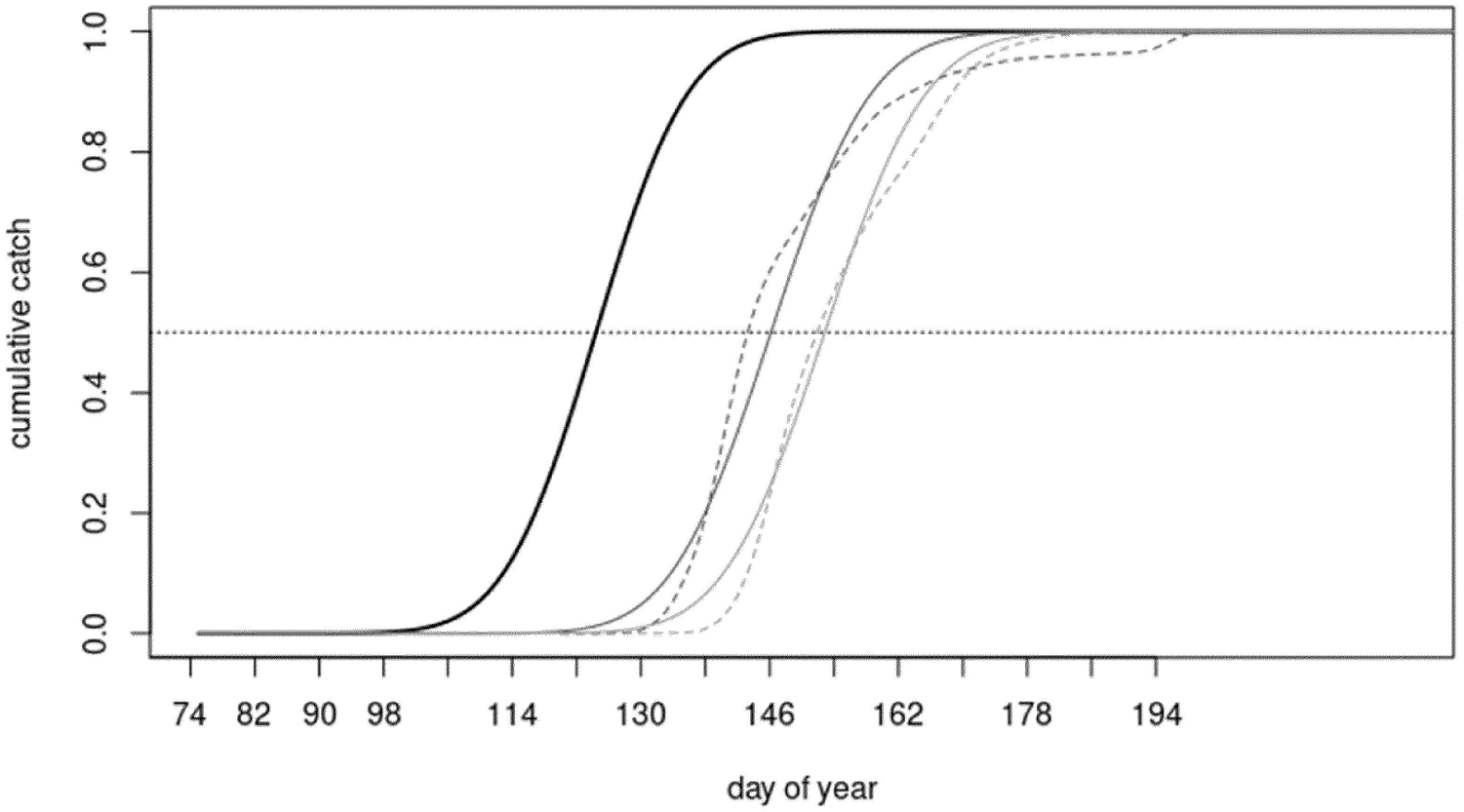
- **"advection diffusion" continuous-time model**

- **parameterised using data from:**
  1)Mission smolt trap
  2)Kintama tracking studies of age-one smolts
  3)Hakai juvenile salmon program

- ***mortality rates uncertain***

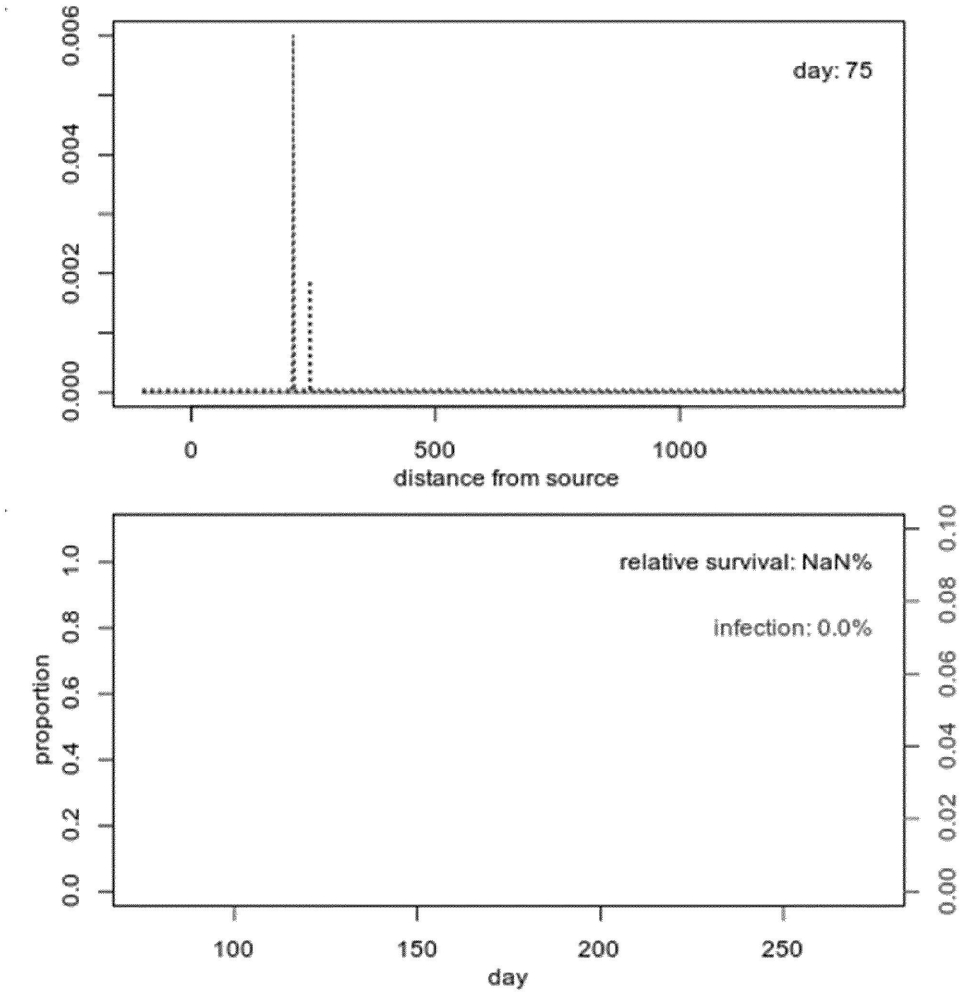


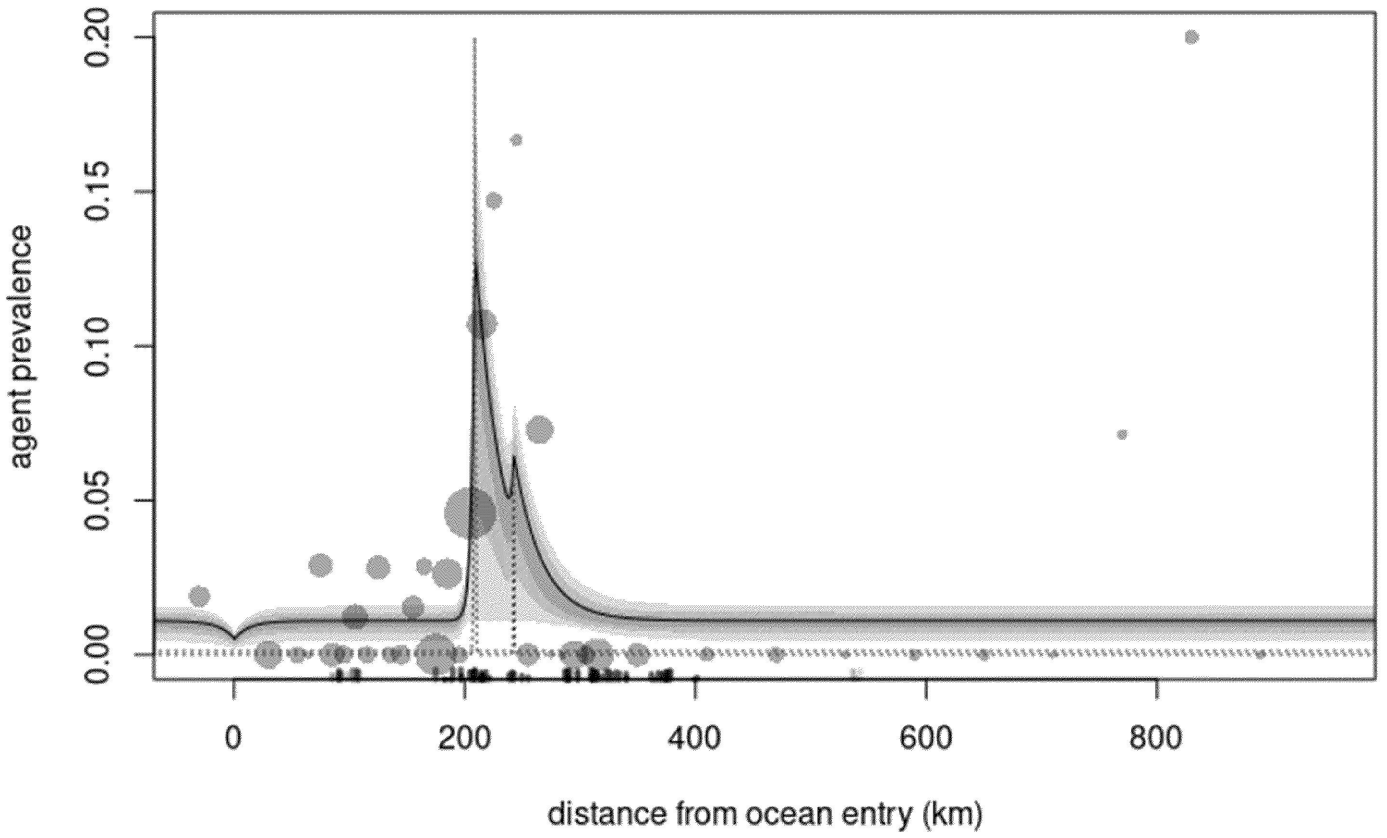




Infection (epidemiological) model

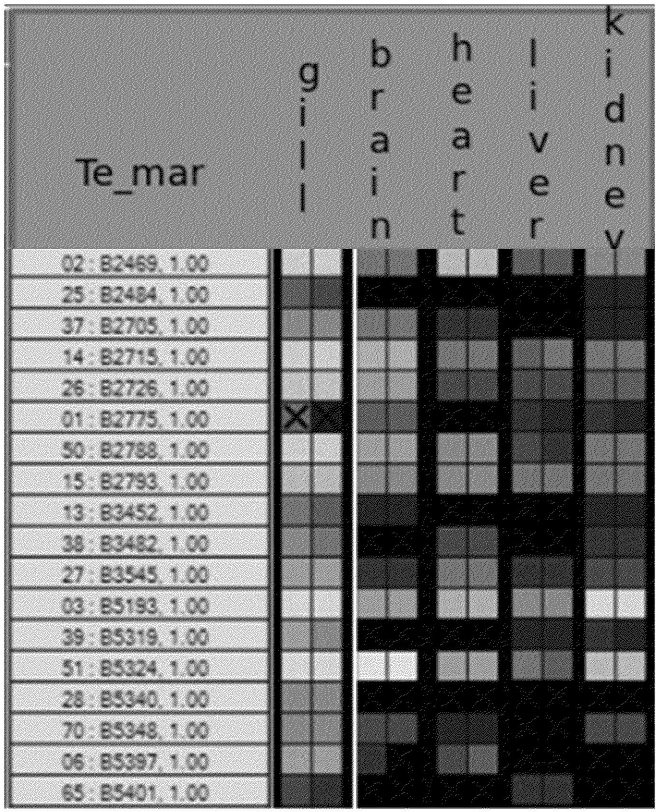
- **"SIS" model**
- **external-source infection only**
- **fit to *Tenacibaculum maritimum* qPCR detection-prevalence data**
  - samples from DFO's High-Seas and Strait-of-Georgia trawl surveys (2008-2016)
- **parameters tuned during fit:**
  1)relative mortality of infected individuals
  2)recovery rate
  3)background infection rate
  4)farm-origin infection rate
  5)farm-origin agent "dispersal"
  6)relative infection pressure from Discovery-Island farms





Uncertainties....

- infection vs exposure



Uncertainties....

- infection vs exposure
- relative farm contributions

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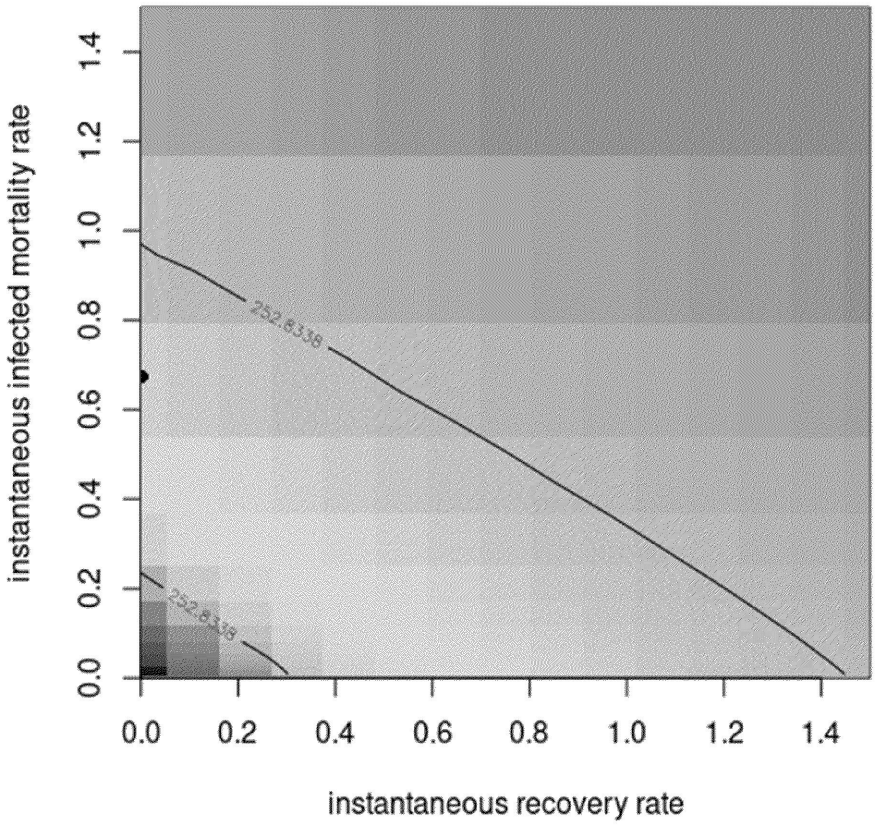
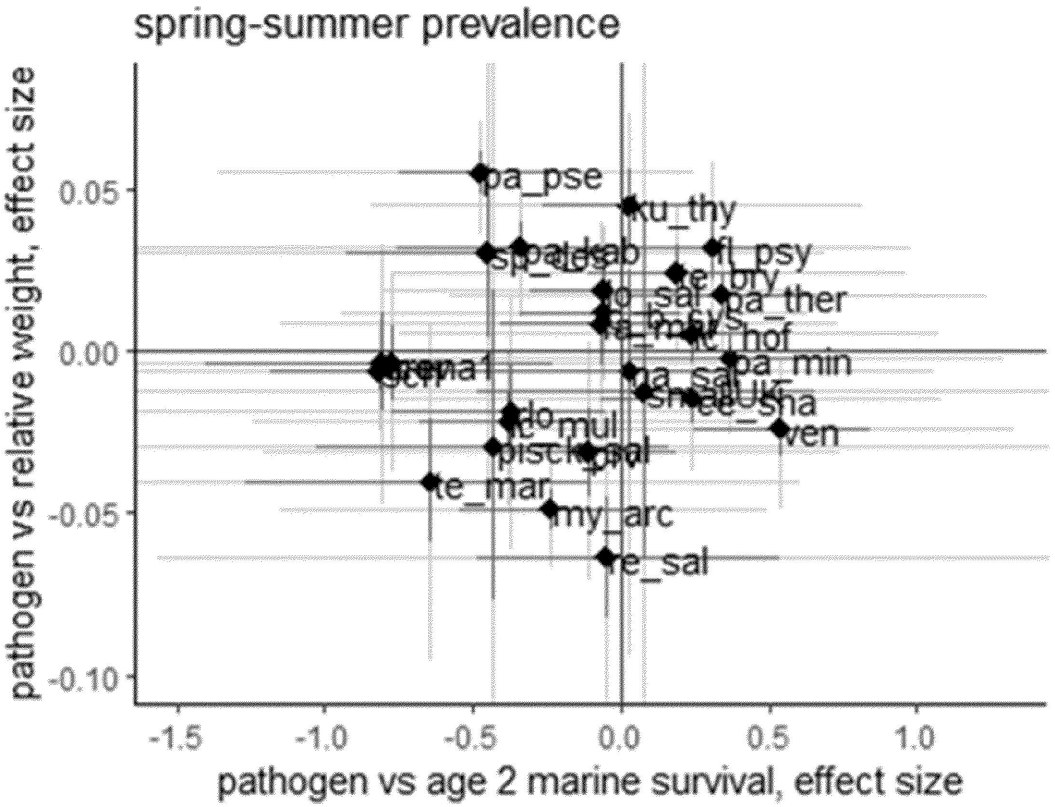
Uncertainties....

- infection vs exposure
- relative farm contributions
- mortality vs recovery



Population-level effects: Chinook



From: Waddington, Zac
Sent: Wednesday, November 4, 2020 6:27 PM
To: Lowe, Carmel; Paylor, Adrienne; MacDougall, Lesley; Price, Derek; Parsons, Jay
Subject: RE: Mtg with BCSFA

Sure thing. I've added that below in red font.

Zac

From: Lowe, Carmel
Sent: Wednesday, November 4, 2020 1:55 PM
To: Waddington, Zac ; Paylor, Adrienne ; MacDougall, Lesley ; Price, Derek ; Parsons, Jay
Subject: RE: Mtg with BCSFA

Good point Zac – do you want to provide a sentence or two for that.

Carmel

From: Waddington, Zac <Zac.Waddington@dfo-mpo.gc.ca>
Sent: Wednesday, November 4, 2020 1:54 PM
To: Lowe, Carmel <Carmel.Lowe@dfo-mpo.gc.ca>; Paylor, Adrienne <Adrienne.Paylor@dfo-mpo.gc.ca>; MacDougall, Lesley <Lesley.MacDougall@dfo-mpo.gc.ca>; Price, Derek <Derek.Price@dfo-mpo.gc.ca>; Parsons, Jay <Jay.Parsons@dfo-mpo.gc.ca>
Subject: RE: Mtg with BCSFA

The only material we discussed not referenced below is the recent and pending publications from KM's lab and co. Particularly around Tenacibaculum.

Not sure if this warrants inclusion.

Otherwise not edits from me,

Zac

From: Lowe, Carmel <Carmel.Lowe@dfo-mpo.gc.ca>
Sent: Wednesday, November 4, 2020 1:38 PM
To: Waddington, Zac <Zac.Waddington@dfo-mpo.gc.ca>; Paylor, Adrienne <Adrienne.Paylor@dfo-mpo.gc.ca>; MacDougall, Lesley <Lesley.MacDougall@dfo-mpo.gc.ca>; Price, Derek <Derek.Price@dfo-mpo.gc.ca>; Parsons, Jay <Jay.Parsons@dfo-mpo.gc.ca>
Subject: Mtg with BCSFA

Proposed draft to Rebecca, Arran, Andy etc… let me know if you have any comments before end of day today …

Hi all,
Just a quick update on our meeting with the BCSFA yesterday. There was a fairly big group on their side - [redacted] and a couple of others). We had good representation from AMD (Zac Waddington, Derek Price, Adrienne Paylor) and Science (Lesley, Jay and I). Overall it was a very productive discussion – and I believe fair to say it well received by both groups.

s.19(1)

Gary Marty provided a detailed overview of their proposed collaborative project. Importantly, it was confirmed the project would be complimentary to, rather than duplicate, the work that Kristi and team have been doing in SSHI. Zac/AMD reinforced the importance the study outcomes would have from an aquaculture management perspective. [redacted] acknowledged our contributions to the project to date – via the samples and asked for our/Depts consideration of an additional $30K contribution to complete their processing. When questioned about how else they saw us contributing they were straightforward in noting that they had all of the relevant expertise required to complete the project and were seeking our commitment of collaboration more from an 'optics' perspective but also indicated they would welcome Derek's or others contribution of expertise. [redacted] and Gary raised the G&M article in this context and [redacted] expressed appreciation for Arran's letter to editor.)

The discussion then pivoted to potential collaborations on wild salmon health. We asked if they would be willing to provide the samples and data they collect on wild fish to us for additional wild fish health analyses/studies. They were very open to this - concurring that we should seek to maximize research value of every wild fish sample – and even offered to collect additional wild salmon samples for us if desired. Both Science and AMD will use this acknowledgement to plan more detailed collaborative research for discussion at follow-up mtgs.

Some recent and pending publications under the Strategic Salmon Health Initiative were also discussed. In particular, the finding that infection with *Tenacibaculum maritimum* and/or *Moritella viscosa* in Chinook, Coho and Sockeye juvenile salmon are associated with poor body condition and potentially indicative of poor health outcomes and subsequent returns. This finding is of relevance to industry and aquaculture management given the relatively frequency of Tenacibaculum and Moritella associated disease (mouth rot and winter ulcer respectively) on farms, and a recent publication demonstrating elevated detections of these pathogens in water collected outside active facilities.

The mtg ended with [redacted] suggesting we schedule regular exchanges/meetings – and there was support from all participants for this and Zac agreed to resurrect a DFO-Industry advisory panel for this purpose.

Carmel

Carmel Lowe, Ph.D.
Regional Director Science | Directrice régionale des sciences
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Government of Canada | Gouvernement du Canada

s.19(1)

From: MacDougall, Lesley
Sent: Thursday, November 12, 2020 3:42 PM
To: Lowe, Carmel; Webb, Allison
Subject: upcoming publications - SSHI Tenacibaculum
Attachments: ANNEX_A__MANUSCRIPT_RECORD_FORM_(MRF)_[redacted]et al 2020.docx; [redacted]submission - SCIENTIFIC REPORTS.pdf

Hi Carmel and Allison – we have submitted a Tab 7 today that (I hope) clarifies the chronology of pending SSHI publications that are due in the next month or so.

To provide an earlier 'heads – up', the summary below details where Tenacibaculum results are expected, and their (ballpark) chronology. (I will send a separate email for other SSHI publications expected in December that don't have Tenacibaculum as a focus)

- Shea paper (ALREADY PUBLISHED)– on eDNA, noted that Tenacibaculum was the agent most closely associated with active farms.
- [redacted] – paper on longitudinal farm samples (DECEMBER 2020) – shows Tenacibaculum is the agent most associated with fish death (one of the results that will be noted; the paper is more broadly focussed on distributions over time and between moribund and live sampled fish for all of the detected agents in the longitudinal study). (MRF and manuscript are attached)
- [redacted] (no manuscript yet – publication next FY) – modelled association between Tenacibaculum risk in sockeye and proximity to active salmon farms in Desolation sound. This paper and its modelling has been discussed with Zac; [redacted] is including treatment data for Mouth Rot in his models at Zac's recommendation. For now he's looking at sockeye alone and may do further papers with other spp – but not right away.
- Tenacibaculum association with survival and relative weight will come out in publications later (no manuscripts yet, next FY – current timeline unknown). [redacted] – sockeye; Art Bass – Chinook, coho.
- [redacted] potential paper on detection of Tenacibaculum and relative weight of farmed salmon (in very early planning stages;)

Lesley MacDougall
Division Manager, Aquatic Diagnostics, Genomics & Technology / Division des diagnostics, la génomique, de la technologie aquatique
Fisheries and Oceans Canada / Pêches et Océans Canada
Pacific Biological Station / Station Biologique du Pacifique
Nanaimo, B.C. V9T 6N7
Contact via Teams or (250) 668-5849
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s.19(1)

ANNEX A: MANUSCRIPT RECORD FORM – MRF (1) – PRIMARY PUBLICATIONS

MRF for PRIMARY (PEER REVIEW) PUBLICATIONS

AUTHOR(S)[1] and AFFILIATIONS

[redacted] Affiliation: Pacific Salmon Foundation, (Corresponding Author)
Angela D Schulze; Affiliation: Fisheries and Oceans Canada,
Karia H Kaukinen; Affiliation: Fisheries and Oceans Canada,
Amy Tabata; Affiliation: Fisheries and Oceans Canada,
Gideon Mordecai; Affiliation: University of British Columbia
[redacted] Affiliation:
Kelsey Flynn; Affiliation: Fisheries and Oceans Canada,
[redacted]; Affiliation: Pacifica Salmon Foundation
Kristina Miller; Affiliation: Fisheries and Oceans Canada,

REMINDER: For bibliometric purposes, please use standard affiliation, i.e., first name, last name and "Fisheries and Oceans Canada". Please identify the Author who will be in communication (main contact) with the journal.

TITLE:

Descriptive multi-agent epidemiology on four Atlantic salmon farms.

ABSTRACT:

The rapid expansion of salmon aquaculture has resulted in large, dense domesticated salmon populations that are host to a diversity of infectious agents. Infectious-agent surveillance and monitoring are critical to disease management in this context. Screening of farm hosts can yield insight into the standing stock of infections, from which disease can arise; can reveal patterns of infection that differ between live fish and dead fish, difficult to collect from wild populations; and can elucidate risks associated with transfer between wild and farmed populations. We report results from a multi-year infectious-agent screening program of four farmed-salmon cohorts in British Columbia, Canada. We employed high-throughput qPCR to assess presence and load of a total of 58 infective agents (viruses, bacteria, and eukaryotes) in 2986 Atlantic salmon. Our analysis reveals temporal trends in agent levels, correlations among agent levels within hosts, and agent-associated mortality signatures. Multiple agents, most notably Tenacibaculum maritimum, displayed higher prevalence or gene-copy intensity in dead and dying salmon than in live-sampled salmon. We also report detections of several agents only recently shown to infect farmed salmon in BC (Atlantic salmon calicivirus, Cutthroat trout virus-2) as well as detections of agents thought to be restricted to seawater in freshwater hatcheries (Kudoa thyrsites and Tenacibaculum maritimum) and a freshwater agent (Flavobacterium psychrophilum) in the ocean. Our results provide information for farm managers, regulators, and conservationists, and suggest further work to elucidate patterns of disease and the risk of transmission between farmed and wild salmon.

PUBLICATION (JOURNAL, SERIES) NAME/FULL CITATION INFORMATION/URL (If not available, please submit when so, to Division Manager):

Scientific Reports

PRE-SUBMISSION REVIEWER(S):

Reviewer Name (print name): Date Submitted:

Reviewer Name (print name): Date Submitted:

[1] The author (main contact) communicating with the journal is this person responsible for managing editorial issues as well as final format and content of the manuscript (an identifier is usually assigned to the communicating author i.e. an asterisk or other symbol). This person is not necessarily the "first" author, which could have different meanings in different fields. For examples, it could a first or a last author or the person overseeing the publication process and, often, responsible for conceiving, supporting, and managing the project.

ANNEX A: MANUSCRIPT RECORD FORM – MRF (1) – PRIMARY PUBLICATIONS

DFO COMMUNICATIONS BRANCH SUPPORT REQUIRED? (Division Manager's Determination):	
Communications Advisor Name (print name):	Date Assigned:
Topic (if not clear from title):	
DFO contacts to be informed of release:	

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ANNEX A: MANUSCRIPT RECORD FORM – MRF (1) – PRIMARY PUBLICATIONS

(Manuscript Reform Form for Primary Publications, page 2)

REMINDER: For PRIMARY peer-reviewed publications only, authors are required to write a very short (i.e., 150 words) plain language summary of the manuscript to explain the relevance of the science to the Department. It is intended for internal use to identify linkages to programs, policies and stakeholders and for use externally in the plain language promotion of science.

PLAIN LANGUAGE SUMMARY:

The rapid expansion of salmon aquaculture has resulted in large, dense domesticated salmon populations that are host to a diversity of infectious agents. Infectious-agent surveillance and monitoring are critical to disease management and can reveal patterns of infection. Farmed Atlantic salmon were sampled throughout the life cycle of four farmed-salmon cohorts in British Columbia, Canada. We employed high-throughput qPCR to assess presence and load of a total of 58 infective agents (viruses, bacteria, and eukaryotes) in 2986 Atlantic salmon. Our analysis reveals temporal trends in agent levels, correlations among agent levels within hosts, and agent-associated mortality signatures. Multiple agents, most notably the bacteria Tenacibaculum maritimum, displayed higher prevalence or gene-copy intensity in dead and dying salmon than in live-sampled salmon. Two new viruses not known to infect farmed salmon in BC were also reported. Our results provide information for farm managers, regulators, and conservationists, and suggest further work to elucidate patterns of disease and the risk of transmission between farmed and wild salmon.

SCIENTIFIC IMPLICATIONS OF THE PAPER (i.e. field, importance, focus, purpose, benefits, etc.)**:**

This study utilized regular sampling of live and moribund salmon collected over the ocean production cycle of four farms to elucidate patterns of infection for 58 infective agents over time. Importantly, it showed that several marine-transmitted agents were detected prior to smolt release from hatcheries, possibly introduced when fish were being pre-acclimated to marine-source waters, something industry may not be aware of. Furthermore, many agents known to cause disease were present within farm populations throughout the production cycle, well before disease manifestation occurred, and others were detected only sporadically. Importantly the study identified several agents showing differential prevalence/abundance in live- and dead-sampled fish, the most notable of which was Tenacibaculum maratimus, the causative agent of mouthrot, which affected all farms sampled. Further mitigative actions to reduce prevalence of this agent on farms may reduce opportunistic outbreaks of disease.

ANY GEOGRAPHICAL SCOPE/REGION and (if applicable) **SPECIES** (to include common names)**:**

British Columbia; Atlantic salmon

RELEVANT TO PROGRAMS, PROJECTS, ACTS, INITIATIVES, ETC. (please identify)**:**

Fisheries management, Strategic Salmon Health Initiative, Fish Health, Response to Cohen, climate change impacts on salmon

ADDITIONAL INFORMATION OF IMPORTANCE:

This is one in a series of studies in the SSHI program to review, evaluated, and understand the infectious agents found within and among fish farms in the waters of British Columbia. This study and subsequent studies on the interactions between fish farms and wild salmon populations were a key research objective of the SSHI. Together they need to be carefully reviewed and considered by managers.

REMINDER: Seek as applicable the necessary Intellectual Property Forms Required; Proprietary Data Permission Required; Collaborative Agreement Permissions Required; DFO's Image Release Forms Required; etc.

AN OPEN ACCESS CHECKLIST (Required if and when open access is effective):

Is the First Author Employed by DFO? If yes, manuscript deposition in repository/open data will apply when Open Access effective. If No, co-author should determine with first author how Open Access will be achieved/for compliance.	**No**
Date of Eligibility for Open Access (i.e. 12 months from publication of a scientific paper)	
Retention of Final, Author-revised, Peer-reviewed Manuscript (not publisher's formatted PDF). Location: (i.e. DFO document system*# OR send to Division Manager/date). *Use privacy settings.	
Contact Information for Dataset Owners: (Include dataset DOI, if and when one exists.)	

ANNEX A: MANUSCRIPT RECORD FORM – MRF (1) – PRIMARY PUBLICATIONS

Are Open Data Permissions Form Completed?	
MANUSCRIPT SUBMITTED AND REVIEWED BY DIVISION MANAGER:	
Print Name:	Date Submitted:
Division Manager's Signature:	Date Approved:
MANUSCRIPT REVIEWED BY REGIONAL DIRECTOR OF SCIENCE (if required):	
Print Name:	
Regional Director of Science's Signature:	
Date:	

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Descriptive multi-agent epidemiology via molecular screening on Atlantic salmon farms in the northeast Pacific Ocean

Running title:
Multi-agent epidemiology on salmon farms

Authors:
[redacted][1,2], Angela D. Schulze[3], Karia H. Kaukinen[3], Amy Tabata[3], Gideon Mordecai[4], Kelsey Flynn[3], Arthur Bass[1,5], [redacted] Kristina M. Miller[3,5]
* corresponding author – [redacted]

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1) Pacific Salmon Foundation, Vancouver, Canada
2) Ecology and Evolutionary Biology, University of Toronto, Toronto, Canada
3) Molecular Genetics, Fisheries and Oceans Canada, Nanaimo, Canada
4) Department of Medicine, University of British Columbia, Vancouver, Canada
5) Forest and Conservation Sciences, University of British Columbia, Vancouver, Canada

Abstract

Rapid expansion of salmon aquaculture has resulted in high-density populations that host diverse infectious agents, for which surveillance and monitoring are critical to disease management. Screening can reveal infection diversity from which disease arises, differential patterns of infection in live and dead fish that are difficult to collect in wild populations, and potential risks associated with agent transmission between wild and farmed hosts. We report results from a multi-year infectious-agent screening program of farmed salmon in British Columbia, Canada, using quantitative PCR to assess presence and load of 58 infective agents (viruses, bacteria, and eukaryotes) in 2931 Atlantic salmon (*Salmo salar*). Our analysis reveals temporal trends, agent correlations within hosts, and agent-associated mortality signatures. Multiple agents, most notably *Tenacibaculum maritimum*, were elevated in dead and dying salmon. We also report detections of agents only recently shown to infect farmed salmon in BC (Atlantic salmon calicivirus, Cutthroat trout virus-2), detection in freshwater hatcheries of two marine agents (*Kudoa thyrsites* and *Tenacibaculum maritimum*), and detection in the ocean of a freshwater agent (*Flavobacterium psychrophilum*). Our results provide information for farm managers, regulators, and conservationists, and enable further work to explore patterns of multi-agent infection and farm/wild transmission risk.

Keywords
marine disease, aquaculture, salmon farming, *Salmo salar*, infective-agent screening, Biomark™, high-throughput RT-PCR, next-generation sequencing

Introduction

The recent rapid pace with which marine organisms have been domesticated [1] has elevated concern about diseases of cultured aquatic organisms [2]. As with agriculture before it [3], aquaculture alters disease dynamics through densification of host populations and provision of novel transmission pathways, impacting both cultured and wild species [4]. As global demand for seafood continues to grow, wild-capture fishery production has plateaued [5], and disease threatens to halt the growth of the aquaculture industry in some parts of the world [6]. Understanding infection and disease patterns in aquaculture is critical for the industry, human food production, and wild species alike.

Atlantic salmon (*Salmo salar*) aquaculture, increasing globally since the 1970s and now dwarfing wild Atlantic salmon capture [7], has struggled with disease since its inception [8]. Several high-profile cases, among them those of parasitic sea lice, infectious pancreatic necrosis virus, and infectious salmon anemia virus, have impacted the industry and at times imperilled sympatric wild salmonids [9–11]. While government disease regulations vary among jurisdictions, the salmon-farming industry has become dominated by a few large companies that exploit economies of scale [12], creating the potential for rapid improvements in disease management through corporate policy. Thus, lessons learned in a given salmon-farming region hold promise for other regions. Disease management in practice, however, does not always realise this potential [11,13].

Studying infectious agents in an aquaculture setting is important for multiple reasons.

First, effective disease management on salmon farms requires an understanding not only of acute disease outbreaks but also of chronic disease and sub-clinical infections involving potential disease agents. Such low-intensity infections may create production challenges, without posing an overall risk to farmed or wild population viability, but may also constitute standing populations from which more virulent strains can evolve, as in the case of infectious salmon anemia virus [14].

Second, farm studies can yield valuable information about how infections play out within populations. Although natural mortality in wild salmon is often upwards of 90% [15], marine predators, like many of their terrestrial counterparts [16], preferentially select parasitized and diseased prey [17–19]. Mortality in wild fish is thus rarely observable [18] as dying fish either drop out of the water column or are quickly consumed by predators. Open-net salmon farming, allowing free-flow of water with the surrounding marine environment, offers the potential to understand disease progression and associated mortality in a semi-natural setting but with an almost complete absence of predators.

Third, farm studies promise insight into infectious agent exchange between wild and farmed fish. The interface between wildlife and livestock presents a nexus for shared [20,21] and emergent [22] infectious disease. In a wildlife/livestock disease context, surveillance and monitoring for disease-agent presence, prevalence, and

infection intensity are critical for disease management in both wildlife and livestock [22,23]. Relevant considerations include the speed with which farmed fish become infected, infectious agents' presence as acute or chronic infections, and correspondence between infectious agents and seasonal patterns of wild-fish migration.

While captive populations offer opportunities for improved understanding of infection and disease, few studies have been undertaken to determine the infection status of farm populations outside of mortality events or to determine the differential patterns of infection between live and moribund fish. By focusing solely on diagnostics of dying fish, we limit our understanding of infection progress and resulting pathogen release, a precondition for subsequent infection, or the role of co-infection in disease development. Moreover, if we are concerned about biosecurity and the risk of pathogen exchange among farms and between farmed and wild salmon, infection levels in the population as a whole, rather than solely in dying fish, will provide a more accurate assessment of transmission risk.

We report findings from a multi-year, multi-infective-agent monitoring program [24], focused on farmed Atlantic salmon in Pacific Canada. This work forms part of a broader research effort using next-generation sequencing in pathogen discovery, followed by high-throughput genetic screening techniques,)developed in parallel and first reported for the human-health field [25]) to monitor infective agents in multiple salmon populations [18,24]. Here, we focus on results from a research-directed screening program, conducted at regular intervals on four Atlantic salmon farms throughout their production cycles. We characterise time series for dozens of infective agents, identify agents associated with mortality, and provide information for future epidemiological study.

Materials and Methods

Four cohorts of farmed Atlantic salmon (in BC's Fish Health Zones A3.2, A3.3, and A3.4; Figure 1, Table 1) were sampled repeatedly throughout their marine production cycles, from ocean entry to the onset of harvest. Both live individuals, after euthanisation, and recently dead or dying individuals were sampled. Tissue from each sampled fish was genetically assayed for 47 different infectious agents (including viruses, bacteria, and metazoans; Table 2). After field sampling and genetic workup, we fit descriptive statistical models to genetic prevalence and intensity time series for individual agents. We modelled temporal trends, calculated agent correlations and overall infection burdens, and looked for differences between live and dead/dying fish.

Ethics statement

All work with animals was performed according to the Canadian Council on Animal Care's (CCAC) Guide to the Care and Use of Experimental Animals, and project protocols were approved by the federal department of Fisheries and Oceans Canada (DFO) through its Pacific Region Animal Care Committee (Animal Use Protocol Number: 13-008). Live-sampled fish were euthanised via overdose of tricaine

methanesulfonate (Syndel laboratories Ltd., Nanaimo BC, Canada). All tissue samples involved were collected under a Material Transfer Agreement between the BC Salmon Farmers Association and Fisheries and Oceans Canada.

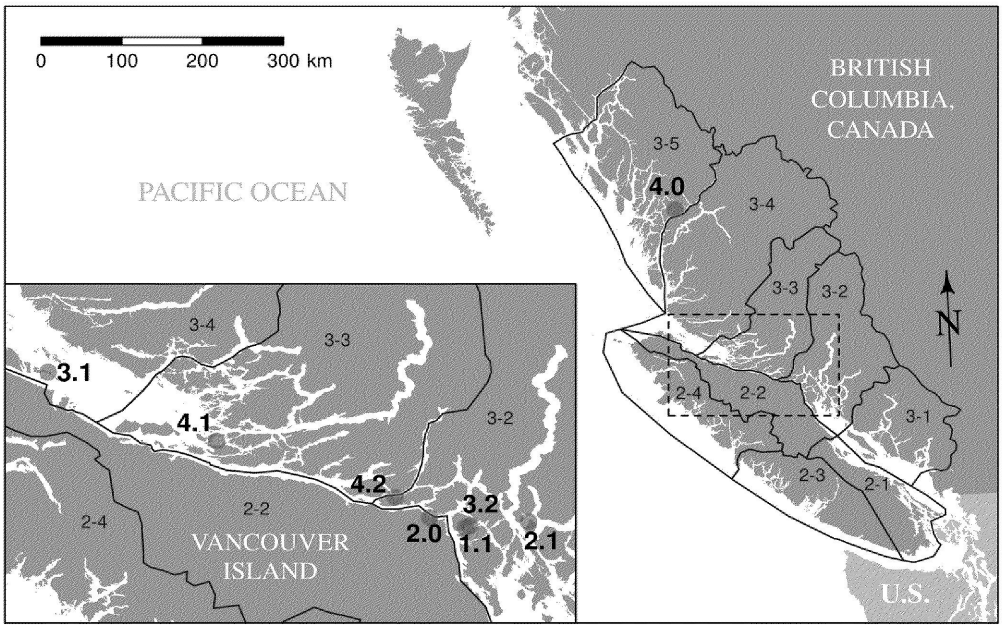

Figure 1. Atlantic salmon-farm locations (points) for the four cohorts from which samples were collected for this study, in relation to Fisheries and Oceans Canada's Aquaculture Management Zones (2-1 through 3-5). For each farm location, labelled *x.y*, *x* indicates a cohort of salmon (1 through 4) while *y* indicates successive locations of that cohort: 0 – freshwater hatchery, 1 & 2 (in some cases) – sequential saltwater net-pen locations.

Data series

Infectious-agent data

Farm schedule and sample collection

Of the four farm cohorts in the study, two entered the ocean in the spring, and another two entered in the fall (Table 1). Each of the two salmon-farming companies involved, Cermaq and Marine Harvest (recently renamed MOWI) Canada, granted access to one spring-entry and one fall-entry cohort. Two of the cohorts were transferred between farm locations approximately halfway through their respective production cycles (Table 1).

For each cohort, live fish were sampled at an approximate rate of 30 individuals every two weeks for the first five months, and 20 individuals per month thereafter until harvest. At each sampling visit, up to 20 dead or dying (moribund) fish from across the farm site were also sampled. For each of the two fall-entry cohorts, fish were also sampled in the respective hatcheries, with approximately 100 juvenile fish sampled prior to vaccination, and approximately 100 sampled post vaccination. Company veterinarians selected a single net pen per site visit from which to sample

live fish, and rotated their selections to reduce handling stress among pens. Industry constraints meant that dead and dying fish from certain mortality or disease events were unavailable, in some cases resulting in reduced dead/dying samples in months with elevated mortality.

Each sampled fish was euthanised if living and then dissected for gill, liver, kidney, heart, and brain. Dissections were conducted with separate external and internal tools (2 full sets) for each fish, and tools were not re-used during the sampling events. Following their use, tools were treated to a regime of water, bleach, water, ethanol, and flame. Fish were dissected using aseptic technique one fish at a time into individual tubes or RNAlater that were closed and sealed once tissue was placed inside. Sampled tissues were held at 4°C overnight then stored at -80°C until laboratory analysis. After each individual fish was dissected, the operating theatre was completely broken down and waste removed from the dissection area. The surfaces were wiped with bleach and then 70% ethanol and a new dissection theatre assembled with fresh gloves, new outside and inside tools, and tubes. Full dissection kits were assembled for each farm site, and following each site visit the entire kit was sterilized.

Laboratory analysis

We used a Fluidigm BioMark™ HD microfluidics-based qPCR platform, developed and validated for salmon infective-agent monitoring [18,24], to screen samples for viral, bacterial, and eukaryotic agents known to infect and potentially cause disease in salmon worldwide. The BioMark™ platform employs assays designed to assess presence and concentration of specific targeted nucleic acid sequences, and is sensitive to between one and three sequence copies per test volume [24]. The data we report are estimates of the number of target gene copies per µL of nucleic-acid solution, extracted from mixed-tissue homogenates and standardised to a fixed total nucleic-acid concentration (see Supplemental Information). We did not attempt to relate gene copies directly to infective-agent numbers, as such work was outside the scope of our study.

Substantial measures were taken to maximise data quality. We used a house-keeping gene assay to gauge sample quality and to ensure that nucleic acid degradation had not occurred. Each assay for an infectious agent was run in duplicate for each sample. Analytical sensitivity and specificity, and assay repeatability of the BioMark™ platform have been previously evaluated [24]. Extraction (DNA and RNA) and analysis protocols are described elsewhere [24,26] and we provide details in the Supplementary Information. Critically, we ran a series of negative controls to minimise false-positive results: negative extraction controls on RNA extraction plates, negative cDNA controls and no RT controls for the cDNA step, negative STA and no primer-STA controls for the specific target amplification step, and a blank buffer at the time of chip loading. We did not apply a limit-of-detection cutoff to the data we analysed, but we did discard results for which duplicate tests run on the same sample disagreed with respect to presence of an agent. We considered successful tests to be those without evidence of control cross contamination, poor amplification curves, or low housekeeping gene signals, and we

discarded results from unsuccessful tests, while retaining successful results for other tests run on the same sample, as appropriate.

Laboratory screening occurred in two main phases. Initially, we screened 933 mixed-tissue samples for a suite of 47 agents (status "known" in Tables 2 and 3). Some of the corresponding results have been reported elsewhere [27]. In subsequent screening, we omitted eleven of the initially known agents (Table 2), which displayed very low prevalence or were not detected at all. In their place during the second phase of screening, we tested for eleven additional viruses, which had not been discovered at the time of the initial experimental design [28,29] (status "new" in Table 3). Of these agents, two – Atlantic Salmon Calicivirus (ASCV) and a recently sequenced variant of Cutthroat trout virus (CTV-2) – displayed high prevalence. To fill in the time series and enable analysis, we re-assayed 215 mixed-tissue samples for ASCV and CTV-2, and assayed a further 16 samples that had not previously had mixed tissues successfully assayed (231 fill-in samples in total), using the Applied Biosystems 7900HT platform. We chose these fill-in samples to maximise temporal representation across farms, and we did not consider their status with respect to other agents during selection.

Statistical analyses

We analysed agent data to assess how apparent infection patterns changed over the course of a cohort's grow-out period, in relation to season, and between live and dead fish. We further analysed multi-agent infectious burden and how agent levels were correlated across hosts.

We note that agent data exhibit sampling bias, because disproportionately few samples were available from high-mortality periods due to farm constraints, and we did not known if, or how often, live fish were sampled from pens with elevated mortality. As a result, we do not attempt to relate infectious-agent levels to on-farm mortality levels.

Single-agent time series

To describe patterns in disease-agent time series from the four focal Atlantic-salmon farm cohorts, we fit generalised additive models [30] to single-agent data. GAMs provide flexible functional forms able to capture epidemiological patterns akin to those described by susceptible-infected-recovered (SIR) models, although they do not share a mechanistic basis.

For each agent with sufficient detections, we fit models to prevalence and intensity responses. We define agent prevalence as the proportion of successful tests with a positive detection, and we define agent intensity as the number of gene copies (the "load") in a sample with a positive detection. First, we fit models of agent prevalence to detection/non-detection data, assuming a binomial response and logit (log-odds) link function. Second, for the samples in which we detected a focal

agent, we fit models of average infection intensity to log-transformed copy-number data, assuming a normal response and linear link function. We incorporated four predictor components in our models: 1) a smooth function of the number of days since ocean entry, parameterised with a cubic-spline basis and allowed to differ among cohorts; 2) an additional smooth function of the number of days since ocean entry to account for differences between live and dead/dying hosts, again parameterised with a cubic-spline basis and allowed to differ among cohorts; 3) a scalar effect for each cohort; and 4) a smooth term with a cyclic cubic-spline basis to account for consistent seasonal patterns across cohorts. In this way, models could capture nonlinear trends over time, allowing for different patterns between live and dead/dying fish, and among farm cohorts. For the prevalence models, we used ten knots in the smooth terms for components 1) and 2), and four knots in the smooth terms for component 4). For the intensity models, we included identical model components, except that we reduced the number of knots in 1) and 2) to eight, aiming to avoid overly flexible models for use with reduced sample sizes after omitting non-detections.

In initial agent-prevalence model fitting, GAM fits in regions of the data with all-zero or all-one responses yielded accurate response predictions but unreasonably wide confidence intervals. We therefore used probability-integral-transform (PIT) residual bootstrapping to estimate confidence intervals [31].

We used the mgcv package [32] in R [33] to fit GAMs.

Relative infectious burden

In addition to the single-agent time series, we modelled temporal changes in relative infectious burden (RIB), a summary measure of agent loads within a given host [34]. For a infective agents assayed in n individuals, normalised RIB for individual i is:

$$\sum_{j=1}^{a} \frac{x_{ij}}{a \cdot \max_{all\,k}\left(x_{kj}\right)}, \qquad (1)$$

where x_{ij} is infection load (copy number) of for agent j in individual i. RIB has been used previously to investigate responses to infection in Chinook salmon [34] and coho salmon [35], and it has been characterised in juvenile sockeye salmon [36].

In calculating RIB, we restricted our dataset to agents for which we had screened in both phases of testing and detected at least five times, plus ASCV and CTV-2, for which we had filled in missing results from the first round of testing (see above). This resulted in RIB calculations based on eighteen infective agents (Table S1).

Agent correlations

To assess general patterns of coinfection, we calculated pairwise Spearman rank correlations between assayed copy numbers for pairs of infective agents, data

permitting, and between assayed copy numbers and the approximate numbers of house-keeping-gene copies per µL. House-keeping-gene copy number is relevant because degraded host tissue should have a lower number of these gene copies. Because qPCR involves a theoretical doubling of target-DNA copies per cycle, two raised to the power of the negative corresponding Ct value is approximately proportional to the number of target-DNA copies in an assay. In this case, we deemed use of $2^{(-Ct_{hkg})}$, ignoring the efficiency of the PCR reaction, to be acceptable, given our use of the measure to calculate a rank correlation.

Results

Data series

Infectious-agent data

We successfully generated infectious-agent data for a total of 2931 samples: 2504 from Atlantic salmon farms in the marine environment and 427 from freshwater hatcheries. Of the successfully assayed samples, 2407 were live-sampled fish, while 524 were opportunistically sampled dead or dying fish (160 moribund, 364 recently dead "fresh silvers"). Of the succsessful hatchery samples, 24 were from dead fish and four were from moribund fish. We initially screened each sample for 47 infectious agents. After screening 933 samples, we replaced assays for eleven extremely rare agents (Table 2) with assays for novel viral variants [28,29]; hence we screened for 58 total agents across the set of samples, but no single fish sample was subjected to every assay. In follow-up screening, we also screened 231 mixed-tissue samples (215 of the initial 933 samples and 16 samples that had not had successful assays previously) for ASCV and CTV-2, the two highest prevalence novel viruses. Overall freshwater agent prevalence ranged from 0 to 39% and overall saltwater prevalence ranged from 0 to 91%, with agents prevalent in freshwater often rare in saltwater, and vice versa (Table 3).

Statistical analyses

Single-agent time series

We note, given the potential bias in the sampling during periods of elevated mortality, that sample trends may not be representative of farm cohorts as a whole.

In the case of agents for which we had sufficient data to fit descriptive models, prevalence time series generally exhibited one of four patterns: 1) an ephemeral spike around the time of ocean entry followed by decline (*Candidatus* Branchiomonas cysticola, *Flavobacterium psychrophilum* [Figure 2A], *Vibrio anguillarum*, *Vibrio salmonicida*); 2) low, chronic prevalence, often with an ephemeral marine spike (*Facilispora margolisi*, *Ichthyophthirius multifiliis*, Putative Narna-like virus, *Parvicapsula kabatai*, *Candidatus* Syngnamydia salmonis [Figure 2B], Putative totivirus); 3) repeatedly fluctuating, substantial prevalence in the marine environment (CTV-2, *Parvicapsula pseudobranchicola* [Figure 2C],

Tenacibaculum maritimum); or 4) presence at low levels in freshwater, with increasing prevalence after ocean entry, often to 100% (ASCV, *Kudoa thyrsites*, *Paranucleospora theridion*, Piscine orthoreovirus [PRV; Figure 2D]). Figure 2 shows exemplar model fits, with all model fits provided in the Supplementary Information.

Patterns of agent intensity in the available samples were not as well characterised as those for prevalence, in many cases due to sparse data. For many agents, intensity varied by five or more orders of magnitude across individuals and through time. General trends for well-represented agents were: decline in CTV-2 intensity throughout marine residence (Figure 3A); increase and then decline for PRV (Figure 3B) and *P. theridion*, both agents that increased in prevalence over time; and substantially elevated but declining intensity for *T. maritimum* in dead and dying fish (Figure 3C). In many cases, agents for which prevalence plateaued appeared to exhibit an intensity peak at around the time that prevalence approached its maximum (ASCV, *K. thyrsites, P. pseudobranchicola, P. theridion*, PRV; Supplementary Information).

Multiple agents showed differences in prevalence or intensity between live and dead/dying fish. We considered models to show statistically significant differences if the confidence region for one sample category's trend failed to contain the other category's trend for a given farm over a given time window. Prevalence of *F. psychrophilum* in dead/dying fish was elevated in-hatchery (Figure 2A), with intensity also elevated in-hatchery for cohort 4. Intensity of *K. thyrsites* was elevated in dead/dying fish for cohorts 3 and 4 (Figure 3D). Prevalence of the putative Narna-like virus was elevated in dead/dying fish in cohort 4, although intensities remained around a single gene copy (Figure S9). In fact, the putative Narna-like virus was particularly prevalent in dead samples (11.9%), compared to dying (1.5%) and live (0.3%) samples. Prevalence of *P. pseudobranchicola* was reduced in dead/dying fish in cohorts 3 and 4 (Figure 2C). Both prevalence and intensity of PRV were elevated for dead/dying fish shortly after ocean entry in cohort 1 (Figures 2D, 3B). Prevalence of *T. maritimum* was variously elevated in dead/dying fish, across cohorts, and intensity was also elevated (Figures 3C, S16), especially in the first year of ocean residence; the latter being perhaps the most striking difference across all agent time series. Prevalence of *C.* Syngnamydia salmonis in dead/dying fish was consistently elevated (Figure 2B), but did not meet our criterion for significance. Both ASCV and CTV-2 displayed elevated prevalence and intensity in dead/dying fish in cohort 3, just after ocean entry (CTV-2 intensity was also elevated for cohort 1 just after ocean entry; Figures 3A, S2, S4).

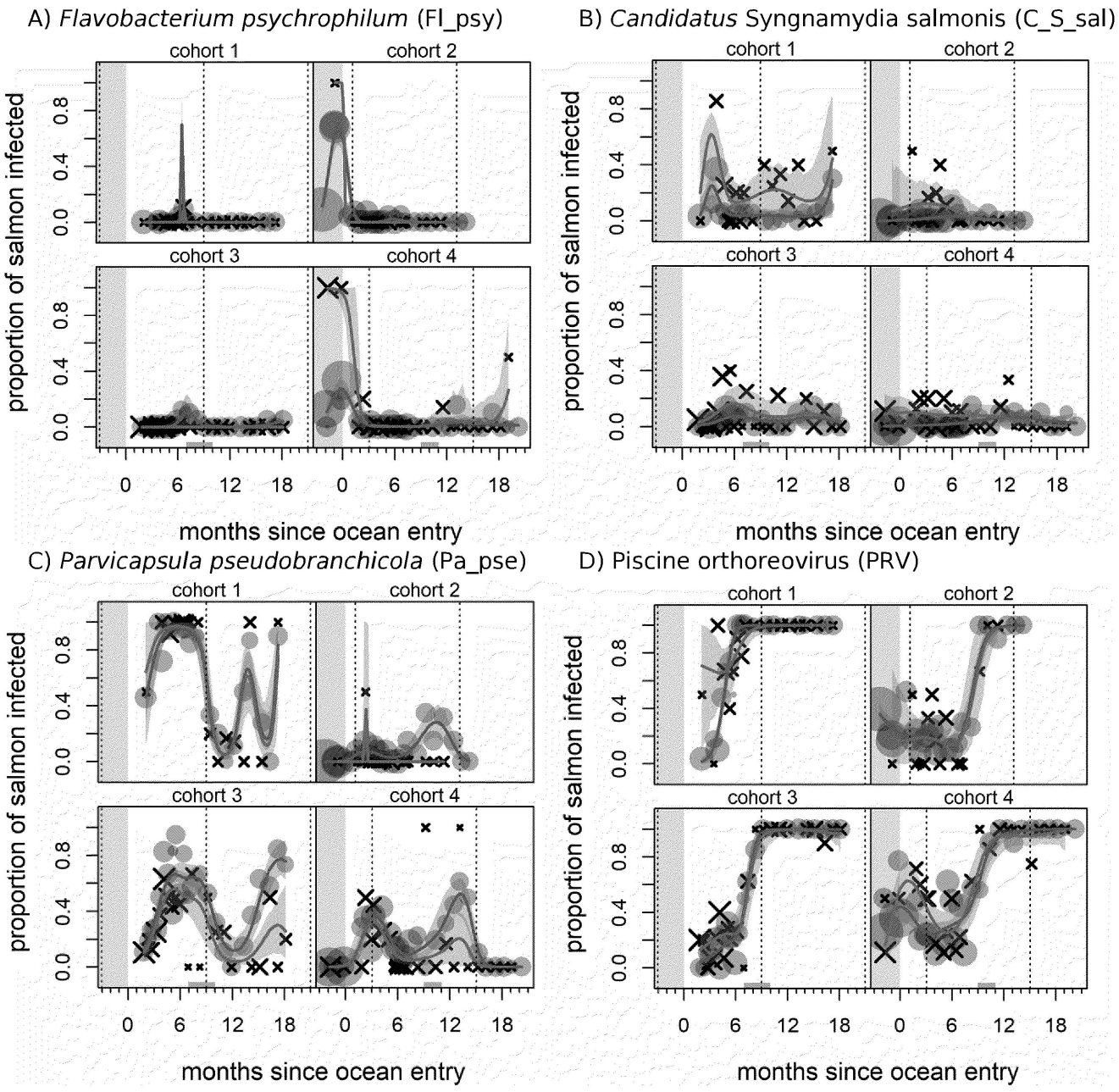

Figure 2. Prevalence of *Flavobacterium psychrophilum* (Fl_psy; A), salmon gill chlamydia *Candidatus* Syngnamydia salmonis (C_S_sal; B), *Parvicapsula pseudobranchicola* (Pa_pse; C), and Piscine orthoreovirus (PRV; D) in farmed Atlantic salmon throughout four production cycles. Grey circles show prevalence in live fish on each sampling date, and black X's show prevalence in dead/dying fish (symbol areas proportional to sample sizes). Curves indicate mean predictions from a generalised additive model; blue and red correspond to live and dead/dying fish, respectively (shaded areas show 95% confidence regions). Left-hand grey region indicates freshwater hatchery residence, grey regions on x-axis indicate period of transfer to another site, and vertical dotted lines correspond to January 1st.

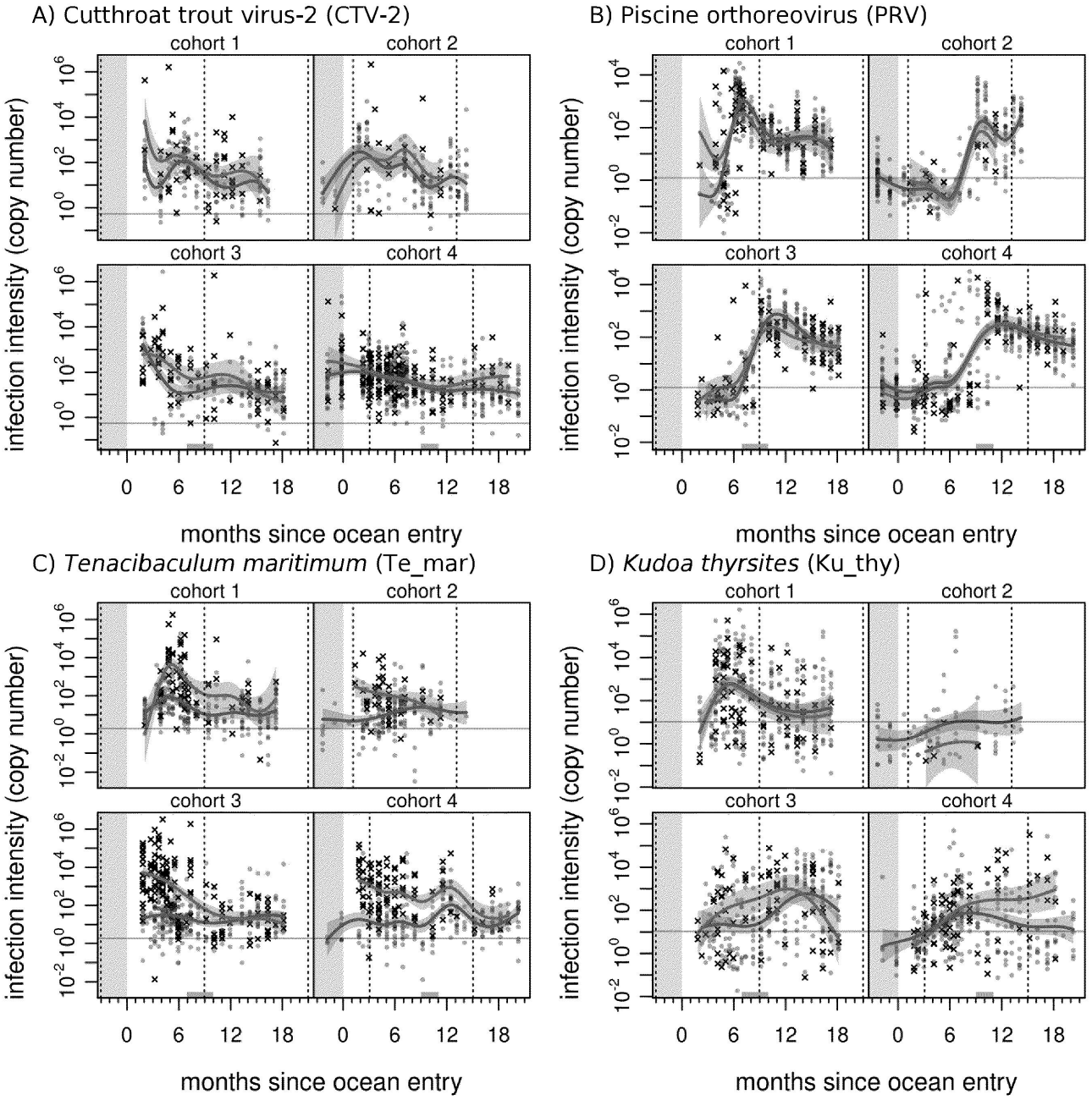

Figure 3. Agent intensity of Cutthroat trout virus-2 (CTV-2; A), Piscine orthoreovirus (PRV-1; B), *Tenacibaculum maritimum* (Te_mar; C), and *Kudoa thyrsites* (Ku_thy; D) in farmed Atlantic salmon throughout four production cycles. Grey circles represent live fish, and black X's represent dead/dying fish. Curves indicate mean predictions from a generalised additive model; blue and red correspond to live and dead/dying fish, respectively (shaded areas show 95% confidence regions). Left-hand grey region indicates freshwater hatchery residence, grey regions on x-axis indicate period of transfer to another site, and vertical dotted lines correspond to January 1st. Horizontal grey line indicates limit of detection (yielding ≈90% true positive rate) for respective qPCR assay run in duplicate. Note log scale.

We present comprehensive results for all infectious agents in the supplementary information (Figures S1 through S20).

Relative infectious burden

Relative infectious burden (RIB) did not show consistent temporal trends across all four sets of samples (Figure 4). RIB in fish sampled from spring-entry cohorts declined after their first autumn at sea, while RIB in fish sampled from autumn-entry cohorts generally increased after first winter at sea. Cohorts 3 and 4 both showed higher levels of RIB in dead and dying fish prior to their first winter at sea.

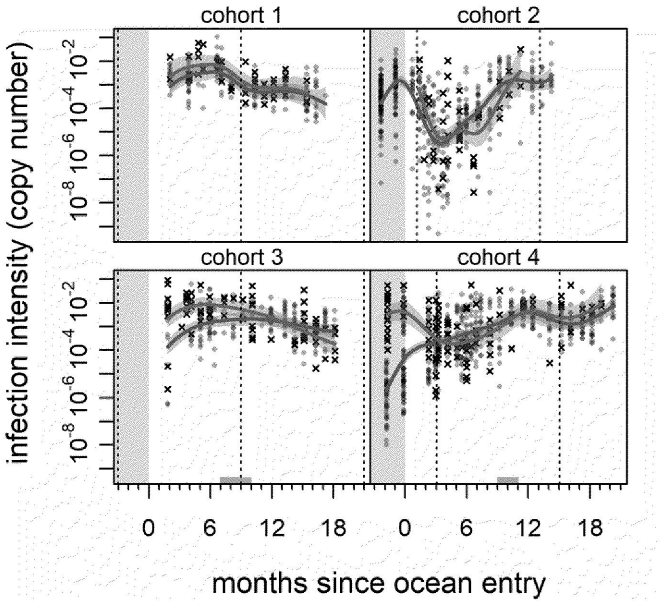

Figure 4. Relative infectious burden (RIB; see main text) multi-agent infection metric in farmed Atlantic salmon throughout four production cycles. Grey circles represent live fish, and black X's represent dead/dying fish. Curves indicate mean predictions from a generalised additive model; blue and red correspond to live and dead/dying fish, respectively (shaded areas show 95% confidence regions). Grey region indicates freshwater hatchery residence, grey regions on x-axis indicate period of transfer to another site, and vertical dotted lines correspond to January 1st. Note log scale.

Agent correlations

Correlations between infective-agent copy number estimates across all samples ranged from -0.39 (between *P. theridion* & *C.* Branchiomonas cysticola) to 0.65 (between PRV & ASCV). Most correlations were low, and 95% of correlations had an absolute value less than 0.25 (Figure 5).

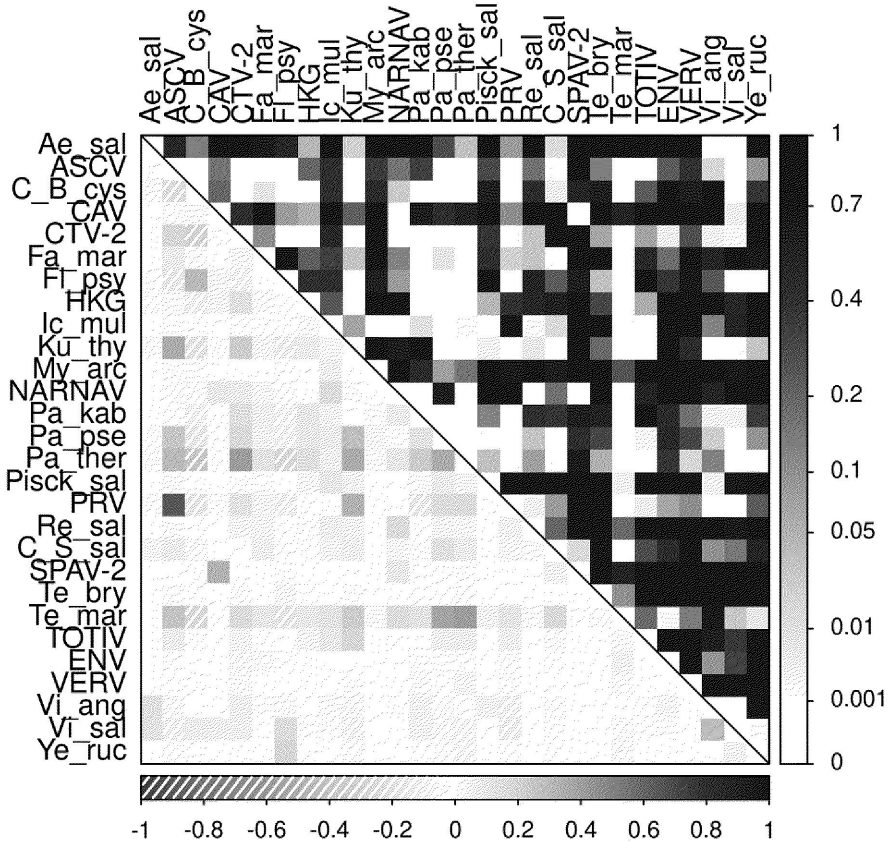

Figure 5. Spearman rank correlations between infectious-agent intensities in farmed Atlantic salmon in BC, Canada throughout four production cycles. See supplementary information for agent abbreviations. Lower left of plot and lower legend indicate correlation values. Upper right of plot and right legend indicate statistical significance of the correlations.

Discussion

We used high-throughput qPCR to screen for 58 infective agents in four Atlantic salmon farm cohorts from British Columbia throughout their production cycles. We measured presence and copy number for target genetic sequences, characteristic of specific viral, bacterial, and eukaryotic agents, including several recently discovered viruses [28,29], known or suspected to cause disease in salmon. These agents displayed various temporal patterns of prevalence and intensity, with several displaying elevated levels in dead and dying fish.

The data and analyses we have presented provide a unique look into the epidemiology of farmed salmon populations, and wildlife/livestock diseases generally. No past studies have had access to multiple farmed-salmon cohorts, throughout their production cycles, with the capacity to molecularly screen for a large suite of infectious agents. Other work has reported agent data for dead-sampled fish collected in BC as part of Fisheries and Oceans Canada's farm audit

program [37], but such analyses lack the time-series nature of the results we have presented. To our knowledge, no other studies have provided such detailed, comprehensive information for infective agents in domestic or wild populations over time. This study, therefore, presents a substantial step toward effectively monitoring shared wildlife/livestock diseases, made possible by cutting-edge technology, as predicted previously [22].

While our findings offer specific insight to salmon farmers, aquaculture managers, and those concerned with the disease ecology of sympatric wild salmon, we caution that results remain correlative, and relevant patterns (e.g. apparent mortality signatures) require further investigation. Unfortunately, a lack of regular testing of dead and dying fish (collection was opportunistic, at farms' discretion) resulted in potential for associated patterns to be obscured. Due to this potential bias in the sampling design, we are unable to draw conclusions related to farm-level mortality rates, but several agents showed patterns of note, including elevated levels in dead and dying fish.

Agent patterns

Perhaps the clearest single-agent pattern – the elevated load of *T. maritimum* in dead and dying fish (Figure 3B) – matches generally accepted patterns in aquaculture. Induced tenacibaculosis can be responsible for substantial on-farm mortality worldwide [38], and mouthrot resulting from *T. maritimum* in the east Pacific causes substantial losses [39]. In our study, mouthrot was noted during veterinarians' sample processing for cohorts one, three, and four in the months after ocean entry. We note that elevated levels in dead and dying fish could represent the bacterium's acknowledged role as an opportunistic pathogen [38], rather than a direct cause of mortality. We also note the positive correlations between *T. maritimum* load and that of a number of different agents (Figure 5), consistent with the view that *T. maritimum* may facilitate co-infections [40]. Given its high overall prevalence in fish (Table 3), secondary factors – such as co-infections – might exacerbate infection with *T. maritimum*, playing a role in mortality.

K. thyrsites intensity was elevated in dead and dying fish for cohorts three and four, around the time they were transferred to their final marine locations (Figure S8). In both cases, the cohorts finished their production cycles in farms on the central east coast of Vancouver Island (Figure 1), a region in which the risk of *K. thyrsites* infection is acknowledged to be high [41]. This myxozoan parasite is economically important due to post-mortem myoliquefaction seen in infected fish, but it is not considered a pathogen [42], and it is unclear why higher gene-copy levels would be observed in dead/dying fish. *K. thyrsites* may merely replicate faster in stressed fish (in this case due to transport). Our surveillance of pathogens did not include skeletal muscle tissue, where *K. thyrsites* spores develop, but it did include heart, which can be infected by the parasite [43]. We note that *K. thyrsites* was correlated with PRV, with both agents known to infect muscle tissue (although red blood cells

are the primary infective tissue for PRV). Follow-up histopathological investigation may provide some insight into *K. thyrsites* distribution and any associations with pathology or patterns of co-infection.

PRV, which is the causative agent of Heart and Skeletal Muscle Inflammation (HSMI) [44] and has recently generated controversy in BC [26,27,45], shows several patterns of note. PRV prevalence increased to near ubiquity over time (Figure 2D), concurrent with an increase, peak, slight decline, and then stabilisation of intensity (Figure 3B). Although our perspective is limited to sampled fish, with a noted potential for bias, the observed PRV trends were consistent across all four cohorts, and the intensity patterns are consistent with previously reported dissemination, peak replication, and long-term persistence phases of the virus within hosts [27,45]. Past findings suggest that PRV may induce an antiviral response in hosts that can protect them against certain co-infections [46,47]. Perhaps counter to the generality of this claim, PRV and ASCV exhibited the strongest load correlation out of any we observed across our data set (Figure 4). ASCV was originally isolated from salmon with HSMI, and was initially thought to play a role in the disease [48]. Other work has found no relationship between ASCV and PRV infections or HSMI [49]. In the case of a related baitfish calicivirus, however, there is evidence that viral co-infection is linked to disease manifestation [50], so further work is needed to tease these relationships apart. In general, dead and dying Atlantic salmon in our study did not show elevated prevalence or intensity of PRV, except shortly after ocean entry in cohort one (Figures 2D, 3B). This mortality signature corresponds to the onset of lesions diagnostic of HSMI in cohort one, which subsequently spread to affect the majority of that farm population for most of a year [27].

The gill chlamydia bacterium, *C.* Syngnamydia salmonis, showed a consistent trend towards elevated prevalence in dead and dying salmon (Figure 2B). Observed intensity was low, however, often averaging approximately a single copy (Figure S15). Sequencing has validated past detections of this agent on the Fluidigm BioMark™, and has also revealed SNP diversity within the primer-binding region, resulting in potential underdetection (Miller et al. unpublished). Given a putative mortality signature and the lack of prior epidemiological study of this recently discovered agent [51,52], we would suggest further work on *C.* Syngnamydia salmonis.

Ephemeral mortality signatures appeared for several agents. *F. psychrophilum* was clearly elevated in dead and dying fish in-hatchery, although we only had access to two hatchery cohorts and cannot draw general conclusions. Intensity of both the ASCV and CTV-2 were elevated in sampled dead and dying fish from at least one cohort shortly after ocean entry (Figures 3A,S2). Both viruses were also present in-hatchery. The previously reported Cutthroat trout virus appears to be apathogenic [53] in trout, and has been detected in Atlantic salmon [54]. Little is known about the novel variant for which we screened, although *in situ* hybridisation has revealed that infection can be systemic and extensive in the brain (Mordecai et al. 2020). As for the ASCV, associated pathology was found to be likely due to PRV contamination

[48]. Extremely limited information about these two viruses, paired with our findings, warrants further investigation (e.g. with histopathology and *in situ* hybridisation) to determine if either virus is linked with pathology. As both these viruses were detected in Chinook salmon (Mordecai et al. 2020), and considering their high prevalence in Atlantic salmon farms, the potential risk they pose to wild Pacific salmon populations should be a priority for future research.

Infectious agent levels overall, as measured by relative infectious burden, showed a clear trend in smolts coming out of freshwater hatcheries for cohorts three and four. There, infectious burden was much higher (in one case 10 000 times higher) in dead and dying fish than in live-sampled fish. While the effect dissipated once fish entered the marine environment, it is clear that hatchery fish are dying with – or of – elevated levels of infection. The patterns we observed likely reflect the transition from freshwater to saltwater, with a coincident shift in infective-agent communities [55]. Smoltification has also been associated with immune depression [56], and elevated infectious burden around the time of ocean entry may reflect this. Where we had dead/dying hatchery samples, however, infectious burden was elevated weeks before ocean entry, hinting at the potential for problems in-hatchery.

Agent idiosyncrasies

Several agents showed unexpected patterns, or patterns that may be connected to their particular biology.

The putative Narna-like virus, a recently discovered agent [29], showed elevated prevalence in dead and dying fish (Figure S9). This pattern was mainly due to over-representation in dead-sampled fish, as we detected the agent in 13.2% of dead fish, 1.6% of moribund fish, and 0.4% of live-sampled fish in saltwater. Given that *Narnaviridae*, of which the putative Narna-like virus is a member, is thought mainly to infect fungi [57], this virus may be associated with a fungal decomposer. This is speculative, however, and recent genomic evidence from across taxa suggests that the *Narnaviridae* may be much more widespread than previously thought [58].

Counter to the common trend, *P. pseudobranchicola* tended to be less common in dead and dying fish than in live-sampled fish (Figure 2C), with dead fish, in particular, tending to exhibit the lowest levels (results not shown). *P. pseudobranchicola* primarily infects the pseudobranch [59], a structure near the gills involved in oxygenating blood in the eye. Infection also occurs in tissue collected for this study, especially gill [60], and we speculate that loads in dead fish could be reduced due to myxospore release or degradation of delicate gill tissue after host death. Given that we did not sample the pseudobranch, it is likely that our data underestimates the load of this organism.

The sampling environments (freshwater or marine) of several detections were unexpected. In particular, we detected *K. thyrsites* and *T. maritimum* (Figure 3C) in

freshwater hatcheries, although these agents are considered marine species [61,62]. It is possible that these hatcheries introduced saltwater in the weeks before ocean transfer, to prepare smolts for release. We also detected *F. psychrophilum,* considered a freshwater bacterium [63], in marine net pens (Figure 2A). The bacterium is known to survive in brackish water [64], however, and this is not the first time it has been detected in a marine setting [37,65].

Broader connections

Not all infective agents cause disease, and even agents that do can be present long before – or long after – clinical symptoms. Our work presents only a piece of the puzzle in what is a multifaceted, complex scenario of shared wildlife/livestock disease in salmon aquaculture. The controversy surrounding PRV in BC, as an example, illustrates this complexity. While conventional lab challenges using PRV from BC sources have failed to reproduce in BC fish the extent of HSMI lesions observed on Norwegian farms [45,66], work related to our study has been able to identify and shed light on HSMI, and related jaundice/anemia in Chinook salmon, in BC salmon farms [26,27]. While we saw a putative mortality signature in one cohort during this study, the normal course of PRV infection was not always associated with mortality (e.g. Figures 2D, 3B). More work will be required to elucidate the nuances of PRV infection, factors that induce associated disease, and possible resultant mortality. A fruitful place to start would be to carry out sampling and diagnostics of dead and dying fish in farms and pens experiencing elevated mortality.

Although we have shown putative mortality signatures for several infective agents in farmed Atlantic salmon, these are not necessarily the agents that pose the greatest risk to wild salmon. For one thing, a given agent need not produce the same effects in different species [26,67]. For another, contact between populations may not coincide with infection maxima. Depending on when farm smolts enter the marine environment, for example, PRV could be at low prevalence in the spring, when a number of wild Pacific salmon species migrate as juveniles [15]. Other times of year would be more relevant for interactions with other wild species, and there is much scope for transfer between farmed and wild environments. In addressing shared wildlife/livestock disease, we need to consider both wildlife and livestock as populations that serve as potential reservoirs of disease agents, and are susceptible to outbreaks [68]. In this context, surveillance and monitoring are essential facets of disease management [23], providing raw material to develop understanding of disease and build effective management strategies. Parallel work is monitoring wild populations for the same agents we have investigated here, with the prospect of cross-referencing patterns and impacts [69–71].

The ubiquity of infectious agents on the farms leads naturally to discussion of potential control strategies, which present a variety of challenges in aquaculture. Vaccination has proven successful at times, but the salmon aquaculture industry

has a somewhat chequered history with uptake, since vaccination can affect host growth, and thus the bottom line [13]. In addition, vaccines have only been developed for a handful of agents. Reducing translocations can be an effective control strategy on land (Mortensen 2006, Bengis 2002, Bajardi 2012), but transmissive properties of the marine environment and highly mobile marine carrier hosts pose challenges to isolating host populations geographically (Krkosek 2015). Our findings provide circumstantial evidence that some agents (e.g. *K. thyrsites*) respond to translocations. The fact that two of our four focal cohorts moved substantial distances throughout their respective marine production may be cause for concern, considering the infective-agent populations we have shown those cohorts to have harboured. In general, aquaculture-associated disease and related management decisions have a history of generating political controversy [72]. Infective-agent monitoring and analyses are critical for designing, implementing, and evaluating effective disease-control measures, and for bridging divides in debate surrounding aquaculture.

Disease monitoring is never complete, and detection always lags behind pathogen spread [73], but new technologies – such as those we employed here – can facilitate efficient, lower-cost surveillance and monitoring. Surveillance for existing pathogens and identification of previously unknown pathogens is part of the integrative approach required to understand and control existing and emerging infectious diseases [22]. Here, we have further demonstrated the utility of high-throughput, modern genetic techniques for monitoring known infective agents and for generating information about previously under-studied agents [24,27–29,34,35]. Further work will target the risk of transfer between wild and farmed hosts and prioritize threats to salmon, farmed and wild.

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Acknowledgements

We are very grateful to the Pacific Salmon Foundation and Genome British Columbia for funding and support to carry out the Strategic Salmon Health Initiative, the overarching program under which this study operated. This program is further part of the Salish Sea Marine Survival Project, led by the Pacific Salmon Foundation under the scientific leadership of [redacted] We appreciate the access to farm samples provided by MOWI Canada West and Cermaq Canada, as well as farm data provided by the Aquaculture Management Division of DFO, without which this study could not have occurred. Thanks to [redacted] and Dylan Conover for sample collection; to Holly Fellowes, Devan Johnson, and Anna Yao for assistance with sample preparation; and to Shaorong Li for APC standard preparation.

Author Contributions

KMM conceived the study and supervised laboratory & statistical analyses. ADS, KHK, AT, and KF performed laboratory analyses and generated and managed infectious-agent datasets. [redacted] designed and carried out statistical analyses and wrote the bulk of the paper. GM, AB, and [redacted] contributed to statistical analysis and results interpretation. All authors contributed to writing and editing.

Conflict of Interest

The authors declare no known conflicts of interest.

Data Availability Statement

Data will be made available in UBC's Strait of Georgia Data Centre (sogdatacentre.ca) prior to publication.

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Tables

Table 1. Movement history for farmed Atlantic salmon used in this study. Geographic locations of individual facilities are shown in Figure 1.

cohort	facility type	facility code (Figure 1)	DFO Fish Health Zone	entry (initial)	exit (final)
1	farm	1.1	3-2	Apr 2013	Mar 2015
2	hatchery	2.0	2-2	-	Sep 2013
	farm	2.1	3-2	Sep 2013	Nov 2015
3	farm	3.1	3-4	Apr 2013	Dec 2013
	farm	3.2	3-2	Nov 2013	Apr 2015
4	hatchery	4.0	3-5	-	Oct 2013
	farm	4.1	3-3	Oct 2013	Aug 2014
	farm	4.2	3-2	Aug 2014	Sep 2015

Table 2. Low-prevalence infective agents in initial rounds of mixed-tissue sample screening in farmed Atlantic salmon.

organism	organism type	test code	status	freshwater		saltwater	
				tests‡	prevalence	tests‡	prevalence
Infectious pancreatic necrosis virus	virus	IPNV	known	0	–	933	0
Infectious salmon anemia virus	virus	ISAV-7	known	0	–	933	0
Infectious salmon anemia virus	virus	ISAV-8	known	0	–	933	0
Oncorhynchus masou herpes virus	virus	OMV	known	0	–	933	0
Piscine myocarditis virus	virus	PMCV	known	0	–	933	0
Salmon alphavirus	virus	SAV	known	0	–	933	0
Aeromonas hydrophila	bacterium	Ae_hyd	known	0	–	933	0
Moritella viscosa	bacterium	Mo_vis	known	0	–	933	0.0096
Spironucleus salmonicida	flagellate	Sp_sal	known	0	–	933	0
Gyrodactylus salaris	fluke	Gy_sal	known	0	–	933	0
Nucleospora salmonis	Microsporidian	Nu_sal	known	0	–	931	0.0150

‡successful tests only (i.e. those without evidence of control cross contamination, poor amplification curves, or low housekeeping gene signals)

Table 3. Infective agents in mixed-tissue samples of farmed Atlantic salmon. † indicates agents newly discovered or not known from salmon in BC [28,29].

organism	organism type	test code	status	freshwater		saltwater	
				tests‡	prevalence	tests‡	prevalence
†Salmon pescarena-virus-1	virus	SPAV-1	new	427	0	1611	0
†Salmon pescarena-virus-2	virus	SPAV-2	new	425	0	1605	0.0019
Atlantic salmon calicivirus	virus	ASCV	new	423	0.1300	1835	0.5384
†Pacific salmon nidovirus	virus	PSNV	new	427	0.0023	1611	0.0006
†Cutthroat trout virus-2	virus	CTV-2	new	426	0.2840	1808	0.6610
†Putative Narna-like virus	virus	NARNAV	new	427	0	1606	0.0212
†Orthomyxovirus	virus	ORTHO	new	427	0	1611	0.0006
†Chinook aquareovirus	virus	CAV	new	426	0.0023	1611	0.0012
Poxvirus	virus	SGPX	new	427	0	1611	0
†Putative RNA virus	virus	RNAV	new	427	0	1611	0.0006
†Putative totivirus	virus	TOTIV	new	427	0.0023	1607	0.0137
Erythrocytic necrosis virus	virus	ENV	known	427	0	2470	0.0049
Infectious hematopoietic necrosis virus	virus	IHNV	known	427	0	2471	0.0004
Piscine orthoreovirus	virus	PRV	known	421	0.3278	2404	0.5420
Pacific salmon parvovirus	virus	PSPV	known	327	0	2101	0
Viral encephalopathy & retinopathy	virus	VERV	known	427	0	2471	0.0012
Viral hemorrhagic septicemia virus	virus	VHSV	known	427	0	2471	0
Aeromonas salmonicida	bacterium	Ae_sal	known	425	0.0094	2466	0.0020
Candidatus Branchiomonas cysticola	bacterium	C_B_cys	known	426	0.3873	2464	0.0369
Flavobacterium psychrophilum	bacterium	Fl_psy	known	414	0.3382	2459	0.0130
Piscichlamydia salmonis	bacterium	Pch_sal	known	427	0	2471	0
Piscirickettsia salmonis	bacterium	Pisck_sal	known	427	0.0023	2468	0.0073
Renibacterium salmoninarum	bacterium	Re_sal	known	427	0	2472	0.0024
Strawberry disease (Rickettsia-like)	bacterium	RLO	known	427	0	2472	0
Candidatus Syngnamydia salmonis	bacterium	C_S_sal	known	427	0.0047	2461	0.0561
Tenacibaculum maritimum	bacterium	Te_mar	known	426	0.0423	2335	0.6081
Vibrio anguillarum	bacterium	Vi_ang	known	423	0.0331	2477	0.0153
Vibrio salmonicida	bacterium	Vi_sal	known	425	0.0965	2458	0.0260
Yersinia ruckeri	bacterium	Ye_ruc	known	427	0.0187	2468	0
Neoparamoeba perurans	amoeba	Ne_per	known	427	0	2472	0.0004
Nanophyetus salmincola	fluke	Na_sal	known	427	0	2472	0
Sphaerothecum destruens	Mesomycetozoan	Sp_des	known	427	0	2471	0.0004
Facilispora margolisi	Microsporidian	Fa_mar	known	427	0	2460	0.0293
Loma salmonae	Microsporidian	Lo_sal	known	427	0	2472	0
Paranucleospora theridion	Microsporidian	Pa_ther	known	410	0.2317	2383	0.9123
Ceratomyxa shasta	myxozoan	Ce_sha	known	427	0	2472	0
Kudoa thyrsites	myxozoan	Ku_thy	known	424	0.0755	2386	0.4438
Myxobolus arcticus	myxozoan	My_arc	known	427	0	2471	0.0020
Myxobolus insidiosus	myxozoan	My_ins	known	427	0	2472	0
Parvicapsula kabatai	myxozoan	Pa_kab	known	427	0.0023	2461	0.1187
Parvicapsula minibicornis	myxozoan	Pa_min	known	427	0	2469	0.0004
Parvicapsula pseudobranchicola	myxozoan	Pa_pse	known	427	0	2312	0.3166
Tetracapsuloides bryosalmonae	myxozoan	Te_bry	known	427	0.0070	2472	0
Cryptobia salmositica	protozoan	Cr_sal	known	427	0	2472	0
Dermocystidium salmonis	protozoan	De_sal	known	427	0	2472	0
Ichthyophonus hoferi	protozoan	Ic_hof	known	427	0	2471	0.0024
Ichthyophthirius multifiliis	protozoan	Ic_mul	known	384	0.0052	2290	0.0157

‡successful tests only (i.e. those without evidence of control cross contamination, poor amplification curves, or low housekeeping gene signals)

Figure legends

Figure 1. Atlantic salmon-farm locations (points) for the four cohorts from which samples were collected for this study, in relation to Fisheries and Oceans Canada's Aquaculture Management Zones (2-1 through 3-5). For each farm location, labelled $x.y$, x indicates a cohort of salmon (1 through 4) while y indicates successive locations of that cohort: 0 – freshwater hatchery, 1 & 2 (in some cases) – sequential saltwater net-pen locations.

Figure 2. Agent prevalence of *Flavobacterium psychrophilum* (Fl_psy; A), salmon gill chlamydia *Candidatus* Syngnamydia salmonis (C_S_sal; B), *Parvicapsula pseudobranchicola* (Pa_pse; C), and Piscine orthoreovirus (PRV; D) in farmed Atlantic salmon throughout four production cycles. Grey circles show prevalence in live fish on each sampling date, and black X's show prevalence in dead/dying fish (symbol areas proportional to sample sizes). Curves indicate mean predictions from a generalised additive model; blue and red correspond to live and dead/dying fish, respectively (shaded areas show 95% confidence regions). Left-hand grey region indicates freshwater hatchery residence, grey regions on x-axis indicate period of transfer to another site, and vertical dotted lines correspond to January 1st.

Figure 3. Agent intensity of Cutthroat trout virus (CTV-2; A), Piscine orthoreovirus (PRV; B), *Tenacibaculum maritimum* (Te_mar; C), and *Kudoa thyrsites* (Ku_thy; D) in farmed Atlantic salmon throughout four production cycles. Grey circles represent live fish, and black X's represent dead/dying fish. Curves indicate mean predictions from a generalised additive model; blue and red correspond to live and dead/dying fish, respectively (shaded areas show 95% confidence regions). Left-hand grey region indicates freshwater hatchery residence, grey regions on x-axis indicate period of transfer to another site, and vertical dotted lines correspond to January 1st. Horizontal grey line indicates limit of detection (yielding ≈90% true positive rate) for respective qPCR assay run in duplicate. Note log scale.

Figure 4. Relative infectious burden (RIB; see main text) multi-agent infection metric in farmed Atlantic salmon throughout four production cycles. Grey circles represent live fish, and black X's represent dead/dying fish. Curves indicate mean predictions from a generalised additive model; blue and red correspond to live and dead/dying fish, respectively (shaded areas show 95% confidence regions). Grey region indicates freshwater hatchery residence, grey regions on x-axis indicate period of transfer to another site, and vertical dotted lines correspond to January 1st. Note log scale.

Figure 5. Spearman rank correlations between infectious-agent intensities in farmed Atlantic salmon in BC, Canada throughout four production cycles. See supplementary information for agent abbreviations. Lower left of plot and lower legend indicate correlation values. Upper right of plot and right legend indicate statistical significance of the correlations.

From: Lowe, Carmel
Sent: Friday, December 11, 2020 3:56 PM
To: McPherson, Arran; Moore, Wayne; MacDougall, Lesley; Parsons, Jay
Subject: FW: Correspondence regarding Discovery Island net pens
Attachments: R Reid Letter Dec 11 2020.docx

Sharing this critique of the CSAS risk assessment prepared by SSHI scientists that will soon be published on the PSF web site.

I propose Lesley and I work with Jay and Wayne to review our Q&A's and ML's.

Carmel

From: Reid, Rebecca
Sent: Friday, December 11, 2020 12:44 PM
To: Thomson, Andrew ; Lowe, Carmel
Cc: Dostal, Alexandra
Subject: FW: Correspondence regarding Discovery Island net pens

FYI – from the PSF.

RR

****

Rebecca Reid
Regional Director General/ Directrice générale régionale
Fisheries and Oceans Canada - Pacific Region/ Pêches et Océans Canada Région du Pacifique
200-401 Burrard Street / 401, rue Burrard, bureau 200
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From: [redacted]
Sent: December 11, 2020 12:41 PM
To: Reid, Rebecca <Rebecca.Reid@dfo-mpo.gc.ca>
Cc: [redacted]
Subject: Correspondence regarding Discovery Island net pens

Rebecca, please see the attached. I would be happy to discuss with you if desired.

[redacted] *Pacific Salmon Foundation,*
300 – 1682 West 7th Avenue, Vancouver, BC
V6J 4S6
604-664-7664 (office phone)
604-664-7665 (office fax)
[redacted] *(cell)*

s.19(1)

Pacific Salmon Foundation, 300 – 1682 W 7th Avenue, Vancouver, B.C. V6N 4S6

December 11, 2020

Ms. R. Reid,
RDG, Dept. Fisheries & Oceans,
Vancouver, B.C.

Re: Comments on CSAS review leading to minimal harm assessment for Fraser River sockeye

As you may know on September 28, 2020, PSF posted a statement regarding DFO's Decision to Consult with First Nations in the Discovery Islands. We also wrote the Minister supporting the removal of open-net pen aquaculture from the Islands, and have prepared comments (attached) on the CSAS process that resulted in DFO's minimal harm assessment for Fraser River sockeye salmon. These comments stem from, and were prepared by, the Strategic Salmon Health Initiative (SSH) team. Following from the past weekend CBC article and subsequent e-mail correspondence, we felt it appropriate to provide these comments to you. Our intention is to post these on the PSF website but we have no plans for further distribution. The SSHI team is presently completing synthesis papers concerning their pathogen surveillance, analytical models (spatial and temporal distributions by pathogen), and association with salmon survival and health. Plus, a final task in the Genome BC Agreement is planned for late February, 2021 to conduct an international workshop to rank the identified pathogens for their potential risk to Pacific salmon. Following the workshop, we would request a meeting with DFO Management in order to present our findings and recommendations.

Yours truly;

[redacted]

cc. [redacted]

s.19(1)

Pacific Salmon Foundation, 300 – 1682 W 7th Avenue, Vancouver, B.C. V6N 4S6

Attachment: Strategic Salmon Health Initiative comments (Dec. 1, 2020)

DFO recently announced plans to consult with Discovery-Islands First Nations, after determining through Canadian Science Advisory Secretariat (CSAS) review processes that the Department deems nine infective agents from Discovery-Island salmon farms to each pose no more than a minimal risk to Fraser River sockeye salmon. However, researchers in the Strategic Salmon Health Initiative have several concerns regarding the CSAS findings and consequently with the final assessment. Participants in the SSHI were involved in some of the CSAS processes, but information has evolved with time and we suggest that the context for the CSAS process was too restricted. Our concerns include:

1. **Any Impacts likely extend beyond the current narrow scope**
   Contrary to verbal claims from DFO at the time of announcement, the CSAS reports did not assess risk to "wild salmon" in general, but specifically focused only on risks to Fraser River sockeye from salmon farms in the Discovery Islands region. The risk assessments, in their current form, cannot be extrapolated to other species, like Chinook and coho, or even sockeye populations from other regions. That said, we know the effects of salmon farms may extend well beyond the scope of impacts considered in the CSAS reports. For example, Viral Haemorrhagic Septicaemia Virus, one of the agents that underwent CSAS review, has a larger impact on herring than on sockeye salmon, potentially extending impacts to all salmon species that rely on this important forage fish. Furthermore, salmon farms are by no means restricted to the Discovery Islands, and many Pacific salmon populations travel through that region, meaning that any impacts farms do have likely affected many more salmon populations than those considered.

2. **Assessments are already out of date**
   Since the CSAS reviews were carried out, new information has come to light which may affect the conclusions in a number of the relevant CSAS reports. Notably, the conversation about Piscine Orthoreovirus (PRV) has changed since its report underwent review in early 2019: DFO fish health scientists have acknowledged PRV's role in jaundice/anemia syndrome in Chinook salmon, and two independent studies (one published and one accepted) have agreed that PRV was introduced to BC waters from the Europe/North Atlantic on two separate occasions. Research from the Strategic Salmon Health Initiative has also better resolved the risk of exposure for Fraser River sockeye to *Tenacibaculum maritimum*, and has identified putative links between infection with this bacterium and reduced marine growth and survival in multiple Pacific salmon species; this work will be submitted for publication by December 2020.

3. **Report error**
   At least one of the CSAS reports contains a key technical flaw. The *Tenacibaculum maritimum* assessment, for one, double-counted the low chance of Fraser-River sockeye infection, failing to independently gauge the likelihood of infection and impact of infection - standard components of overall risk assessment.

4. **Communication glazes over uncertainty**
   Interpretation to date has all but ignored the glaring assessment uncertainty inherent in the CSAS findings. Given the lack of scientific data from wild fish, all the reports based their final results on information with large underlying uncertainties or on expert opinion, making the overall conclusions *at most* a "best guess."

5. **Cumulative effects ignored**
   While DFO announced the CSAS reports as determining "minimal risk" from the nine agents examined, that risk refers exclusively to risk from *individual* agents. These agents clearly do not exist in isolation, but there has been a total lack of consideration of cumulative effects from the nine agents together. Even a simple summation of the likely effects, as appropriate, might paint a different picture than that announced.

6. **Sea lice ignored**
   Sea-louse infection is likely the best known topic concerning open-net pen (ONP) salmon aquaculture and wild Pacific salmon, but it is completely missing in these risk assessments. The risk posed by sea lice remains a major concern wherever ONP salmon farming is practiced around the world. Moreover, while chemical treatments were once effective to control sea-louse outbreaks, industry has grappled with higher than usual sea-louse loads over the last several years as drug-resistance appears to have taken hold. Hence DFO's contention that risks from sea lice are effectively managed is no longer universally the case. Co-infection between sea lice and pathogens is certainly one example of cumulative effects that the CSAS risk assessments have not addressed.

7. **A broader base for First Nation consultations**
   Although the salmon farms considered in the nine CSAS reviews are in the Discovery Islands region of BC, the sockeye salmon considered migrate to and from spawning grounds throughout the Fraser River watershed. It is not apparently how First Nations whose territories comprise that watershed will be consulted about the identified "minimal" risks to sockeye salmon that spawn there.

From: MacDougall, Lesley
Sent: Monday, December 14, 2020 1:56 PM
To: Lowe, Carmel
Subject: FW: Namgis SPA
Attachments: SPA_Template_Namgis Project_Dec 11 2020-To Namgis_AC.docx

Hi Carmel – here is the current draft of the 'Namgis/DFO agreement

---

From: Candy, John
Sent: Monday, December 14, 2020 10:54 AM
To: MacDougall, Lesley
Subject: FW: Namgis SPA

Lesley here is the Namgis draft.
Do you have time for a quick call right now.
Can I call you in
John

From: Miller-Saunders, Kristi <Kristi.Saunders@dfo-mpo.gc.ca>
Sent: Monday, December 14, 2020 10:28 AM
To: Candy, John <John.Candy@dfo-mpo.gc.ca>
Subject: RE: Namgis SPA

Here is the SPA agreement with all changes accepted. This is currently under review by the Namgis, [redacted]

Kristi Miller-Saunders, PhD
Head, Molecular Genetics
Pacific Biological Station
3190 Hammond Bay Rd
Nanaimo BC V9T 6N7
250-756-7155
Kristi.Saunders@dfo-mpo.gc.ca

From: Candy, John <John.Candy@dfo-mpo.gc.ca>
Sent: Monday, December 14, 2020 10:08 AM
To: Miller-Saunders, Kristi <Kristi.Saunders@dfo-mpo.gc.ca>
Subject: Namgis SPA

Hi Kristi
If you can get the Namgis SPA to me today [redacted] It will still have to go back through Finance after that.

John Candy
Section Head
Molecular Genetics Laboratory
Pacific Biological Station
Nanaimo BC V9T 6N7
(250) 756-7036
John.candy@dfo-mpo.gc.ca

s.21(1)(b)
s.23

CANADA – 'NAMGIS FIRST NATION COLLABORATIVE AGREEMENT

THIS AGREEMENT is made in duplicate between

HER MAJESTY the Queen in right of Canada ("Canada"), as represented by the Minister of Fisheries and Oceans on behalf of Fisheries and Oceans Canada ("**DFO**")

And

'Namgis First Nation having a mailing address at PO Box 210 Alert Bay, BC V0N 1A0 ("**'Namgis**")

and is effective as of the date of execution by DFO and 'Namgis (the "**Effective Date**")**.**

RECITALS

WHEREAS 'Namgis and DFO (each a "**Party**" wish to collaborate on a project entitled "Collaborative Salmon Farm Research" as described in Appendix A hereto ("**Project**");

WHEREAS pursuant to the Letter of Understanding, dated November 30, 2018 (the "**LOU**") between 'Namgis First Nation, Mamalilikulla First Nation, and Kwikwasut'inuxw Haxwa'mis First Nation (collectively, the "**First Nations**") and the Province of British Columbia (the "**Province**") addressing the renewal of the tenure for 17 fish farms located in the Broughton area;

WHEREAS under the LOU, the First Nations and the Province agreed on an orderly transition of the 17 fish farms from the Broughton area (the "**Fish Farms**") with specific actions taken in the immediate, medium, and longer term (years 2019-2023);

WHEREAS pursuant to the LOU, the Provincial tenures issued to those Fish Farms required the establishment and implementation of an Indigenous Monitoring and Inspection Plan (the "**IMIP**") to oversee the operations of the Fish Farms during the orderly transition in an effort to document, understand, avoid, and mitigate potential harmful effects on wild Pacific salmon and other marine resources and the ecosystems on which they rely;

WHEREAS, the First Nations entered into agreements with Mowi Canada West Ltd. and Cermaq Canada Ltd. (collectively, the "**Tenure Holders**" and individually a "**Tenure Holder**"), dated for reference September 6, 2019 and September 9, 2019 respectively, to implement the IMIP (the "**IMIP Agreements**");

WHEREAS the First Nations agreed that 'Namgis would act as the administrative lead for the First Nations for the purposes of implementing the IMIP Agreements, including receiving, administering and paying out funds necessary for the implementation of the IMIP;

WHEREAS the First Nations and DFO have a joint interest in the expected results of this collaboration and have shared and compatible objectives associated with the Project;

WHEREAS 'Namgis and DFO agree to a fair allocation of risk, supported by a project management and risk mitigation framework associated with the Project; and

WHEREAS the Project is relevant to the First Nations' and DFO's respective mandates, core responsibilities and priorities;

THEREFORE the Parties agree as follows:

1 The Project

(a) General description, purpose and expected results of the Project

This project will analyze samples collected by the 'Namgis First Nation using the Fluidigm Biomark system to detect and quantitate agreed upon salmon pathogens in fish tissue and filtered water.

The Intellectual Property and training provided in this Project by the DFO's Genetics and Genomics Section will be applied to establish a First Nations run genomic laboratory that the First Nations can rely on for the IMIP First Nations' oversight of the Fish Farms (the "**FN Genomics Lab**").

The Project will also undertake new research on the utility of environmental DNA ("eDNA") as a non-invasive monitoring tool to identify shifts in infectious profiles on farms, including associations between eDNA and farm disease status.

(b) Benefits each party will receive from the Project.

i. foster technology transfer to the First Nations and the FN Genomics Lab by training laboratory technicians who will be working in the FN Genomics Lab, as well as the laboratory leader, on high throughput infectious agent monitoring using the Fluidigm BioMark™ platform. This training will include technical, analytical, and interpretive aspects of the tool sufficient for the First Nations to become self-reliant to monitor and interpret infective agent distributions in farmed and wild salmon;

ii. strengthen the working relationship and build greater trust between DFO and the First Nations by providing an environment for direct interaction and shared knowledge exchange, including the Indigenous knowledge and science, that may inform management approaches in both organizations;

iii. provide trusted information to community members of the First Nations on the collaborative fish health and water research on the Fish Farms, with the goal of promoting a better working relationship between the First Nations and the DFO;

iv. develop a reliable, non-invasive means to monitor and inform mitigations that may reduce the impacts of Fish Farms on wild Pacific salmon and other marine resources, including by sampling and testing for the correspondence between pathogen burdens in farmed salmon and those in the water within net pens and surrounding the farm tenure that pose a risk of transmission of pathogens, diseases, or disease agents to wild Pacific salmon and other marine resources in proximity to the Fish Farms;

v. protect and restore wild Pacific salmon and other aquatic resources, and the ecosystems on which they rely within their Territories.

2 Definitions

(a) In this Agreement:

(i) "**Account**" means the account into which funds received by DFO under the Agreement will be deposited and will be used to pay for Recoverable Project Expenditures;

(ii) "**Agreement**" means the recitals, definitions, terms, conditions and obligations stipulated herein including the stipulations in the appendices affixed hereto;

(iii) "**Agreement Term**" means the term the agreement is effective, between the Effective Date and the third anniversary of the Effective Date;

(iv) "**Annual Implementation Report**" means the annual written progress report on the implementation of the Agreement prepared by the Leadership Team;

(v) "**Annual Project Report**" means the written progress report on all technical and scientific aspect of the Project prepared by the Research Team;

(vi) "**Background Information**" means information in a Party's possession that is required by the Receiving Party to perform any Project activities for which the Receiving Party is responsible, excluding information subject to third-party intellectual property rights;

(vii) "**Biological Material**" means any living organisms, including animals, and any material produced by and extracted from living organisms;

(viii) "**CFIA**" means the Canadian Food Inspection Agency;

(ix) "**Chain of Custody Protocol**" means the handling, transportation, storage and testing of all samples under this Agreement as outlined in Schedule 2 to Appendix A of this Agreement;

(x) "**Competitive Information**" has the meaning ascribed to it in section 1.1 of Appendix D;

(xi) "**Confidential Information**" has the meaning ascribed to it in section 1.1 of Appendix D;

(xii) "**Contribution**" and "**Contributions**" mean resources that are provided and used by either Party for the Project. The term should not be confused with a Government of Canada Contribution, as per the Treasury Board Policy on Transfer Payments;

(xiii) "**DFO Representative**" means the representative appointed by DFO to manage and oversee the implementation of this Agreement on its behalf;

(xiv) "**DFO Research Lead**" means the person appointed under this Agreement to lead the Project on behalf of the Federal Government;

(xv) "**Disclosing Party**" means the Party which has Background Information;

(xvi) "**Disclosure List**" means the list maintained by DFO of persons to whom any Competitive Information is disclosed;

(xvii) "**eDNA**" means the environmental DNA, as defined in section 1(b);

(xviii) "**Effective Date**" means the date on which this Agreement has been executed by authorized representatives from both Parties;

(xix) "**Final Implementation Report**" means the final report on the implementation of the Agreement prepared by the Leadership Team;

(xx) "**Final Project Report**" means the final project report prepared by the Research Team for the DFO Representative and the FN Represntative;

(xxi) "**First Nations**" means the 'Namgis First Nation, who are acting on behalf of the Broughton Nations (also including Mamalilikulla First Nation, and Kwikwasut'inuxw Haxwa'mis First Nation);

(xxii) "**Fiscal Year**" means any twelve month period starting April 1st of the year and ending March 31st of the following year;

(xxiii) "**Fish Farms**" means the 17 fish farms that are subject to the orderly transition from the Broughton area subject to the LOU and under the First Nations' oversight pursuant to the IMIP Agreements;

(xxiv) "**FN Genomics Lab**" means a First Nations run genomic laboratory using eDNA technology developed according to this Agreement;

(xxv) "**FN Representative**" means the representative appointed by 'Namgis to manage and oversee the implementation of this Agreement on behalf of the First Nations;

(xxvi) "**FN Research Lead**" means the person appointed to lead the Project and to oversee the Project on behalf of the First Nations;

(xxvii) "**IMIP**" means the Indigenous Monitoring and Inspection Plan;

(xxviii) "**IMIP Agreements**" means those agreements between the First Nations and the Tenure Holders establishing the IMIP dated for reference September 6, 2019 and September 9, 2019;

(xxix) "**IMIP Pathogens**" means the pathogens, diseases, and disease agents listed in Schedule 1 to Appendix A of this Agreement;

(xxx) "**Indemnifying Party**" as defined in section 20(a) of this Agreement;

(xxxi) "**In-kind Expenditures**" means Project Expenditures that a Party incurs internally for the Project, accounting for its contribution to the Project in the form of salaries and salary benefits for its employees participating in the Project and other Project expenditures, but excluding any financial contribution to the other Party and costs associated with equipment, instruments and facilities acquired by the Party prior to the Project;

(xxxii) "**Intellectual Property**" or "**IP**" means any invention, and any other product of intellectual activity in the industrial, scientific, literary, or artistic fields including all intellectual creation that may be or is legally protected through patents or as copyright, industrial design, integrated circuit topography, under the plant breeders' rights, or subject to protection under the law as trade secrets or as confidential information;

(xxxiii) "**IP Manager**" means the Party that has contributed the most to the Joint IP;

(xxxiv) "**Joint IP**" means the IP rights in Research Findings generated jointly by officers, employees, trainees, agents and contractors of both Parties will be jointly owned by the Parties;

(xxxv) "**Leadership Team**" means the DFO Representative and the FN Representative who are responsible for overseeing the implementation team made up of senior representatives of the Parties established under section 9 of this Agreement;

(xxxvi) "**LOU**" means the Letter of Understanding between the First Nations and the Province dated November 30, 2018 which addresses the renewal of the tenure of the Fish Farm;

(xxxvii) "**MGL**" means the DFO's molecular genetics laboratory;

(xxxviii) "**Non-confidential Information**" has the meaning ascribed to it in section 1.2 of Appendix D;

(xxxix) "**Post Doc**" an analytical post-doctoral and/or contract statistician hired by the Research Team;

(xl) "**Project**" means the Collaborative Salmon Farm Research as described in Appendix A;

(xli) **"Project Description"** means the description of the Project contained in Appendix A;

(xlii) "**Project Expenditures**" means expenditures required for the Project, including all applicable taxes, which are itemized in Appendix B, and consisting of In-kind Expenditures and Recoverable Project Expenditures;

(xliii) "**Project Risk Analysis**" means that risk analysis for the Project which is outlined in Appendix C;

(xliv) "**Province**" means the province of British Columbia;

(xlv) "**Publishing Party**" means a Party who wishes to publish any Research Findings;

(xlvi) "**Receiving Party**" means the Party who required Background Information;

(xlvii) "**Recoverable Project Expenditures**" means Project Expenditures that DFO incurs for the Project, and which DFO may recover from 'Namgis' financial contribution to DFO;

(xlviii) "**Reportable Pathogens**" means specific pathogens, diseases and disease agents which DFO is required by law to report;

(xlix) "**Research Findings**" means all data, software, products and processes arising from the Project whether or not they may be subject to IP rights, other than Testing Results;

(l) "**Research Team**" means the DFO Research Lead and FN Research Lead who are responsible for overseeing the conduct of the Project and all work associated with it according to the terms of this Agreement;

(li) "**Residual**" means any funds remaining in the Account after accounting for all Recoverable Project Expenditures;

(lii) "**Tenure Holders**" means Mowi Canada West Ltd. and Cermaq Canada Ltd. collectively and "**Tenure Holder**" means one of them individually;

(liii) "**Testing Results**" means the results of tissue samples, obtained from fish on the Fish Farms and the Tenure Holders' freshwater hatcheries, being tested for the IMIP Pathogens.

3 Term of the Agreement and Amendments

(a) The Agreement will expire, unless terminated sooner in accordance with the termination provisions herein, on the third anniversary **[To be determined]** of the Effective Date (the "**Agreement Term**").

(a) While the Agreement is in effect, it may be amended by a written agreement signed by authorized representatives of the Parties.

4 DFO's and 'Namgis' Contributions

(a) DFO's and 'Namgis contributions to the Project are outlined in the table below**:**

Grand Totals of All Contribution Table	'Namgis		DFO	
Fiscal year	Financial Contribution to DFO	In-Kind Contribution	In-Kind Contribution	Fiscal year
2021-2022			175,820	2020-2021
2022-2023			0	2021-2022
Total			**$175,820**	**Total**

(b) DFO will not make any financial contribution to 'Namgis for this Project.

(c) 'Namgis shall make its financial contribution to DFO for the Project, upon receiving a request for payment, according to the payment schedule below:

Fiscal Year	Estimated Date of Payment	Payment Amount
[2021-2022]	The Effective Date	
[2022-2023]	April 1, 2021	
	Total	

In the table above,

a) the 1st payment should be scheduled to be paid at signature.

b) payments must be scheduled to ensure that funds are always available before incurring Specified Project Expenditures

c) the total of the payments from 'Namgis for each Fiscal Year must equal the amounts per Fiscal Year under the column 'Financial Contribution to DFO' in the table in article 4(a) above]

(b) DFO shall deliver the request for payment to the attention of 'Namgis' Project Authority.

(c) All payments to DFO shall be made payable to the Receiver General for Canada, shall reference the following DFO coding [Insert DFO Coding [XXXXX]–[XXX]–760–3239–[XXXXX]] and shall be delivered to the DFO Project Authority, unless otherwise indicated in the request for payment.

(d) Amounts received by DFO under the Agreement will be deposited in a Specified Purpose Account and used to pay for Specified Project Expenditures.

(e) Upon expiration or upon termination of the Agreement, DFO shall provide to 'Namgis a financial statement in respect of Specified Project Expenditures actually incurred or that will be incurred during the same Fiscal Year and will return to 'Namgis any funds remaining in the Specified Purpose Account after accounting for all Specified Project Expenditures ('Residual') if the Residual is over $100. Otherwise the Residual will be credited to the Government of Canada as non-respendable miscellaneous revenue.

(f) Throughout the Term of the Agreement and for one year after expiration or termination of the Agreement, 'Namgis may request access to DFO records related to Specified Project

Expenditures and DFO shall provide reasonable facilities and co-operation to allow the Organization to review these records and to take copies, as required.

5 Ownership of Equipment

(a) Any equipment, instruments, and supplies acquired by either Party under this Agreement shall belong to that Party.

6 Project Authorities

(a) The Project Authority for DFO is:

Kristi Miller-Saunders, PhD
Research Scientist
Pacific Biological Station
3190 Hammond Bay Rd
Nanaimo BC V9T 6N7
Telephone:
Fax: 250-756-7155
E-mail: Kristi.saunders@dfo-mpo.gc.ca

(b) The Project Authority for 'Namgis is:

[redacted]
Broughton Aquaculture Transition Initiative
49 Atli Street, P.O. Box 210
Alert Bay BC V0N 1A0
Telephone:
Fax: 1-250-974-5900
E-mail: [redacted]

(c) Either Party may by written notice to the other designate a new Project Authority.

(d) The Parties hereby create a Leadership Team by appointing a DFO Representative and a FN Representative.

(g) The Parties hereby create the Research Team by appointing:

i. Dr. Kristi Miller as the research lead (the "**DFO Research Lead**") on behalf of the DFO ; and

ii. [redacted] as the research lead (the "**FN Research Lead**") on behalf of the First Nations.

(h) Either Party may change its appointee to the Research Team by notifying the other Party in writing.

7 Project Management

(a) The Leadership Team will:

(1) meet at the request of any Party and will meet and communicate regularly and as often as required to oversee the implementation of this Agreement;

(2) promote the timely sharing of information between the DFO and the First Nations;

(3) work together to promote the successful implementation of this Agreement by the Parties throughout the Agreement Term, including responding in a timely manner to unexpected outcomes and situations;

(4) create and oversee the Research Team and any committees or working groups that will facilitate the implementation of this Agreement; and

(5) where possible, rely upon the Research Team or their own teams to exchange information and assistance.

(b) The Parties acknowledge and agree that they will implement the Project according to the technical description contained in Appendix A (the "**Project Description**") and that the Research Team will be responsible for implementing the Project according to this Agreement.

(c) The Research Team will be responsible for conducting the Project and all work associated with it according to the terms of this Agreement.

(d) The Research Team will**:**

i. work under the direction of the Leadership Team;

ii. make decisions by full consensus, and where it cannot reach consensus it will seek the direction of the Leadership Team;

iii. communicate with each other and meet as often as required to complete the Project;

iv. oversee and conduct the research, including quarterly reviewing and, as required, approving any amendments to the technical methods;

v. work together to promote the successful completion of the Project and any associated work throughout the Agreement Term, including responding in a timely manner to unexpected outcomes and situations;

vi. oversee the implementation of the research, including quarterly reviewing and, as required, approving any amendments to the technical methods;

vii. oversee and conduct all laboratory training and analyses on the Fluidigm BioMark™, and field and laboratory training associated with eDNA;

viii. hire an analytical post-doctoral and/or contract statistician (the "**Post Doc**") for a one-year contract approximately six months after the Project begins;

ix. ensure the Post Doc conducts analyses of the molecular data, including assessing associations between infectious profiles (detections and loads of each agent) in the fish and those in the eDNA; and

x. supervise the Post Doc's preparation of the Research Findings for publication.

(e) The FN Research Lead will:

i. be responsible for training and supervising the First Nations' field trainees;

ii. work with Tenure Holders to oversee all field sampling activites, including pre-field sample preparation, fish tissue collections, and eDNA collections;

iii. conduct independent histopathological investigations, where required, and compile the molecular and fish health data into a report for each hatchery and farm visit;

iv. supply samples to the DFO's molecular genetics laboratory (the "**MGL**");

v. acquire information from farm veterinarians and staff on environmental conditions, mortality records, clinical signs of disease, results of diagnostic testing, and other pertinent

information deemed to be required to inform assessments of the health and condition of the fish by the FN Research Lead;

vi. perform veterinary diagnostics required to relate eDNA profiles to shifting disease states; and

vii. provide the Post Doc with relevant fish health, diagnostic, and environmental data required to develop models to explore factors contributing to eDNA abundance in the water column, and provide insight into the factors contributing to variance in shedding rates among agents, information pertinent to assess risks of agent spread and transmission between farmed and wild salmon.

(f) DFO Research Lead will:

i. provide molecular biology training to First Nations' staff on:

(a) technical IP developed pertaining to high throughput monitoring of infectious agents on the Fluidigm BioMark™ platform;

(b) the development and maintenance of a database to hold and output collection and molecular data; and

(c) basic analytical scripts to perform rudimentary analysis of the complex data.

8 Risk Management

(a) The Parties have discussed and completed a risk analysis, which is outlined in Appendix C (the "**Project Risk Analysis**").

(b) The Parties agree that the risk allocation in Appendix C is a fair allocation of risk for the Project.

(c) If a risk event identified in the Project Risk Analysis or any other unanticipated risk event occurs, the Parties will make reasonable efforts to implement appropriate mitigation measures, including those set out in the Project Risk Analysis, however the Parties do acknowledge that the occurrence of any risk event may require an extension to the Term of the Agreement or termination of the Agreement in accordance with the section entitled "Termination".

(d) For greater certainty, if for any reason, if the collection of samples at the Fish Farms is interrupted, once that interruption has been resolved, the Parties will work together collaboratively, and the First Nations will work with the Tenure Holders pursuant to the IMIP Agreements, to ensure that the sample collection continue for the twelve (12) months contemplated by the Project Description.

9 Communications, Reports and Notices

(a) The Parties will encourage the sharing of information between themselves and the Tenure Holders providing access to sampling on their farms, as well as sharing general information on the health of fish to their managers and constituents.

(b) Information which will be shared between the Parties under this Agreement includes:

i. SOPs for sampling fish and eDNA, molecular analyses, database processing, and rudimentary data analysis;

ii. fish health and environmental data compiled by the FN Research Lead;

iii. full data outputs from the Fluidigm BioMark™, showing both singleton and duplicate detections;

iv. Ct and copy number of each agent, annotated with information from the farms and hatcheries; and

v. basic plots and tables agreed upon by both Parties that will be used to populate all reports relating to the technical and scientific aspect of the Project to the Parties.

(c) The Research Team will provide reports to both Parties within 7 days after molecular data is completed. The Leadership Team will be responsible for delivering and communicating all reports to the Parties and may rely on the Research Team for assistance when doing so.

(d) Notices, reports and other communications relating to the Agreement will be in writing and will be addressed to the Parties.

(e) Within sixty (60) days of the end of each Fiscal Year, the Research Team will prepare a written progress report on all technical and scientific aspects of the Project and deliver that report to the Leadership Team (the "**Annual Project Report**").

(f) Each Fiscal Year, within 30 days of receiving the Annual Project Report, the Leadership Team will prepare a written progress report on the implementation of the Agreement (the "**Annual Implementation Report**") for the Parties.

(g) As soon as reasonably possible after the completion of the Annual Implementation Report, the Leadership Team will deliver the Annual Implementation Report and the Annual Project Report to their respective Parties.

(h) Within sixty (60) days following expiration or termination of this Agreement, the Research Team will complete the final report for the Leadership Team (the "**Final Project Report**").

(i) Within ninety (90) days following expiration or termination of this Agreement, the Leadership Team will prepare a final report on the implementation of the Agreement (the "**Final Implementation Report**").

(j) As soon as reasonably possible after completion of the Final Project Report and the Final Implementation Report, the DFO Representative and the FN Representative will deliver both of those reports to their respective Parties.

(k) 'Namgis will promptly notify DFO, and provide full particulars, upon:

(i) changing its corporate name;

(ii) changing its controlling interests;

(iii) filing for bankruptcy or involving itself in any insolvency proceedings;

(iv) taking advantage of any statutes relating to the orderly payment of debts; or

(v) being subject to criminal prosecution or convicted of a criminal offence.

10 Access to DFO Grounds and Buildings

(a) **'Namgis**, its employees and its agents participating in the Project shall abide by all legislations, regulations, orders and policies with respect to access to DFO sites, vessels and buildings and utilization of facilities therein, including orders and policies related to security, health and safety, and shall not bring any people, equipment or any materials into DFO sites, vessels and buildings without the prior written consent of the DFO Project Authority.

(b) To facilitate training, two 'Namgis' trainees, under a government to government exchange, will use and occupy the MGL and the Pacific Biological Station in Nanaimo, and work in collaboration with the staff there under the supervision of the DFO Research Lead. The First Nations shall not bring any

additional people, equipment or materials into DFO sites, vessels and buildings without the prior written consent of the DFO Representative.

(c) 'Namgis trainees using DFO facilities will abide by all legislations, regulations, orders and policies with respect to access to DFO sites, vessels and buildings and utilization of facilities therein, including orders and policies related to security, health and safety.

11 Confidential Information, Testing Results, Results and Intellectual Property Rights

(a) Confidential Information, Testing Results, Results and IP rights will be subject to the provisions of Appendix D.

12 Biological Material

(a) Biological Material produced from Project-related activities, Biological Material provided by the Organization to DFO under this Agreement and Biological Material issued therefrom shall be subject to the provisions of Appendix E.

13 Dispute Resolution

(a) If any dispute, other than a matter of public law arises between the Parties in connection with or arising out of the Agreement, the Parties will use their best efforts to settle any such dispute by negotiations or mediation. If the Parties fail to resolve the dispute within a period of thirty (30) days or such greater period as may be mutually agreed, then either Party may refer the dispute to arbitration in accordance with the *Commercial Arbitration Act*. The Parties agree to have arbitration hearings conducted at Nanaimo, British Columbia. The decision rendered by the arbitrator will be final, executable, not subject to appeal and binding on the Parties.

14 Liabilities

(a) Each Party (referred to as "**Indemnifying Party**" for the purpose of this section) hereby agrees to indemnify and hold the other harmless from and against all claims, legal actions or causes thereof, liabilities and costs arising from the negligence or willful misconduct of the Indemnifying Party's officers, employees, trainees, agents and contractors in connection with the execution of this Agreement provided that the Party to be indemnified gives prompt notice of the claim to the Indemnifying Party, and provides all relevant information and reasonable assistance as requested.

(b) The obligations herein will subsist after expiration or termination of this Agreement in respect of any cause or event connected with any activity undertaken by the Indemnifying Party, or by its officers, employees, trainees, agents and contractors prior to the expiration or termination of this Agreement..

15 Insurance and Risks

(a) The Government of Canada underwrites its own risks, including the risk of liability for the acts or omissions of its officers and employees while they are acting within the scope of their employment with DFO.

(b) **'Namgis** warrants and represents that it has adequate liability insurance to cover its officers, employees and agents participating in the Project.

(c) Each Party hereby assumes any and all risks of personal injury and property damage attributable to the negligent acts and negligent omissions of that Party and its officers, employees and agents participating in the Project.

16 Termination

(a) Either Party may terminate the Agreement by notice to the other without liability, and the other Party hereby waives its rights to initiate any proceedings against the terminating Party if:

i. the other Party breaches any terms or conditions of the Agreement and does not rectify the breach within thirty (30) days after being notified in writing of the breach; or

ii. the other Party fails to perform the Project in accordance with Appendix A and does not rectify the matter within thirty (30) days after being notified in writing of the specific rectifications required; or

iii. the other Party has submitted or submits false or misleading information in respect of the Project or in respect of its obligations pursuant to the Agreement, such termination to take effect immediately after the notice date; or

iv. resources that the terminating Party is expected to contribute to the Project (in DFO's case 'resources' include resources that are subject to appropriations approved by Parliament) are reduced or not available, unless the other Party agrees to amend the Agreement to address the reduction in resources, such termination to take effect thirty (30) days after the notice date; or

v. a risk event identified in the Project Risk Analysis in Appendix C or any other unanticipated risk event jeopardized the scientific integrity of the Project or prevented the Project from being completed within a reasonable period of time despite mitigation measures that may have been implemented.

(b) DFO may terminate the Agreement by notice to the Organization without liability, and the Organization hereby waives its rights to initiate any proceedings against DFO or Canada if:

i. 'Namgis is insolvent, in receivership, bankrupt, files for bankruptcy, or is involved in any act of bankruptcy or any bankruptcy proceeding, such termination to take effect immediately after the notice date; or

ii. 'Namgis is subject to criminal prosecution or is convicted of any criminal or regulatory offence under any law, order or regulation of Canada or the provinces or of a duly constituted authority thereof, or convicted as an accessory to any such offence, such termination to take effect immediately after the notice date.

(c) Expiration or termination of the Agreement shall not relieve either Party from its obligations pursuant to the section entitled 'Communications, Reports and Notices' and the sub-section entitled 'Indemnification' or from its obligations, as set out in Appendix D, in respect of Background (Confidential) Information, Results and Intellectual Property Rights.

(d) Failure by either Party to notify the other of a breach of the Agreement or of any other circumstances possibly warranting termination of the Agreement, or to terminate the Agreement because of such breach or such other circumstances shall not constitute an acceptance of the breach by that Party or a waiver of its right to terminate this Agreement in accordance with its provisions, and, if applicable, to recover from the other Party any sums due under the Agreement.

17 *Impact Assessment Act* (IAA)

(a) The Parties agree that, if applicable, the Project will be assessed and approved in accordance with the *Impact Assessment Act* prior to commencing the Project.

18 Canadian Council on Animal Care (CCAC)

(a) The Parties agree that, if applicable, the Project will be assessed and approved in accordance with the standards of the Canadian Council on Animal Care. 'Namgis contractors will abide by the Animal Care provisions set forth by the Aquaculture industry.

19 General

(a) Entire Agreement

This Agreement, including any appendices or schedules appended hereto, which form part of this Agreement, sets forth the entire agreement between the Parties hereto concerning the Project and supersedes and revokes all negotiations, arrangements or communications, of any nature whatsoever whether they be verbal or in writing, between the Parties or their authorized representatives or any other person purporting to represent DFO or 'Namgis.

(b) Interpretation

If there are any inconsistencies between this Agreement and the appendices or shcedules attached hereto, this Agreement will prevail.

(c) No Agency

Nothing contained in the Agreement shall be considered or construed as creating a relationship of partners, principal and agent, lessor and lessee, licensor and licensee (except with respect to Intellectual Property, in accordance with Appendix D) or of employer and employee between the Parties. In particular, each Party shall be solely responsible for any and all payments and/or deductions required to be made including those required for Canada Pension Plan, Employment Insurance, Workers' Compensation, or Income Tax for all its employees participating in the Project, and for any and all fees payable to its agents participating in the Project. In addition, each Party shall be solely responsible for the supervision, scheduling of work and tasking for its employees and agents participating in the Project.

(d) Member of Parliament

'Namgis will ensure that no member of Parliament is admitted to any share or part of the Agreement or to any benefit that may arise from it.

(e) Former Public Servants

'Namgis will ensure that any former public office holder who is currently employed by or an agent of 'Namgis is in compliance with the post-employment provisions of the Fisheries and Oceans Canada Values and Ethics Code, which is posted at http://www.dfo-mpo.gc.ca/reports-rapports/vicr-virc/vicr-virc2012-eng.htm or comparable Treasury Board or other federal government department code.

(f) Laws in Force

This Agreement shall be interpreted in accordance with federal laws of Canada and the laws in force in the Province of British Columbia.

(g) Location

The Project shall be performed at Nanaimo, in the Province of British Columbia.

(h) Force Majeure

No breach of an obligation under this Agreement by either Party shall be deemed a breach of this Agreement or create any liability if such breach arises from any cause or causes beyond the

control of such Party including, without limitation, fire, natural disaster, inclement weather, power failures, accident, war, rebellion, insurrection, riot and invasion provided that the Party remedy such breach resulting from one of the above causes as soon as it is practicable after the occurrence of one or more of the above causes, as appropriate.

(i) Severability

Should a court of competent jurisdiction hold that any provision of the Agreement is invalid, illegal, or unenforceable, such provision shall be considered severed from the Agreement and all other provisions of the Agreement, and all rights and obligations therein shall continue to be in force and effect.

(j) No Assignment

Neither Party may assign the Agreement, in whole or in part, without the prior written consent of the other Party.

(k) Communication

(i) The Parties agrees to acknowledge each other's contribution in any public communications related to and/or resulting from work carried out under this Agreement. Neither Party may use any symbol or mark of the other Party without the express written permission of the other Party.

(ii) 'Namgis will provide to DFO a copy of any materials developed by 'Namgis for communication at least one month prior to public disclosure, including materials to be presented at scientific conferences, manuscripts accepted for publication in scientific journals, and direct communications to media.

(iii) 'Namgis agrees that if DFO's involvement in the Project is mentioned in any communication or announcement to the public, the communication or announcement will be made in both official languages.

(l) Official Languages

The Agreement was prepared in English at the request of the Organization / Cette entente fut rédigée en anglais à la demande de l'Organisation.

(m) *Lobbying Act*

'Namgis must ensure that any person lobbying DFO, any other federal department or any federal agency on behalf of the Organization is registered pursuant to and in compliance with the *Lobbying Act*.

(n) Time of Essence

Time is of the essence with respect to all deliverables under the Agreement.

(o) Representation and Warranty

'Namgis represents and warrants that it is not under a disability to contract with Her Majesty as set out in section 750 of the Criminal Code of Canada.

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(p) Order of Precedence

If there is any conflict or ambiguity between these sections of the Agreement and any appendices or schedules thereto, these sections of the Agreement shall prevail.

IN WITNESS WHEREOF this Agreement has been executed by DFO and 'Namgis through their duly authorized representatives.

'Namgis First Nation	**Her Majesty the Queen in Right of Canada, as represented by the Minister of Fisheries and Oceans**
Chief Don Svanvik	
Printed Name and Title of Organization's authorized representative	*Printed Name and Title of DFO's authorized representative*
Date	*Date*

Appendix A: The Project

Description, purpose and expected results

The general description, purpose and expected results of the Project are as set out in section 1 of this Agreement.

Technical Description

The Project aims to compare the profile of infective agents, including the IMIP Pathogens, detected using standard molecular monitoring practices based on destructive samples of fish tissues collected from farms and hatcheries, with results from the same molecular tests performed on nucleic acids extracted from filtered water samples collected in the tanks of the hatcheries and in/around the net pens of the marine sites.

Fish tissue and eDNA samples will undergo molecular screening with the microfluidics Fluidigm BioMark™ platform for 34 agents known to infect salmon on farms to assess presence and load of agents across hatchery/farm populations; 15 of these agents are IMIP Pathogens and will be included in all Farm reports, and the remaining agents are known to infect farmed salmon and are thus important to the eDNA study.

All active Fish Farms that are part of the IMIP will be sampled monthly over a year for both tissue and water sample assessments to gain sufficient sample sizes to statistically assess their correlations. Through industry health records provided by consultation between industry veterinarians and the veterinary pathologist contracted to oversee farm sampling, health data will also be collected to assess whether shifts in agent profiles associated with disease development are detectable from water samples.

Standard collections of fish tissues preserved for molecular and pathological investigation from lice and moribund fish will provide the "baseline" of the current knowledge and proficiency of fish health monitoring standard operating procedures (SOPs), and will be compared to "water-based" environmental approach inside and outside of pens to establish the efficiency and sensitivity of this new method. To assist in the timely implementation of the IMIP, data resulting from this research will be provided to the FN Representative on an ongoing basis as soon as the testing for a given farm or hatchery is completed. This research will continue for one (1) year (12 months of sampling) to ensure the technical and supervisory staff are properly trained on the technical implementation of field sampling and molecular analyses on the Fluidigm platform, and to realize sufficient project results to analyze co-variation between eDNA and farm samples.

Deliverables

1) Matched infective agent monitoring for fish and water samples from 13 farm sites (based on projected stocking, average of 10 farms will be active in a given month; remaining will be fallowed) will be collected monthly and the same fish and water samples will be collected from 5 hatcheries collected 2 times each Calendar year.
    a. Estimated number of fish monitored – 3,600 hatchery and 4,800 farm.
    b. Estimated number of water samples monitored – 180 hatchery and 1,920 farms, 84 fallow and 84 control sites (see detailed budget).
2) Evaluation of farm health records and follow-up histopathology to evaluate disease occurrence.
3) Statistical analysis evaluating the correlation between agent profiles (single and multi-agent) between fish and water samples, and linkages with evidence of disease.

4) Training for two First Nations technical staff and one scientific supervisor on the technology associated with molecular analyses required to perform studies of this type. Training of three additional First Nations technical staff on field sampling.
5) Transfer of technology to the FN Genomics Lab to continue carrying out the IMIP program in the future, including a pipeline for data processing, quality assessment, and data analysis.
6) The Research Findings will be developed into a peer reviewed manuscript. The Research Team will prepare the manuscript and any publication of Research Findings will be subject to Appendix D.

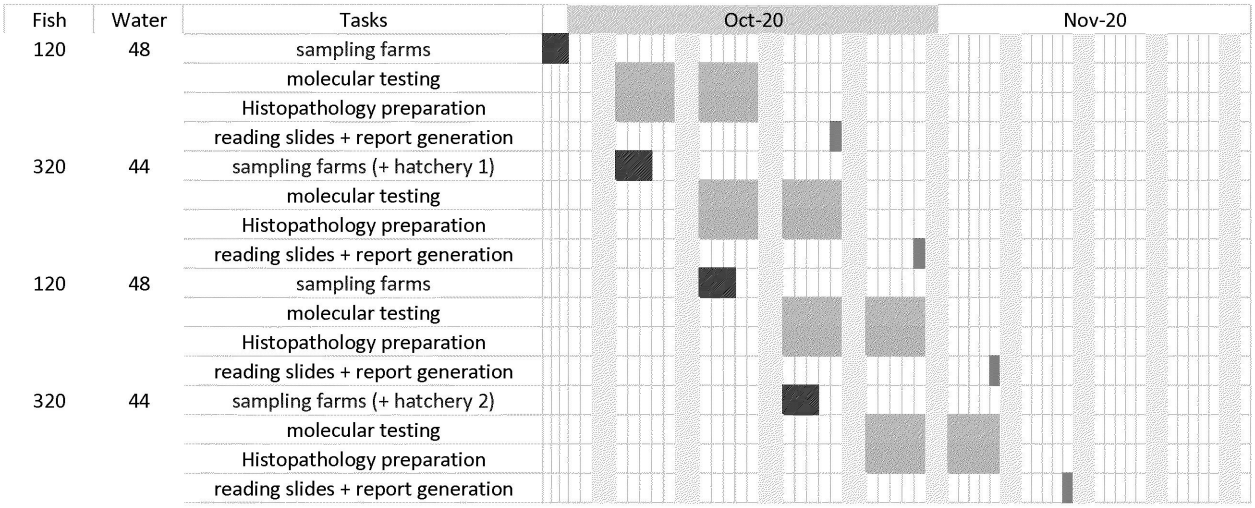
If water-based environmental monitoring is shown to provide sensitive, specific, consistent and comparable infectious profiles with those obtained using standard fish health monitoring procedures, this new technology may be implemented for the IMIP according to the terms of the IMIP Agreements.

Work Plan: Timelines, Milestones and Work Responsibilities

Date/ Period	Milestones	Responsible Party
[04/01/2021]	Project start	N/A
04/01/2021- 03/31/2022	**Farm and hatchery field sampling** to take place on an ongoing basis for a year, including approximately 10 active farms per month (and fallowed control farms). Hatchery sampling will be more sporadic, when fish are to be moved to farms	**'Namgis** (FN Research Lead)
04/01/2021- 03/15/2022	**Training of FN Genomics Laboratory personnel** Training provided on an ongoing basis by DFO staff – for full sample processing and analysis on tissue and eDNA nucleic acid extraction and analysis on the Fluidigm BioMark™ microfluidics platform	**DFO**
04/08/2021- 03/15/2022	**Molecular analysis of eDNA and tissue samples** Samples will be analysed on a continuous basis as they are provided from the field, with an anticipated two week turn-around	**DFO**
04/08/2021- 04/15/2022	**Histopathological analysis of tissues** Samples will be analysed on alternate weeks when [redacted] is not in the field	**'Namgis** (FN Research Lead)
10/01/2021- 09/31/2022	**Data Analysis** The Post Doc will be hired for one year to analyse the data derived from the Project, and interpret the relationships between eDNA profiles and farmed fish profiles.	**DFO**
04/30/2021- 04/30/2022	**Reporting of results** Infectious agent profiles from eDNA and water samples and data pertaining to farm diseases will be reported on each month, with reports provided to both Parties. 'Namgis will share these reports with Industry. Reports will jointly be prepared by the DFO Research Lead and the FN Research Lead.	Joint **DFO/'Namgis**

Date/ Period	Milestones	Responsible Party
12/31/2022	**Final Project Report** The Final Project Report will be written by the Post Doc with supervision by the DFO Research Lead and FN Research Lead, due two month after project completion.	Joint **DFO/'Namgis**

Example of one month schedule of activities -- 2-3 farms are sampled each week (Monday-Wednesday), with reporting (green) occurring Fridays, three weeks post sampling. Histology is limited to up to 20 fish per farm/hatchery sample, with slides cut by an external contract. This schedule may tighten up as 'Namgis trainees become more proficient. On months that include hatchery sampling, numbers of fish increase by 240 and water by 12. This schedule repeats each month for a year. Alternate DFO technical staff will step in during vacations.



Project Evaluation

Evaluation of the Project should be performed by DFO and the First Nations and should address the questions below and any lessons learned (as applicable).

Milestones including training, field sampling, molecular data acquisition, disease data acquisition, and reporting will all be evaluated at Project end, as listed below:

1) Were the milestones achieved?
2) Did the intended activities take place within the scope/budget?
3) Were the deliverables of the Project delivered?
4) Did the collaboration achieve its purpose?
5) Briefly describe any successes of the Project and potential improvements for future projects.

Appendix A – Schedule 1: IMIP Pathogens

Infective Agent	Type of Agent	Disease	Ranking
PMCV	Virus	Cardiomyopathy syndrome	FW-1
PRV	Virus	HSMI-EIBS-Jaundice/anemia	FW-1
ASCV	Virus	unknown	FW-4
CTV	Virus	unknown	FW-4
CoV	Virus	unknown	FW-4
Tenacibaculum maritimum	Bacteria	Marine flexibacteriosis (mouth/fin rot)	FW-2
Listonella anguillarum	Bacteria	Vibriosis	FW-2
Aliivibrio salmonicida	Bacteria	Cold water vibriosis	FW-2
Piscirickettsia salmonis	Bacteria	Piscirickettsiosis (SRS)	FW-2
Piscichlamydia salmonis	Bacteria	Epitheliocystis	FW-3
Gill Chlamydia	Bacteria		FW-3
Flavobacterium psychrophilum	Bacteria	Bacterial cold water disease	FW-3
Renibacterium salmoninarum	Bacteria	Bacterial kidney disease	FW-2
Yersinia ruckeri	Bacteria	Yersiniosis (Enteric red mouth)	FW-2
Aeromonas salmonicida	Bacteria	Furunculosis	FW-2

Appendix A – Schedule 2: Chain of Custody Protocol

(d) All collections of fish tissues and eDNA samples associated with farms will be led and conducted by First Nation contractors, and will remain in First Nation chain of custody during the day of sampling, transferred to DFO chain of custody within two days of sampling for immediate analysis.

(e) Two sets of molecular tissues will be collected for each fish (frozen in RNA later and maintained in a -80 freezer after an initial 24 hours on ice or at 4°C, both of which will be transferred to DFO. One set of histopathology tissues and eDNA samples will be collected. In the field, eDNA filters will be stored in a liquid nitrogen Dewar and histology tissues maintained in cassettes (two per fish) in 10% buffered formalin. These will also be placed in DFO's chain of custody after collection.

(f) DFO will preserve molecular tissue and eDNA samples in a -80 freezer specifically purchased for the 'Namgis project. Two sets of tissue samples will be held, one that will extracted for the Project and remain in the custody of DFO in perpetuity, and the other that will be held until Project end or such time as the First Nations make a written request to relocate it into their chain of custody, or provide it back to Tenure Holders or to other laboratories. These samples may be used by a secondary laboratory to validate detections, or for any other purpose deemed necessary by the First Nations' leadership team. 'Namgis will pay the shipping costs associated with such a transfer.

(g) Only staff of DFO, the FN Research Lead, and the trainees hired under contract by 'Namgis will have access to the freezer holding the samples, which will be locked at all times. DFO biologist, Karia Kaukinen, who will be responsible for molecular training of the First Nations' trainees, the FN Research Lead and the DFO Research Lead will hold the only keys to the freezers. All samples removed from the freezer will be carefully tracked into a sample database throughout each processing step, including notations of all individuals handing such samples, what processes were performed and where samples are stored each step of the way.

Pathogen Testing Performed on Timelines to Meet IMIP Agreements

(a) The DFO Research Lead and the FN Research Lead will work together to ensure all samples are tested using the Fluidigm BioMark™ technology for molecular disease profiling for 34 infective agents, including all the pathogens, diseases, and disease agents listed in Schedule 1 to Appendix A of this Agreement (the **"IMIP Pathogens**"), as well as additional parasites, viruses and bacterial agents observed on farms (SSHI data) that are important for the eDNA water sampling research.

(b) The First Nations have advised DFO that they will rely on the Project's timely testing of tissue samples obtained from fish on the Fish Farms, and the Tenure Holders' freshwater hatcheries, for the IMIP Pathogens (the "**Testing Results**") to implement the IMIP.

(c) The Research Team will prepare a report describing the Testing Results.

(d) DFO will take all reasonable efforts to ensure the timely reporting of the Testing Results to the FN Representative.

(e) DFO further agrees that it will provide the Testing Results to the FN Representative for any samples from a Tenure Holder's freshwater hatchery, within ten (10) days of being provided such samples.

(f) When less than one percent (1%) of a batch of samples from a Tenure Holder's freshwater hatchery tests positive for an IMIP Pathogen ranked as a FW-1 Pathogen in Schedule 1 to Appendix A, DFO agrees that it will immediately re-test those samples that tested positive for the FW-1 Pathogen, including any duplicate samples, and will provide 'Namgis with the results of any re-testing as soon as those results are available.

(g) When DFO must retest samples pursuant, 'Namgis will immediately provide DFO with any necessary duplicate samples it has in its possession following the chain of custody protocol contained in Schedule 2 to Appendix A of this Agreement (the "**Chain of Custody Protocol**").

(h) The Parties acknowledge and agree the re-testing of any FW-1 Pathogens must be completed with urgency and will work co-operatively and without delay to complete the re-testing of any samples or duplicate samples.

(i) The eDNA water sampling research described in this Agreement and undertaken within the MGL will not be included in reports of the Testing Results or used to make any decisions pertaining to farming regulations or practices until such time as the First Nations and the Tenure Holders agree that the information coming from this technical approach provides a reliable, accurate representation of the infection and disease status on the farms.

Communications with the Tenure Holders

(a) DFO agrees that it will not communicate with the Tenure Holders with respect to the Project or any data, software, products and processes arising from the Project whether or not they may be subject to IP rights, other than Testing Results (the "**Research Findings**") until FN Representative has confirmed that the communication is consistent with this Agreement, including Appendix D and the IMIP Agreements.

(b) The First Nations have advised DFO that the First Nations must provide the Tenure Holders with a copy of the Project Description for their review, and that pursuant to the IMIP Agreements, the Tenure Holders will provide their written confirmation of their support for the Project provided the Technical Description is consistent with the IMIP Agreements and the Tenure Holders' regulatory obligations. 'Namgis has further advised DFO that the First Nations have provided the Tenure

Holders with a copy of Appendix A and the Tenure Holders have confirmed their support for the Project.

Publication of Research Findings

(a) In accordance with the Project Description contained in Appendix A, the Research Team will collaboratively develop the Research Findings into a paper (or papers) for publication in a peer reviewed journal. The DFO Research Lead will lead the prepration of the paper(s) and supervise the Post Doc's work preparing the paper(s).

(b) The Research Findings will be developed into a manuscript and prepared for publication by the Research Team.

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Appendix B: Project Expenditures

Budget Summary for Fiscal Year [2021-2022]

Detailed Expenditures Table	Organization			DFO	Total Value
Description	Financial Contribution to DFO	Namgis In-Kind Contribution	Use of Fish	In-Kind Contribution	
Salary – Term employees					0
Salary – Indeterminate employees				75,820	
Overtime					
Benefits (e.g. 27% of Salary)					
Salary – Casual employees					
Salary- Field tech hired by Namgis					
Salary- Trainee hired by Namgis					
Consultant Contract [Analytical Scripts for ONA]					
Postdoc					
Salary (Namgis to PSF)					
Salary (Namgis to PSF for postdoc)					
Contract Histo Slides					
Equipment					
Material					
Supplies					
Travel					

s.19(1)

s.20(1)(b)

Facilities				100,000	100,000
Vessels [specify: CCG, Organization's, or procurement contract]					
Other Expenses [specify]					
Totals				175,820	

Budget Summary for Fiscal Year [2022-2023]

Detailed Expenditures Table	**Organization**			**DFO**	**Total Value**
Description	**Financial Contribution to DFO**	**Namgis In-Kind Contribution**	**Use of Fish**	**In-Kind Contribution**	
Salary – Term employees					0
Salary – Indeterminate employees	0			0	0
Overtime					0
Benefits (e.g. 27% of Salary)	0				0
Salary – Casual employees					0
Salary- Student/tech hired by Namgis		0			0
Salary- Trainee hired by Namgis		0			0
Consultant Contract [specify work]	0				0
Postdoc					
Salary (Namgis to PSF)		0			0
Salary (Namgis to PSF for postdoc)		0			0

s.19(1)

s.20(1)(b)

Contract Histo Slides		0			0
Equipment					0
Material					0
Supplies	0				0
Travel		0			0
Facilities				0	0
Vessels [specify: CCG, Organization's, or procurement contract]					0
Other Expenses [specify]					0
Totals					

Grand Totals of All Contributions Table

Grand Totals of All Contribution Table	**'Namgis**		**DFO**	
Fiscal year	**Financial Contribution to DFO**	**In-Kind Contribution**	**In-Kind Contribution**	**Total Value**
2020-2021			175,820	
2021-2022			0	
Total			**$175,820**	

[The Grand Totals Table, once completed should be copied and inserted in article 4(a) of the Agreement]

s.20(1)(b)

Appendix C: Risk Management

[This table must clearly identify the risks associated with the Project, and corresponding mitigation measures, along with the responsible Party. See 'Collaborative agreement drafting instructions'. Complete a risk analysis table for each activity or deliverable at risk; add tables as required.]

Project Risk Analysis

Activity or Deliverable	Field Sampling and Laboratory Analysis		
Description of risk event and its consequences	Another outbreak of COVID-19 results in DFO laboratory closures and government issuance of Stay at Home provisions, precluding continuance of farm sampling program.		
	Likelihood	Impact	Risk Rating
	4	3	12
Mitigation measures	We have accounted for this by stipulating that the project will run for 12 full sampling months, which if interrupted, will continue being counted from the last month collections were done.		
Responsible Party	[**'Namgis** and **DFO**]		

Activity or Deliverable	Hiring 'Namgis (ONA) personnel for training		
Description of risk event and its consequences	One of the key deliverables is training of FN Genomics Lab staff for both field sampling and for molecular analysis on the Fluidigm. It will take a full year to train on the Fluidigm, hence, if there is a delay in hiring the appropriate trainees, the project should not start until this staff is identified.		
	Likelihood	Impact	Risk Rating
	2	1	3
Mitigation measures	The FN Genomics lab (run by ONA) has already been advertising the molecular positions and two individuals have already been on contract with 'Namgis to fulfill the sampling positions; we will require a third. An existing DFO term staff member is also interested in one of the molecular positions. Project should not start until these positions are in place, so the only risk is really a delay in the start date.		
Responsible Party	[**'Namgis**]		

Activity or Deliverable	Entire project		
Description of risk event and its consequences	COVID-19 closures of laboratory and field sampling involving DFO staff.		
	Likelihood	Impact	Risk Rating
	2	2	4
Mitigation measures	There is a possibility of revolving closures of DFO labs if the COVID-19 pandemic resurges in Canada, in which case the Project, and funding, would have to be delayed during the closure months. It could, however, still be		

	completed provided training staff can be kept on by 'Namgis and 12 months of samples and testing can be conducted.
Responsible Party	[**DFO**]

Activity or Deliverable	Field sampling		
Description of risk event and its consequences	Access to boats for farm visits and field eDNA samples are essential for Project success. 'Namgis is responsible for making arrangements with farms or using their own boats to transport personnel to access farms. Sampling cannot proceed without this boat access. Weather may also affect some sampling dates.		
	Likelihood	Impact	Risk Rating
	1	2	3
Mitigation measures	Lack of boat availability would delay some of the sampling dates, but as we are sampling 2-3 farms per week, sampling dates can be shifted around if need be. It is important, however, that each farm is sampled once per month.		
Responsible Party	['**Namgis**]		

Activity or Deliverable	Molecular analysis		
Description of risk event and its consequences	If very junior trainee staff are hired with little if any molecular experience, this could impede the rate of uptake of the technology they are being trained on. We asked that they have an advanced degree that includes at least some molecular biology coursework. If these trainee staff are not retained for the full Project, this could also impede the training objective.		
	Likelihood	Impact	Risk Rating
	2	2	4
Mitigation measures	We will have a DFO biologist and technician training the 'Namgis personnel on this Project full time, both of whom have considerable experience training undergraduate students. Samples will continue to be run by DFO staff until such time that 'Namgis (ONA) staff are proficient. We would have to revisit the training level of the two by Project end to determine if they are sufficiently proficient to carry out the analysis independent of DFO by end of Project. We will also provide some training to [redacted] Hence it will ultimately be his responsibility to provide additional training if staff are not completely competent at end of Project.		
Responsible Party	[**DFO**]		

s.19(1)

Table to determine Risk Rating

Impact						
	5. Extreme					
	4. Very High				**High**	
	3. Medium			**Medium**		
	2. Low	**Low**				
	1. Negligible					
		1. Rare	2. Unlikely	3. Low	4. Likely	5. Almost Certain
		Likelihood				

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Appendix D: Background Information, Results and Intellectual Property Rights

1. **Backround Information**[1]

1.1. **Confidential information.** The following is a non-exhaustive description of confidential information (the "**Confidential Information**"): all information obtained, collected, generated or produced through the work conducted under this Agreement, including without limitation, information the First Nations obtained from the Tenure Holders and provided to DFO, including any information marked as "Competitive Information" as that term is defined in the IMIP Agreements ("**Competitive Information**").

1.2. **Non-Confidential Information.** This Agreement does not restrict disclosure or use of information that:

(a) is, at the time of disclosure, already in a Party's possession without an obligation of confidentiality, and the prior possession of that information can be proven by written records of the Party;

(b) is developed independently without any breach of this Agreement or the IMIP Agreements, and does not use any Confidential Information, and the Party is able to prove independent development of that information by written records of that Party;

(c) is, or becomes, known publicly or is, or becomes, otherwise in the public domain without any breach of this Agreement;

(d) is received from a third party who, to the knowledge of the receiving Party, is not bound by an obligation of confidentiality to the other Party or to one of the Tenure Holders; or

(e) is disclosed by a Party to a third party without breach of the IMIP Agreements or any obligation of confidentiality binding on that third party (collectively, "**Non-Confidential Information**").

1.3. **Obligations of Confidentiality.** Each Party agrees it will:

(a) use the Confidential Information solely for the purposes of this Agreement;

(b) use reasonable care and prudent precautions, but in no event and without limiting the level of care required, no less than the same degree of care that it uses to protect its own confidential and proprietary information of similar importance, to prevent the unauthorized use, disclosure, publication or dissemination of Confidential Information;

(c) not disclose any Confidential Information, except as expressly permitted under this Agreement; and

(d) not disclose Competitive Information to any third party, including not disclosing Competitive Information received by one Tenure Holder to the other Tenure Holder.

1.4. **Disclosures Required by Law.** Other than disclosures of Confidential Information permitted

pursuant to this Appendix D, DFO may disclose Confidential Information only if required by any judicial or governmental request, requirement or order and then only after DFO has, in a timely manner, provided the First Nations with immediate notice of the request, requirement or order and the First Nations have confirmed in writing that their obligations under the IMIP Agreements are not applicable, or if the First Nations' obligations under the IMIP Agreements are applicable, then DFO and the First Nations have worked together to ensure that:

(a) the First Nations have notified the affected Tenure Holder(s);

(b) the First Nations have consulted with the Tenure Holder on taking legally available steps to resist or narrow the request or lawfully avoid the requirement;

(c) where the Tenure Holder is not able to seek a protective order or other appropriate remedy on its own without involving any of the First Nations or DFO, and if requested by the Tenure Holder, then DFO, working with the First Nations, will take all reasonable steps and cooperate with the Tenure Holder, to seek a protective order or other appropriate remedy; or

(d) if a protective order or other remedy is not available, or if the Tenure Holder waives the First Nations' compliance with the applicable obligations under the IMIP Agreements, then:

(1) the FN Representative will inform DFO that it may disclose to the person requiring disclosure only that portion of the Confidential Information that is legally required to be disclosed as advised by the DFO's legal counsel;

(2) the DFO, working with the First Nations, will exercise reasonable efforts to obtain assurance that confidential treatment will be accorded to such portion; and

(3) the DFO will not be liable for such disclosure unless the disclosure was caused by or resulted from a previous disclosure by DFO in breach of this Agreement.

1.5. **Confidentiality of officers employees, contractors or agents.** For purposes of the Agreement, DFO may share certain Confidential Information with some of its officers employees, contractors or agents. Before sharing such information with any officers, employees, contractors or agents, DFO will enter into a confidentiality agreement with those officers, employees, contractors or agents containing terms and conditions substantially similar to those contained in this Appendix D.

1.6. **Liability for Representatives.** DFO is responsible and will be liable to the First Nations for all breaches of this Appendix D by any one or more of its officers, employees, contractors, or agents.

1.7. **Competitive Information Failure.** Any failure of an officer, employee, contractor, or agent to adhere to the terms of this Appendix D in respect of Competitive Information will result in the officer, employee, contractor, or agent being prohibited from receiving any further Competitive Information, and all Competitive Information in their possession being returned to the First Nations or the Tenure Holder, or confirmed destroyed.

1.8. **Disclosure List.** DFO will maintain a list of persons to whom any Competitive Information is disclosed (the "**Disclosure List**"). At the request of the FN Representative, from time to time, DFO will provide the FN Representative with an up-to-date Disclosure List. The Disclosure List may include a general statement that all Competitive Information is disclosed to the named person without listing the specifics of those disclosures.

1.9. Breach. A breach of this Appendix D includes:

(a) use of Confidential Information for any purpose other than this Agreement; and

(b) sharing of Confidential Information with third parties in a way that is prohibited by this Agreement.

1.10. **Indemnity.** A Party receiving Confidential Information, subject to the provisions of this Agreement, will be responsible for and indemnify the other Party for any damages arising from any breach of this Appendix D, including any breach by that Party's officers, employees, contractors, or agents.

1.11. **Specific Performance and Injunctive Relief.** A Party receiving Confidential Information pursuant to this Agreement agrees and acknowledges that money damages would not be a sufficient remedy for any breach of this Appendix D, and that the disclosing Party will be entitled to specific performance and injunctive relief as remedies for any such breach. Such remedies shall not be deemed to be the exclusive remedies for a breach of this Appendix D by the disclosing Party but shall be in addition to all other remedies available at law or in equity.

1.12. **Destruction & Return**. Competitive Information shared under the Agreement may only be retained by DFO for as long as reasonably necessary for purposes of the Agreement, and in any event, will not be retained for a period exceeding 60 days following the expiry of the provincial licence of occupation for the Fish Farm to which the information relates, after which date, that Competitive Information will be destroyed or returned, at the discretion of the Tenure Holder. At the commencement of that 60 day period, the Tenure Holder will provide the First Nations with a list of the Competitive Information to be returned or destroyed and if applicable the FN Representative will inform DFO of any Competitive Information that DFO must destroy or return to the First Nations.

1.13. **Competitive Information Failure.** Without restricting the generality of the Appendix D, any failure of a Party receiving Confidential Information to adhere to the terms of this Confidentiality Agreement specifically as it relates to Competitive Information will result in that Party being prohibited from receiving any further Competitive Information, and all Competitive Information in that Party's possession being immediately returned to the disclosing Party or the Tenure Holder, or confirmed destroyed.

1.14. **Inside Information.** DFO acknowledges that:

(a) one Tenure Holder is a subsidiary of Mitsubishi Corporation, a company listed on the Toyko and Nagoya exchanges and the other Tenure Holder is a subsidiary of Mowi ASA, a company listed on the Oslo exchange;

(b) the Competitive Information provided or made available by the Tenure Holder to the First Nations may be considered "inside information" that is not generally available to the public or to the markets in which the shares of the Tenure Holder's publicly listed parent corporation are traded; and

(c) the DFO, its officers, employees, contractors and agents will be prohibited under applicable securities laws and stock exchange rules from using that information (and from communicating that information to another person for the purpose of using that

information) to trade in the securities of a Tenure Holder's publicly traded parent corporation.

2. Reporting of Testing Results and the Publication of Research Findings

2.1. Each Party will promptly inform the other of any Testing Results or Research Findings. Each Party ("**Disclosing Party**") shall promptly disclose to the other ("**Receiving Party**") any background information in its possession that is required by the Receiving Party to perform any Project activities for which the Receiving Party is responsible, excluding background information subject to third-party intellectual property rights (the "**Background Information**"). The Disclosing Party retains its rights in any Background Information disclosed to the Recipient Party.

2.2. Background Information disclosed by either Party shall be deemed confidential; however, the confidentiality of Background Information disclosed orally shall expire unless transferred in tangible form to the Receiving Party within two (2) weeks following disclosure. A Receiving Party may not disclose to third parties in any way whatsoever confidential Background Information of the Disclosing Party without the prior written authorization of the Disclosing Party.

2.3. The confidentiality obligations in article 1.2 above shall not apply to Background Information that is or falls lawfully in the public domain, that was lawfully in the possession of a Receiving Party prior to receiving it from a Disclosing Party, or that is received by a Receiving Party from a third party not bound by any confidentiality obligations, subject to evidence.

2.4. Any confidentiality obligation with respect to Background Information shall remain in effect until such time as the information becomes public.

3. Research Findings

3.1. The Parties understand and agree that any Research Findings arising under this Agreement should be managed in the best interest of the Parties.

3.2. Each Party shall promptly inform the other of any Research Findings it generates and provide to the other Party all technical information that may be necessary to enable that Party to use those Testing Results or Research Findings.

3.3. DFO agrees that 'Namgis will be responsible for communicating Testing Results to the Tenure Holders and it will not disclose any Testing Results unless:

(a) 'Namgis has provided DFO instructions in writing to disclose those Testing Results; or

(b) 'Namgis has confirmed that the First Nations have already provided those Testing Results to the appropriate Tenure Holder and communicated those Testing Results to their communities.

3.4. The First Nations have advised DFO that the First Nations must provide the Tenure Holders with timely prior notice before the publication of Research Findings or Testing Results flowing from the Project and the Parties agree that neither Party will publish any Research Findings until such time that 'Namgis confirms in writing that the First Nations have provided the Tenure Holders with timely prior notice of that publication.

3.5. Either Party is free to publish any Research Findings in accordance with sub-article (a) provided it ensures that data integrity is preserved in the publication, and that the publication does not jeopardize the authorship interest of the other Party's employees or the IP rights of the other Party.

3.6. If a Party wishes to publish any Research Findings ("**Publishing Party**"), it will submit those Research Findings to the other Party for review. The other Party may, within thirty (30) days, request the Publishing Party, by written notice, to withhold publication of the Research Findings or any portions thereof, for a reasonable time, not longer than two months, for the purpose of securing its employees' authorship interest and protecting IP rights.

3.7. Each Party is free to publish any Research Findings in accordance with this Appendix D provided it ensures that data integrity is preserved in the publication, and that the publication does not jeopardize the authorship interest of the other Party's officers, employees, trainees, agents and contractors or the IP rights of the other Party.

3.8. For greater certainty, the Parties agree that once any Testing Results have been communicated to the Tenure Holders and the First Nations' communities pursuant to section 2.2(b) those Testing Results may be published as part of Research Findings pursuant to this Appendix D.

4. Reportable Pathogens

4.1. 'Namgis acknowledges that DFO is required by law to report detections of specific pathogens, diseases, disease agents (the "**Reportable Pathogens**") to the Canadian Food Inspection Agency ("**CFIA**").

4.2. DFO acknowledges and agrees that when reporting the detection of any Reportable Pathogen to the CFIA, it will copy the FN Representative and the appropriate Tenure Holder on any such correspondence.

4.3. 'Namgis acknowledges and agrees that reporting detections of Reportable Pathogens to the CFIA consistent with Article 3 of this Appendix does not constitute a breach of this Articles 2 or 3 of this Appendix D.

5. Intellectual Property ("IP") Rights[2]

5.1. Ownership of IP rights in Research Findings

(a) DFO owns the IP rights in Research Findings generated solely by its officers, employees, trainees, agents and contractors. This includes the IP for which DFO is training First Nations' personnel within DFO laboratories.

(b) 'Namgis owns the IP rights in Research Findings generated solely by its officers, employees, trainees, agents and contractors and will otherwise be free to determine ownership of such IP rights.

(c) The IP rights in Research Findings generated jointly by officers, employees, trainees, agents and contractors of both Parties will be jointly owned by the Parties (referred to as "**Joint IP**" for the purposes of this Appendix), and will be managed according to section 4.

(d) Notwithstanding any conflict with any other provision in this Agreement, any student of 'Namgis who may be involved in the Project retains the copyright in any research report, Masters or PhD thesis subject only to the confidentiality provisions herein.

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[2] "**Intellectual Property" or "IP"** is defined in section 2 of this Agreement.

5.2. Licensing of IP rights in Research Findings

(a) Any Party that owns IP rights in Research Findings hereby grants to the other a non-exclusive, non-transferable, royalty-free and paid-up licence in respect of such IP rights and for the duration of the IP rights, allowing the other Party to use, reproduce, modify and translate the IP and any parts thereof for non-commercial research purposes only.

(b) 'Namgis may request from DFO, a licence to use, reproduce, modify and translate DFO-owned IP rights for commercial purposes. The request will be in writing and will be delivered to DFO no later than three (3) months following the end of the Agreement. The Parties will negotiate the terms and conditions of such a licence in good faith; however, if they cannot agree within three (3) months following the beginning of licence negotiations, or at such later time as they may agree, DFO will no longer be obligated to continue licence negotiation with 'Namgis.

5.3. Patenting of inventions derived from Research Findings

(a) The Parties will fully cooperate with each other and assist each other free of charge in the preparation and filing of patent applications related to inventions associated with any Research Findings however neither Party may file patent applications incorporating Research Findings of the other Party without the prior written permission of that Party.

(b) For greater certainty, neither Party may patent IP that the other Party has transfered directly to it.

(c) Each Party will promptly provide to the other a copy of every patent application that it files in relation to any such inventions.

(d) Each Party will execute such conveyances or other documents as reasonably required for the filing, prosecution and maintenance of any patent applications and for defending any issued patents related to such inventions; however, neither Party will be obligated to incur any costs in relation to any such patent applications or any such patents.

6. Management of Joint IP

6.1. The Parties agree that Joint IP will be managed by the Party that has contributed the most to such Joint IP (referred to as the "**IP Manager**" for the purpose of this Appendix). DFO will be considered the IP holder for all IP generated in their labs. The IP Manager, acting consistent with this agreement, will determine any disclosure, protection, reproduction and commercialization of the Joint IP taking into consideration the other Party's interests and internal policies, except if the Joint IP consists of an invention or software in which case section 4.3 will also apply.

6.2. It is agreed that the IP Manager may assign management of a Joint IP to the other Party who upon accepting the assignment becomes the IP Manager of such Joint IP.

6.3. With respect to Joint IP consisting of an invention or software that has a significant commercial potential, the Parties agree to co-operate in good faith to develop a detailed management plan relating to the protection and commercialization of the Joint IP, while ensuring that the Parties' mutual interests in the Joint IP are protected.

7. Term of Application

7.1. The obligations of the Parties in this Appendix shall survive the expiration or termination of the Agreement.

Appendix E: Provisions related to Biological Materials

1) Biological Material produced from Project-related activities performed by either Party will belong to that Party.

2) Ownership of Intellectual Property related to Biological Material produced from the Project will be determined in accordance with the provisions of Appendix D.

3) If DFO receives any Biological Material from 'Namgis, DFO will not return the Biological Material to 'Namgis unless requested, in writing, any time while the Agreement is in effect, in which case DFO will return to 'Namgis any such Biological Material that is no longer needed for the Project and remaining in its possession, subject to the following provisions:

4) The First Nations and the FN Research Lead will work with the Tenure Holders to obtain Biological Samples of fish and filtered water and will provide the samples to MGL);

(a) duplicate samples of the fish tissues will be collected, with one set used in the molecular analysis performed within the MGL, and thereafter the property of the Crown, and the second set held in a -80 freezer in the office/lab of the FN Expert;

(b) the original set of samples analyzed in the DFO laboratory, and property of the Crown, may be made available for research follow-up, with no restrictions, at the discretion of DFO;

i. any follow-up research objectives and methods would be shared with 'Namgis to assess the utility of the information to support their interests;
ii. it is anticipated that this research follow-up could include, but is not limited to:

(1) high throughput sequencing to support phylogenetic research and assessments of transmission dynamics;

(2) research associated with newly discovered viruses in farmed salmon;

(3) research to identify associations between agents, disease states, and host transcriptome responses;

(4) research into eDNA dispersion in coastal marine environments, and farm-to-farm connectivity; and

(5) research pertaining to host response to harmful algal bloom events.

5) Biological samples pertaining to eDNA collections shall be the property of the Crown and remain in DFO archives for possible follow-up research post project completion.

6) Ownership of Intellectual Property related to Biological Material produced from the Project shall be determined in accordance with the provisions of Appendix D.

From: Lowe, Carmel
Sent: Monday, December 14, 2020 2:50 PM
To: Marquis, Paul (DOJ)
Cc: MacDougall, Lesley; Moore, Wayne
Subject: [redacted]
Attachments:

Hi Paul,

[redacted]

Regards
Carmel
Carmel Lowe, Ph.D.
Regional Director Science | Directrice régionale des sciences
Fisheries and Oceans Canada | Pêches et Océans Canada
Pacific Biological Station | Station biologique du Pacifique
3190 Hammond Bay Rd, Nanaimo, BC, Canada V9T 6N7
Carmel.Lowe@dfo-mpo.gc.ca
Telephone | Téléphone 250-756-7177
Facsimile | Télécopieur 250-729-8360
Government of Canada | Gouvernement du Canada

s.21(1)(a)
s.21(1)(b)
s.23

From: MacDougall, Lesley
Sent: Friday, December 11, 2020 12:12 PM
To: Lowe, Carmel
Subject: [redacted]

Hi Carmel – [redacted]

[redacted]

Lesley MacDougall
Division Manager, Aquatic Diagnostics, Genomics & Technology / Division des diagnostics, la génomique, de la technologie aquatique
Fisheries and Oceans Canada / Péches et Océans Canada
Pacific Biological Station / Station Biologique du Pacifique
Nanaimo, B.C. V9T 6N7
Contact via Teams or (250) 668-5849
Lesley.MacDougall@dfo-mpo.gc.ca

s.21(1)(a)
s.21(1)(b)
s.23

Pages 131 to / à 165
are withheld pursuant to section
sont retenues en vertu de l'article

23

of the Access to Information Act
de la Loi sur l'accès à l'information

Lawrie, Kirsten

From: Reid, Rebecca
Sent: Wednesday, December 16, 2020 3:10 PM
To: McPherson, Arran; Dostal, Alexandra
Cc: Girouard, Louise
Subject: RE: Tenacibaculum findings from the SSHI
Attachments: FW: Tenacibaculum findings from the SSHI.msg

Hi Arran – here is the info we have. We will prepare a paragraph on it, for our weekly report. I am not sure if the DM wants more information at this point but nobody like surprises. It may be something the media picks up?

RR

****

Rebecca Reid
Regional Director General/ Directrice générale régionale
Fisheries and Oceans Canada - Pacific Region/ Pêches et Océans Canada Région du Pacifique
200-401 Burrard Street / 401, rue Burrard, bureau 200
Vancouver, BC/CB V6C 3S4
Office / Téléphone: 604-666-6098
Cell / Cellulaire: 604 323 6422 E-mail/ Courriel: rebecca.reid@dfo-mpo.gc.ca

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From: McPherson, Arran <Arran.McPherson@dfo-mpo.gc.ca>
Sent: December 16, 2020 11:07 AM
To: Dostal, Alexandra <Alexandra.Dostal@dfo-mpo.gc.ca>
Cc: Reid, Rebecca <Rebecca.Reid@dfo-mpo.gc.ca>
Subject: Re: Tenacibaculum findings from the SSHI

Hi both, report isn't enclosed so don't have the full details but am happy to help in any way. In terms of process, I have been sending key updates on papers and findings once available. In this case, there doesn't appear to be a publication - and the information is coming forward to inform a discussion with management. However, agree a head's up would be useful. Would you like me to gather the full details and provide or alternatively, happy if you do. Just let me know. Arran

Arran McPherson
Science DFO | MPO
613 222 4052

> On Dec 16, 2020, at 1:56 PM, Dostal, Alexandra <Alexandra.Dostal@dfo-mpo.gc.ca> wrote:
>
> The DM may wish to know when this research will be in the public domain as well. I assume this will come after the peer review component?
>
> A.

Alix Dostal
343-550-0501

From: Reid, Rebecca <Rebecca.Reid@dfo-mpo.gc.ca>
Sent: Wednesday, December 16, 2020 1:50 PM
To: McPherson, Arran <Arran.McPherson@dfo-mpo.gc.ca>
Cc: Dostal, Alexandra <Alexandra.Dostal@dfo-mpo.gc.ca>
Subject: FW: Tenacibaculum findings from the SSHI

Hi Arran – I feel like this issue should be raised to the DM asap, given the current context. How would you suggest be brief on this? I can send the DM a heads up? But I am not sure what process you usually follow.

Thanks.

RR

****

Rebecca Reid
Regional Director General/ Directrice générale régionale
Fisheries and Oceans Canada - Pacific Region/ Pêches et Océans Canada Région du Pacifique
200-401 Burrard Street / 401, rue Burrard, bureau 200
Vancouver, BC/CB V6C 3S4
Office / Téléphone: 604-666-6098
Cell / Cellulaire: 604 323 6422 E-mail/ Courriel: rebecca.reid@dfo-mpo.gc.ca

From: Webb, Allison <Allison.Webb@dfo-mpo.gc.ca>
Sent: December 16, 2020 10:47 AM
To: Reid, Rebecca <Rebecca.Reid@dfo-mpo.gc.ca>; Thomson, Andrew <Andrew.Thomson@dfo-mpo.gc.ca>; Dostal, Alexandra <Alexandra.Dostal@dfo-mpo.gc.ca>; Campbell, John P. <John.Campbell@dfo-mpo.gc.ca>
Cc: Struthers, Alistair <Alistair.Struthers@dfo-mpo.gc.ca>; Lawrie, Kirsten <Kirsten.Lawrie@dfo-mpo.gc.ca>
Subject: RE: Tenacibaculum findings from the SSHI

Will do and coordinate with Carmel on this. The summary is below (just had a chance to skim it now) and will elicit interest:

Our models raise realistic and serious concerns about farm-origin transmission of *T. maritimum* to Fraser
River sockeye salmon and population-level impacts to Chinook, coho, and sockeye. As with any statistical
findings, there remains uncertainty in our model results, but it is the bulk of evidence, rather than any one
particular model, that should give pause. Taken together, results from wild-salmon screening within the
SSHI highlight *T. maritimum* as one of the most likely candidates for population-level impacts on wild

populations, and present evidence that infections in Fraser River sockeye may originate from salmon-farm
sources, especially in the Discovery Islands region. Given knowledge about the depressed state of Fraser-
River sockeye stocks, the evidence we have presented suggests extreme caution and further research are
required.

Allison Webb, Directrice, Gestion de l'aquaculture/Director, Aquaculture Management
Direction de la gestion des peches/Fisheries Management Branch
Fisheries and Oceans Canada / Pêches et Océans Canada
Cel +1 604 754-3325
Allison.webb@dfo-mpo.gc.ca

On the traditional territories of the xʷməθkʷəy̓əm (Musqueam), Sḵwx̱wú7mesh (Squamish) and Tsleil-Waututh First Nations

---

From: Reid, Rebecca <Rebecca.Reid@dfo-mpo.gc.ca>
Sent: Wednesday, December 16, 2020 10:41 AM
To: Webb, Allison <Allison.Webb@dfo-mpo.gc.ca>; Thomson, Andrew <Andrew.Thomson@dfo-mpo.gc.ca>; Dostal, Alexandra <Alexandra.Dostal@dfo-mpo.gc.ca>; Campbell, John P. <John.Campbell@dfo-mpo.gc.ca>
Cc: Struthers, Alistair <Alistair.Struthers@dfo-mpo.gc.ca>; Lawrie, Kirsten <Kirsten.Lawrie@dfo-mpo.gc.ca>
Subject: RE: Tenacibaculum findings from the SSHI

Thanks Allison. Suggest we include a paragraph on this in our weekly ROCS.

RR

****

Rebecca Reid
Regional Director General/ Directrice générale régionale
Fisheries and Oceans Canada - Pacific Region/ Pêches et Océans Canada Région du Pacifique
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Vancouver, BC/CB V6C 3S4
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From: Webb, Allison <Allison.Webb@dfo-mpo.gc.ca>
Sent: December 16, 2020 8:55 AM
To: Thomson, Andrew <Andrew.Thomson@dfo-mpo.gc.ca>; Reid, Rebecca <Rebecca.Reid@dfo-mpo.gc.ca>; Dostal, Alexandra <Alexandra.Dostal@dfo-mpo.gc.ca>; Campbell, John P. <John.Campbell@dfo-mpo.gc.ca>
Cc: Struthers, Alistair <Alistair.Struthers@dfo-mpo.gc.ca>
Subject: FW: Tenacibaculum findings from the SSHI

Please be aware of this. Just received yesterday. Assuming that this could begin to be in the public environment sooner rather than later.

Allison Webb, Directrice, Gestion de l'aquaculture/Director, Aquaculture Management
Direction de la gestion des peches/Fisheries Management Branch
Fisheries and Oceans Canada / Pêches et Océans Canada
Cel +1 604 754-3325
Allison.webb@dfo-mpo.gc.ca

On the traditional territories of the xʷməθkʷəy̓əm (Musqueam), Sḵwx̱wú7mesh (Squamish) and Tsleil-Waututh First Nations

From: Miller-Saunders, Kristi <Kristi.Saunders@dfo-mpo.gc.ca>
Sent: Tuesday, December 15, 2020 1:54 PM
To: MacDougall, Lesley <Lesley.MacDougall@dfo-mpo.gc.ca>; Candy, John <John.Candy@dfo-mpo.gc.ca>
Cc: Lowe, Carmel <Carmel.Lowe@dfo-mpo.gc.ca>; Paylor, Adrienne <Adrienne.Paylor@dfo-mpo.gc.ca>; Webb, Allison <Allison.Webb@dfo-mpo.gc.ca>
Subject: FW: Tenacibaculum findings from the SSHI

FYI these documents represent the results from our Tenacibaculum research that that [redacted] and I have been discussing with Zac and Derek since last September. They are relevant to our risk framework pertaining to farms in the Discovery Islands and sockeye salmon, but note that our models have revealed population-level associations with survival and condition with this agent more broadly for Chinook, coho and sockeye salmon. The briefing note document provides a lay description of our findings, while the technical summary provides a detailed description of the models and results. We will be turning this around into a peer reviewed manuscript in the new year, but wanted you to be aware of the findings well in advance.

Happy to discuss further.
Thanks,

Kristi

Kristi Miller-Saunders, PhD
Head, Molecular Genetics
Pacific Biological Station
3190 Hammond Bay Rd
Nanaimo BC V9T 6N7
250-756-7155
Kristi.Saunders@dfo-mpo.gc.ca

From: [redacted]>
Sent: Tuesday, December 15, 2020 1:38 PM
To: Waddington, Zac <Zac.Waddington@dfo-mpo.gc.ca>; Price, Derek <Derek.Price@dfo-mpo.gc.ca>
Cc: Miller-Saunders, Kristi <Kristi.Saunders@dfo-mpo.gc.ca>
Subject: Tenacibaculum findings from the SSHI

Hi Zac and Derek (Kristi cc'd), **s.19(1)**

Further to our ongoing conversations about *Tenacibaculum maritimum* on salmon farms and its potential transfer to and impacts on wild salmon, I've prepared the attached briefing note and technical summary, based on relevant findings from the SSHI.

Hopefully these clarify a few more details. The technical document also contains a summary of the population-level associations I mentioned in a past email, between T. maritimum infection and reduced survival or body condition in Chinook, coho, and sockeye. (Please note: the information in this document corrects a number of minor errors in the summary email I sent a few days ago.)

As always, I'm happy to discuss further once you've had a chance to read these.

Best regards,

[redacted]

s.19(1)

Tenacibaculum maritimum from BC salmon farms: Production & spread, likely infection of Fraser-River sockeye, and signs of population-level impacts in Chinook, coho, and sockeye

- *Tenacibaculum maritimum* is a cosmopolitan marine bacterium that is widespread on BC salmon farms and can quickly (days after ocean entry) cause acute "mouthrot" disease and associated mortality in farmed Atlantic salmon [1,2].

- Mouthrot is treatable with antibiotics, but treatment can persist for several months on an individual farm [1,2]

- *T. maritimum* is detectable via genetic screening in farmed fish throughout their production cycles, displaying elevated levels in dead and dying fish through much of that time [3].

- In environmental-DNA samples collected near active and inactive salmon farms, *T. maritimum* was almost exclusively detected near active sites, and showed one of the strongest associations with active salmon farms of 39 salmon pathogens screened [4].

- Based on population-level sampling of 2463 Chinook, 916 coho, and 2059 sockeye salmon in their first year of marine residence, *T. maritimum* infection is associated with depressed marine survival for Chinook and sockeye and with reduced body condition (often linked to fitness) in Chinook and coho; this is one of the most consistent patterns across infective agents (Bass, [redacted] et al., in preparation; technical results summary attached).

- Recent spatial/epidemiological models, fit to data from migrating Fraser River sockeye, identify salmon farms in the Discovery Islands as the likely dominant source of *T. maritimum* infection along the Fraser River sockeye migration route (Bateman et al., in preparation; technical methods & results summary attached)

- Taken together, this recent and new evidence raises substantial concern by suggesting that:
    1. salmon farms consistently elevate levels of *T. maritimum* in the marine environment,
    2. Fraser River sockeye become infected with *T. maritimum* as they pass salmon farms (especially those in the Discovery Islands), and
    3. Chinook, coho, and sockeye may all suffer population-level impacts due to *T. maritimum* infection.

Unpublished findings come from the Strategic Salmon Health Initiative.

prepared by: [redacted] & Kristi Miller-Saunders

References

1. Frisch, K. *et al.* Experimental induction of mouthrot in Atlantic salmon smolts using *Tenacibaculum maritimum* from Western Canada. *Journal of Fish Diseases* **41**, 1247–1258 (2018).
2. Mimeault, C. *et al. Assessment of the risk to Fraser River Sockeye Salmon due to Tenacibaculum maritimum transfer from Atlantic Salmon farms in the Discovery Islands area, British Columbia*. 57 (2020).
3. Bateman, A. W. *et al.* Descriptive multi-agent epidemiology via molecular screening on Atlantic salmon farms in the northeast Pacific Ocean. *Scientific Reports* (in press).
4. Shea, D. *et al.* Environmental DNA from multiple pathogens is elevated near active Atlantic salmon farms. *Proc. R. Soc. B.* **287**, 20202010 (2020).

Evidence for farm-origin infection and population-level impacts of *Tenacibaculum maritimum* in Fraser River sockeye salmon

[redacted] Arthur Bass, and Kristi Miller-Saunders

Summary

Tenacibaculum maritimum is a cosmopolitan marine bacterium that infects fish. While infection does not invariably cause disease, *T. maritimum* is responsible for tenacibaculosis globally, and causes "mouth rot" in Atlantic salmon (S*almo salar*) on farms in BC (Frisch et al. 2018).

The risk posed by Atlantic salmon farms was a major focus of the Cohen Commission of Inquiry into the decline of Fraser River sockeye (Cohen 2012), which led to particular scrutiny on the potential for disease transfer from salmon farms in the Discovery Islands region, near Campbell River, BC. This resulted in several risk-assessment reports produced by the Canadian Science Advisory Secretariat (CSAS), with one focusing specifically on *T. maritimum* (DFO 2020). That CSAS report concluded that *T. maritimum* from Discovery-Islands farms presented a minimal risk to Fraser River sockeye salmon; however, only preliminary data from the Strategic Salmon Health Initiative (SSHI) were available at the time.

Using the most up-to-date data pertaining to *T. maritimum* in juvenile Fraser River sockeye, we developed a set of empirical spatio-epidemiological models to evaluate support for different transmission-dynamic scenarios during early marine residence, from approximately April through August. During this period, Fraser River sockeye enter the marine environment south of Vancouver, BC, and then overwhelmingly migrate northwest between Vancouver Island and mainland BC, as they move to feeding grounds in the open Pacific Ocean. During this migration, sockeye interact with many other populations of fish, including substantial populations of farmed Atlantic salmon. In a recent environmental-DNA study, out of 39 salmon pathogens screened, *T. maritimum* was one of the most strongly associated with active salmon farms (Shea et al. 2020).

The models and data we present are consistent with farm-source *T. maritimum* infection and associated mortality in Fraser River sockeye. In conjunction with population-level evidence of associations between *T. maritimum* infections and reduced marine survival or body condition in sockeye, coho (*O. kisutch*), and Chinook (*O. tshawytscha*) salmon, our results provide cause for concern.

Methods and Results in brief

As part of the SSHI, a joint project of DFO and the Pacific Salmon Foundation, juvenile Fraser River sockeye salmon (*Oncorhynchus nerka*) caught during the course of existing marine sampling programs were sub-sampled for pathogen and molecular analysis. Specifically, sockeye came primarily either from DFO's High Seas or Straight of Georgia trawl programs, or from the Hakai Institute's purse-seine sampling program, and were identified as Fraser River fish via genetic stock identification. The sockeye were screened for the presence of *T. maritimum* (among other agents) using molecular techniques described in detail elsewhere (Miller et al. 2016). Briefly, the methods involve nucleic acid extraction followed by quantitative polymerase chain reaction (qPCR) infectious-agent screening on the Fluidigm BioMark™ nanofluidics platform to detect and estimate the number of copies of agent DNA within a standardised sample.

Molecular *T. maritimum* detection data were available for 2,270 north-westward-migrating Fraser River sockeye salmon in their first year of marine residence (Figure 1). These data came from spring and summer collections from 2008 through 2018.

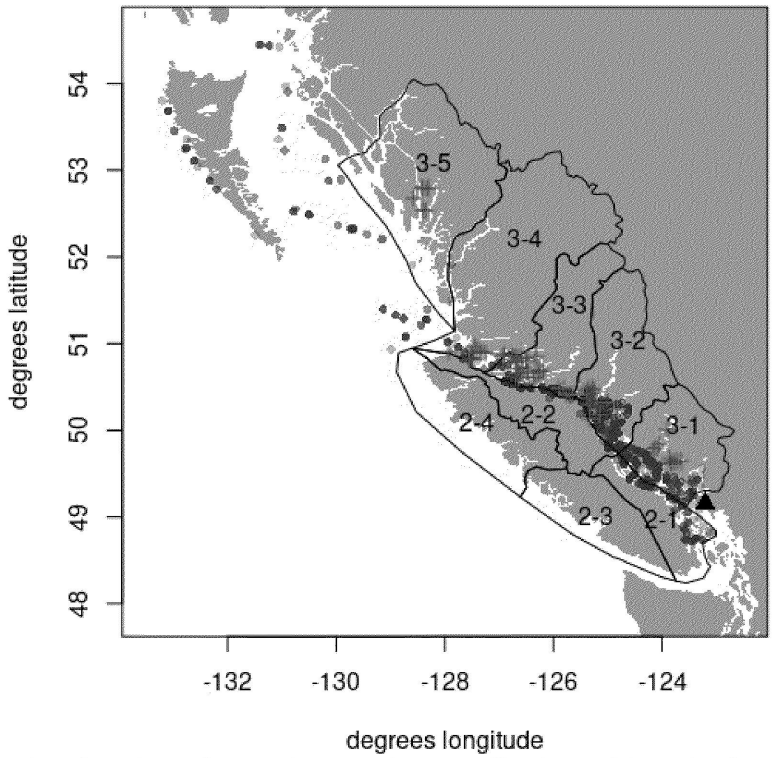

Figure 1. Collection locations for sockeye salmon collections (blue dots), along their north-westward migration from marine entry at the Fraser River mouth (black triangle), from which molecular detections of *Tenacibaculum maritimum* were analysed. Black, labelled regions indicate DFO's Aquaculture Management zones, and orange crosses show the locations of open net salmon farms within zones 3-1 through 3-5.

We built models to describe infection dynamics for these sockeye, as they migrate away from the mouth of the Fraser. The partial differential equation (PDE) models we used combined two basic parts: a spatial component, to describe the changing distribution of sockeye as the Fraser population migrates, and an epidemiological component, to describe exposure to *T. maritimum*, development of an associated infection, and subsequent recovery from or mortality due to that infection. To make the scenario tractable, we simplified the two-dimensional locations of the sampled fish into one measure of migration distance along a single spatial axis, representing seaway distance (generally to the northwest) from the Fraser River mouth.

The spatial component of our models took the form of standard "advection-diffusion-decay" equations. This class of models tracks the distribution of individuals over space and time, describing directed movement (advection) associated with migration, as well as spread (diffusion) due to variation in migration speed or milling behaviour. These models also capture natural mortality (decay) over the course of migration, so that the spatial distribution of sockeye amounts to a smaller and smaller fraction over time.

The epidemiological component of our models took a standard "susceptible-exposed-infected-susceptible" (SEIS) form, decomposing the time-varying spatial distribution of sockeye into susceptible, exposed, and infected components. We assume that sockeye leave freshwater as uninfected, susceptible individuals. Susceptible fish can become exposed due to some spatially varying infection pressure in the marine environment, but we assume that molecular detection of *T. maritimum* is impossible until those exposed fish develop into infected fish. Infected fish can return to the susceptible category via recovery from infection.

The overall model takes the form:

$$\frac{\partial S(x,t)}{\partial t} = D\frac{\partial^2 S(x,t)}{\partial x^2} - \frac{\partial v(x)S(x,t)}{\partial x} + f(x,t) - \mu S(x,t) - S(x,t)\phi(x) + \gamma I(x,t) \quad (1A)$$

$$\frac{\partial E(x,t)}{\partial t} = D\frac{\partial^2 E(x,t)}{\partial x^2} - \frac{\partial v(x)E(x,t)}{\partial x} - \mu E(x,t) + S(x,t)\phi(x) - \rho E(x,t) \quad (1B)$$

$$\frac{\partial I(x,t)}{\partial t} = D\frac{\partial^2 I(x,t)}{\partial x^2} - \frac{\partial v(x)I(x,t)}{\partial x} - \mu_I I(x,t) + \rho E(x,t) - \gamma I(x,t) \quad (1C)$$

Here, S, E, and I are the space- and time-varying relative densities of susceptible, exposed, and infected individuals; x is the spatial migration-distance dimension; t is time; D is the spatial diffusion coefficient and v is the migration speed (below, we describe how v changes in space); f represents the time-varying input of sockeye smolts at the Fraser River mouth; μ is mortality (with a different rate, μ_I, for infected individuals); ϕ represents the spatially varying cumulative infection pressure (below, we describe how this is modelled), ρ is the development rate of exposed into infected individuals; and γ is the recovery rate of infected individuals. This model form assumes that sockeye salmon can become infected with *T. maritimum* from external sources but, given the short time window during which they can be sampled, secondary transmission does not occur.

Movement model portion

We tuned the advection-diffusion-decay component of the model using data from a number of sources. We used the approximate long-term mean and standard deviation of sockeye-smolt captures in the from the Mission rotary screw trap (Preikshot et al. 2012) to parameterise a Gaussian form for the input function, f. We drew migration speeds, v, from a tracking study of age-one smolts (Stevenson et al. 2019), using values of 9.5 km per day from the Fraser River to the Discovery Islands region, and 14.5 km per day thereafter. We set the diffusion coefficient, D, by matching the cumulative distribution of smolts that had passed given spatial locations with cumulative distributions of catch-per-unit-effort from purse-seine sampling run by the Hakai Institute between 2015 and 2019 (Johnson et al. 2019). We set the baseline mortality rate, μ, such that survival over the course of our model period would be 25%, to approximately align with Stevenson et al. (2019). Results of the advection-diffusion-decay movement model matched catch data well (Figure 2).

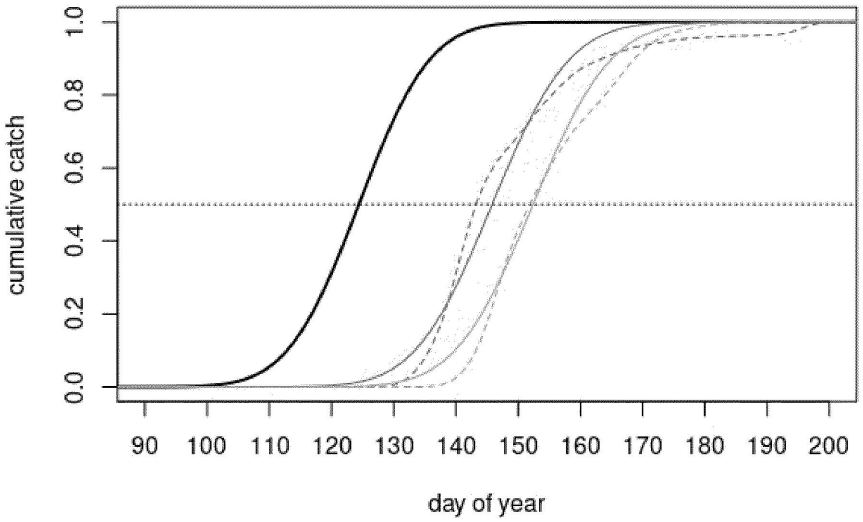

Figure 2. Cumulative Fraser-River sockeye salmon smolt passage at Mission, BC (black curve, parameterised from long-term data) and in the Discovery Islands (blue) and northern Johnstone Straight (grey) regions of their north-westward migration route. For the latter two locations, solid curves come from a parameterised advection-diffusion-decay model of sockeye movement, while dashed curves show empirical data from 2015 through 2019, collected by the Hakai Institute & colleagues.

Epidemiological model portion

Given the parameterised movement portion of the model, we could fit remaining components of the model to the *T. maritimum* detection data from sockeye smolts. The development rate (ρ), recovery rate (γ), and infected mortality rate (μ_I) were fit using free parameters. The remaining component of the model – infection strength (ϕ), critical for inference – required additional consideration.

We considered four candidate models for infection pressure, ϕ, based on a combination of infection pressure from background and salmon-farm sources (ϕ_b and ϕ_f, respectively). Two candidate sub-models considered background sources only: a constant background infection pressure for all x, and background pressure that varied by DFO Fish Health Zone (classified as 3-1 & south, 3-2, 3-3, 3-4, and 3-5 & north; Figure 1). Two candidate sub-models considered farm-source infection, in addition to constant background pressure: one that considered infection risk declining with distance from each active farm, averaged across months in our study period, and another that allowed for Discovery-Islands farms to contribute different infection pressure than all other farms.

For each of the four infection sub-models, we considered both a SEIS version of the PDE model (1) and a slightly less complex "SIS" version, in which exposed individuals immediately become infected, without passing through a separate exposed class. Background and farm-source infection levels were scaled via free parameters. For the farm-source infection sub-models, spread of infection around farms was fitted as an additional free parameter. Exposure to infection from each farm at each migration distance, x, was averaged across the approximate range of distances to that farm experienced by sockeye at that point in their migration.

Model fitting

We numerically solved the model in R (R Core Team 2020) using the *ReacTran* package (Soetaert and Meysman 2010). With the *optim* numerical optimiser, we fit the model by using the ratio of the infected to total (susceptible, exposed, and infected) population density at each point in space and time as the binomial probability that corresponding sockeye smolts would be positive or negative for *T. maritimum*, according to the qPCR screening test. We compared models using information-theoretic Akaike's information criterion

"parsimony" scores (ΔAIC; Burnham and Anderson 2002), where lower ΔAIC values indicate "better" models. Associated Akaike weights represent the strength of evidence for each model.

Table 1: Comparison of spatio-epidemiological models to describe patterns of *Tenacibaculum maritimum* detection in Fraser River sockeye salmon smolts in their early marine phase

candidate model	parameters	-log(likelihood)	ΔAIC	Akaike weight
SIS + constant background infection	3	269.5	29.3	0%
SIS + spatially varying background infection	7	258.3	15.0	0%
SIS + background & farm infection	5	261.0	16.3	0%
SIS + background, farm, & DI-farm infection	6	252.3	1.9	28.1%
SEIS + constant background infection	4	268.7	29.8	0%
SEIS + spatially varying background infection	8	256.1	12.5	0.1%
SEIS + background & farm infection	6	260.6	17.5	0%
SEIS + background, farm, & DI-farm infection	7	250.8	0	71.7%

The best model overall, accounting for 71.7% of model support, was the SEIS version in which farm-source infection differed between Discovery-Islands and other farms (Table 1). Combined with the corresponding SIS model, this version of infection pressure accounted for 99.8% of model support (Table 1). The best model described a pattern of infection prevalence that was relatively constant throughout the sockeye migration route, except around Discovery-Island farms (Figure 3). While the model described a wave of overall population density travelling north (Figure 2), the spatial pattern of infection changed little over the course of the migration season.

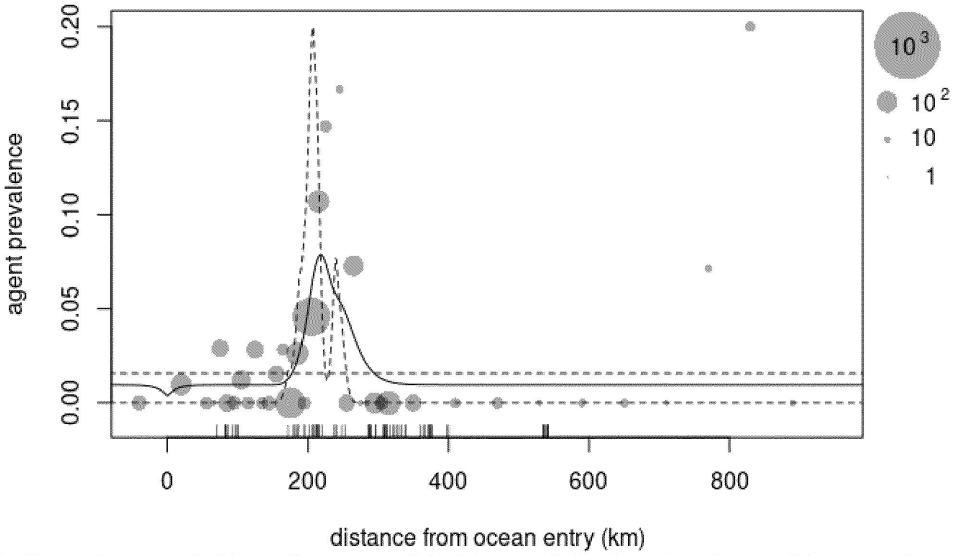

Figure 3. Prevalence of *Tenacibaculum Maritimum* infection in Fraser-River sockeye salmon smolts migrating north-westward from the mouth of the Fraser River, BC (x=0). Grey circles represent smolts caught in trawl surveys and purse-seine sampling between 2008 and 2018 (aggregated by location to illustrate pattern). Black curve shows predictions from a spatio-epidemiological model of migration and infection dynamics, fitted to the prevalence data and plotted for the average Julian day of fish capture. Red dashed lines show relative infection pressure from constant and farm-origin sources, primarily in and around the Discovery Islands, BC. "Rug" shows location of salmon farm tenures, with red indicating Discovery Islands.

The best model describes a scenario in which sockeye salmon smolts are subject to *T. maritimum* infection from both background and salmon-farm sources. Contributions from Discovery Island farms dwarfed those from other farming locations, and farm-source infection pressure peaked at 12.7 times background infection pressure.

The best model highlights that apparent *T. maritimum* prevalence need not be high to cause substantial mortality. The best-fit parameters indicate a high mortality rate and relatively low recovery rate in infected individuals, producing the decline in prevalence as fish migrate past the Discovery Islands (Figure 3). Infection in the model resulted in an 87.9% reduction in smolt survival by the end of the annual migration window, despite low average infection prevalence in the sockeye population through space and time. The maximum population-wide prevalence predicted at any time in the migration was 1.2%, and the maximum prevalence predicted by the model at any spatial location was 8.9% (Figure 3). This counter-intuitive mismatch between infection prevalence and associated mortality is, in part, due to external-source infection pressure, whereby the sockeye population itself did not have to sustain and transmit the infection internally. We note, however, that we were unable to resolve the relative role of mortality versus recovery from infection, as our best model did not significantly differ from versions without recovery (likelihood ratio test, p=0.82) or without infection-induced mortality (likelihood ratio test, p=0.42). Nonetheless, the model illustrates that *T. maritimum* has the potential to cause impact far greater than its apparent prevalence.

Inter-annual variation

Although we fit our models to data spanning all years of sampling, there is variation in *T. maritimum* detection rates across years. 2015, especially, saw particularly high prevalence in sockeye smolts relative to the other years in our study. Because model fitting was time consuming and somewhat delicate, and because we did not have access to annual-scale input data (e.g. Mission rotary screw trap catches), we did not fit a version of the model with annually varying parameters. We did, however, fit the best model to data from 2015 and data from other years separately.

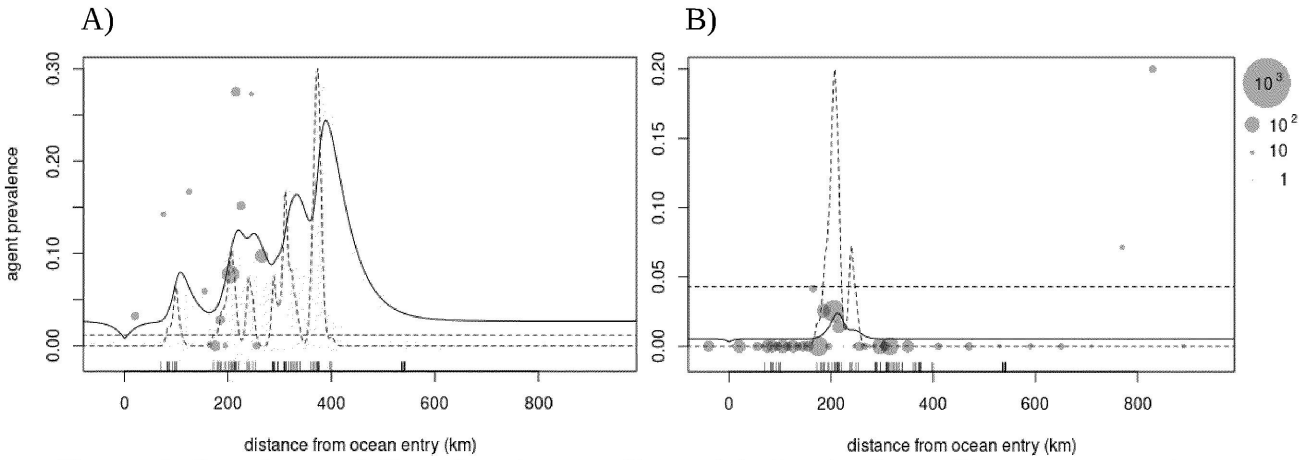

Figure 4. Prevalence of *Tenacibaculum maritimum* infection in Fraser-River sockeye salmon smolts migrating north-westward from the Fraser River, BC (*x*=0). Grey circles represent smolts caught in trawl surveys and purse-seine sampling in (A) 2015 and in (B) other years from 2008 through 2018 (aggregated by location to illustrate pattern). Black curve shows predictions from a spatio-epidemiological partial-differential-equation model of migration and infection dynamics, fitted to the prevalence data and plotted for the average Julian day of fish capture. Red dashed lines show relative infection pressure from fitted constant and farm-origin sources in the corresponding time periods. "Rug" shows location of salmon farm tenures, with red indicating Discovery Islands. Note different scales.

Several notable differences emerge from the models for the two time periods (Figure 4). The fitted model for 2015 indicates more even contributions from salmon farms along the sockeye migration route, due to

higher rates of *T. maritimum* detection in fish caught in the Salish Sea. Unfortunately, sampling was spatially restricted in 2015, precluding validation of the pattern further to the north. Although infection rates across other years were lower, the model still picks up a rise in infection around Discovery-Island farms. (Note also the detections around 800 km, near Haida Gwaii, which none of our models are able to explain.)

Information from salmon farms

Information from salmon farms indicates that Atlantic salmon can remain infected or become reinfected with *T. maritimum* over an 18-month production cycle (et al. in press), but Atlantic salmon rarely, if ever, develop clinical mouthrot twice (Waddington and Price, personal communication 2020). Not knowing how infection plays out in sockeye, we considered a "SEIR" version of the best-fitting model that included a "recovered" class of individuals, but the results & model fit were practically identical. This aligns with our results indicating that our modelling framework cannot distinguish among processes that serve to reduce infection prevalence.

While farmed salmon do not tend to experience recurrent mouthrot, the initial bout on a farm can lead to substantial mortality, and fish are treated with antibiotics (Frisch et al. 2018). Treatment with appropriate antibiotics may therefore be an indicator of farm outbreaks during which *T. maritimum* release would be elevated (Waddington and Price, personal communication 2020). We considered an additional modification to the best-fitting model, allowing treatment on farms during the migration period to contribute to farm-source infection pressure at a rate different from that due to stocking alone. This model did not significantly improve the model fit (likelihood ratio test, p=0.36). While treatment is almost certainly related to a disease state in farmed fish, this lack of effect in our model aligns with *T. maritimum* observations drawing from other studies (Laurin et al. 2019; Shea et al. 2020): treatment is associated neither with detection rate in fish sampled as part of DFO's audit program nor with detections via eDNA sampling in the nearby marine environment (data not shown). Further, although treatment can last for several months (Waddington and Price, personal communication 2020), dead and dying fish on farms can show elevated *T. maritimum* detection loads for many months, long after any reported mouthrot outbreak has passed (et al. in press).

Population-scale associations with *T. maritimum*

Concurrent work within the SSHI has sought to identify infectious agents associated with cohort survival and individual fitness, using pathogen data from sockeye, coho, Chinook salmon during early marine residence in ocean-entry years 2008 through 2018. To test for associations between cohort survival (as determined by coded wire tag recoveries for coho and Chinook, and stock-recruit relationships for sockeye) and pathogen prevalence (the percentage of individuals in a group testing positive for a given pathogen), we used Bayesian multi-level models that accounted for sea surface temperature (SST), random variation across populations, and random variation due to ocean-entry year. For any pathogen negatively associated with cohort survival, we would expect to see a decrease in survival as pathogen prevalence increases. To test for associations between body condition and pathogen load (the number of DNA copies per sample, assumed to be representative of the severity of infection), we used multi-level models of individual mass accounting for body length, SST, and random effects including population, ocean-entry year, and month of capture. Here, if a pathogen is negatively associated with mass, then as pathogen load increases fish tend to weigh less for a given body length, which may indicate a negative physiological impact.

Within these models, *T. maritimum* detected in the spring-summer months displayed a negative association with cohort survival for Chinook and sockeye salmon (although 95% credible intervals overlapped zero; Figure 5). Chinook and coho salmon displayed a consistently negative association between *T. maritimum* load and mass at length: with increasing *T. maritimum* infection intensity, individuals were increasingly thinner than would be expected. Of all the infective agents tested in the same manner, only *T. maritimum*

and one other demonstrated consistently negative patterns in condition across all seasons in Chinook and coho. The weight effect was particularly strong for Chinook in the spring-summer period – the same species and seasons for which we saw the strongest negative associations with cohort survival.

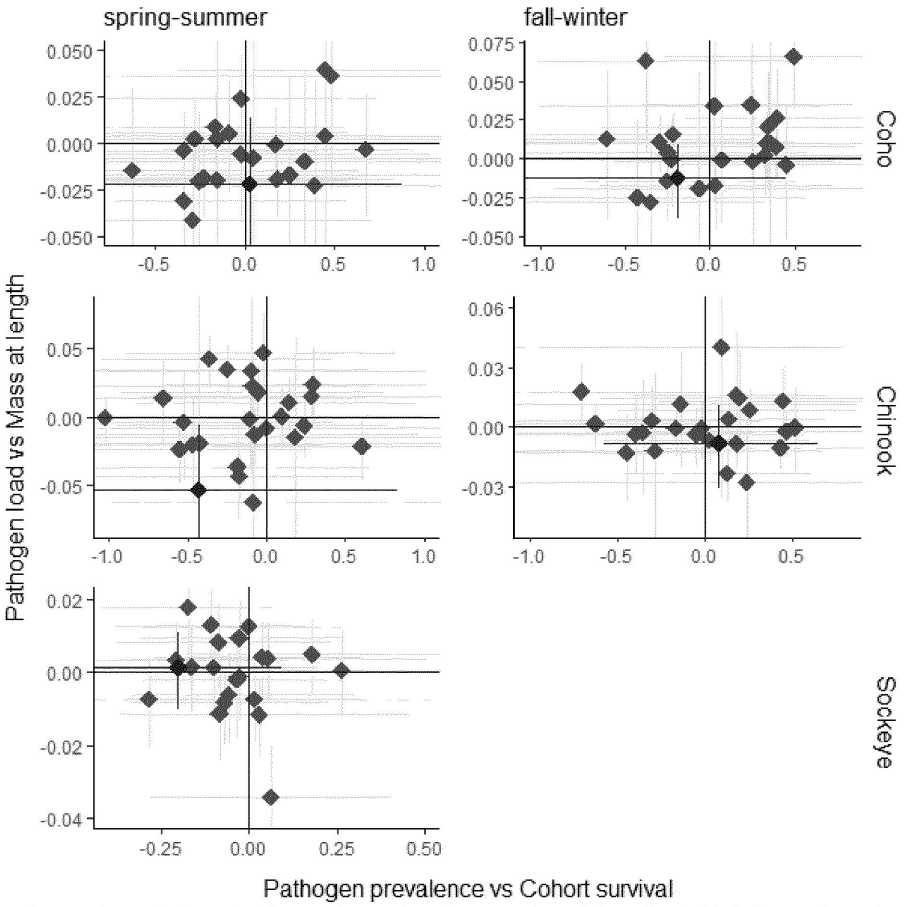

Figure 5. Bi-plots of model coefficients for coho (top row), Chinook (middle), and sockeye (bottom) salmon in the spring-summer (left column) and fall-winter periods (sockeye are primarily present in the study area in the spring-summer). Diamonds represent model coefficients from both survival (x-axis) and mass at length (y-axis) models. Gray lines represent the 95% credible intervals around these model estimates. Blue points represent the ≈25 pathogens assayed, and red points represent the model estimates for *Tenacibaculum maritimum*. Red lines represent zero, and points falling in the bottom left quadrant of each plot would indicate negative associations with both cohort survival and condition.

Interpretation

Overall, it is clear that detections of *T. maritimum* in Fraser River sockeye smolts are highest around the Discovery Islands. Our modelling shows that this pattern is consistent with a simple but epidemiologically and empirically informed description of infection from farm-origin and background sources. In addition, *T. maritimum* prevalence in sockeye is associated with reduced population-level survival, and survival or body-condition associations exist for coho and Chinook.

Past scepticism has been levelled at the use of mixed-tissue (including gill) samples for screening on the Fluidigm BioMark™ platform. Gills are, however, one of the tissues in which mouthrot manifests in Atlantic salmon (Frisch et al. 2018), and assessments of single tissue results from the SSHI (results not shown) indicate that detections are often systemic, especially when detected loads are high. Nonetheless, our "infected" fish may combine truly infected individuals and those exposed at high loads. Nonetheless,

we see Fraser River sockeye infected with or exposed to *T. maritimum*, especially around farms in the Discovery Islands.

Our models raise realistic and serious concerns about farm-origin transmission of *T. maritimum* to Fraser River sockeye salmon and population-level impacts to Chinook, coho, and sockeye. As with any statistical findings, there remains uncertainty in our model results, but it is the bulk of evidence, rather than any one particular model, that should give pause. Taken together, results from wild-salmon screening within the SSHI highlight *T. maritimum* as one of the most likely candidates for population-level impacts on wild populations, and present evidence that infections in Fraser River sockeye may originate from salmon-farm sources, especially in the Discovery Islands region. Given knowledge about the depressed state of Fraser-River sockeye stocks, the evidence we have presented suggests extreme caution and further research are required.

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From: Miller-Saunders, Kristi
Sent: Wednesday, December 16, 2020 3:45 PM
To: Candy, John; Lowe, Carmel; MacDougall, Lesley
Subject: RE: Tenacibaculum findings from the SSHI
Attachments: ROCS - ADGT Tenacibaculum_KM.docx

Here are my revisions, keeping it to four key bullets.
Kristi

From: Candy, John
Sent: Wednesday, December 16, 2020 12:26 PM
To: Lowe, Carmel ; Miller-Saunders, Kristi ; MacDougall, Lesley
Subject: RE: Tenacibaculum findings from the SSHI

Hi Carmel
We have the template and I have sent a draft for Kristi to review and modify.
John

From: Lowe, Carmel <Carmel.Lowe@dfo-mpo.gc.ca>
Sent: Wednesday, December 16, 2020 12:03 PM
To: Miller-Saunders, Kristi <Kristi.Saunders@dfo-mpo.gc.ca>; MacDougall, Lesley <Lesley.MacDougall@dfo-mpo.gc.ca>; Candy, John <John.Candy@dfo-mpo.gc.ca>
Subject: RE: Tenacibaculum findings from the SSHI

Thanks for sending this along Kristi. Can you please draft a ROCS for this and send to me before end of day (which is weekly deadline) – Tarah can provide the template if you don't have one handy.

Thanks
Carmel

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Sent: Tuesday, December 15, 2020 1:54 PM
To: MacDougall, Lesley <Lesley.MacDougall@dfo-mpo.gc.ca>; Candy, John <John.Candy@dfo-mpo.gc.ca>
Cc: Lowe, Carmel <Carmel.Lowe@dfo-mpo.gc.ca>; Paylor, Adrienne <Adrienne.Paylor@dfo-mpo.gc.ca>; Webb, Allison <Allison.Webb@dfo-mpo.gc.ca>
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Happy to discuss further.
Thanks,

s.19(1)

Kristi

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Head, Molecular Genetics
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250-756-7155
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To: Waddington, Zac <Zac.Waddington@dfo-mpo.gc.ca>; Price, Derek <Derek.Price@dfo-mpo.gc.ca>
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Further to our ongoing conversations about *Tenacibaculum maritimum* on salmon farms and its potential transfer to and impacts on wild salmon, I've prepared the attached briefing note and technical summary, based on relevant findings from the SSHI.

Hopefully these clarify a few more details. The technical document also contains a summary of the population-level associations I mentioned in a past email, between T. maritimum infection and reduced survival or body condition in Chinook, coho, and sockeye. (Please note: the information in this document corrects a number of minor errors in the summary email I sent a few days ago.)

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Best regards,
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Weekly Input: Briefing Note To Minister & MinO Briefing Schedule – December 2, 2020		Secret	
Issue	**Key Information**	**Lead Sector / Region**	**Mino Briefing Request**
Provide a short description of the issue. *(1 sentence max.)* Association of bacterial infection (*T. maritimum*) fish farms and migration of Fraser River Sockeye	Provide a short overview of the issue: what is it; why is this coming forward now (e.g. what is the departmental implication); key dates; actions taken or planned by the Department (including but not limited to the drafting of memorandum, meetings with stakeholders or other government officials). If a MINO briefing is requested, indicate why one is needed now. *(4 bullets, 1 line each max. Spell out acronyms in first usage.)*		Is your Sector / Region requesting a MINO briefing?
	• There is recent and new evidence that the bacterial pathogen *Tenacibaculum maritimum* shed by farmed salmon may pose more than a minimal risk to migratory sockeye salmon. • Of 39 agents tested, *T. maritimum*, the causative agent of the disease mouthrot on farms, was the most strongly associated with active salmon farms as determined from a recent environmental-DNA study. • Population-level models based on surveillance data for 25 pathogens in Chinook, coho, and sockeye salmon identified T. maritimum as the top marine-transmitted agent consistently associated with depressed marine survival and reduced body condition • Spatial epidemiological models identify salmon farms in the Discovery Islands as the likely dominant source of *T. maritium* infection in juvenile migratory Fraser River sockeye.	Science ADGT/Pacific	Not required ☐ Next week ☐ Week after ☐
Provide a short description of the COVID related issue. (1 sentence max.)	Provide a short overview of any issues stemming from COVID-19 that are affecting departmental operations, including interruptions to regular operations, changes in operations, delays, etc. *(4 bullets, 1 line each max. Spell out acronyms in first usage.)*		
	• • • •		

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Issue	**Key Information**	**Lead Sector / Region**	**Mino Briefing Request**
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	• There is recent and new evidence that the bacterial pathogen *Tenacibaculum maritimum* shed by farmed salmon may pose more than a minimal risk to migratory sockeye salmon. • Of 39 agents tested, *T. maritimum*, the causative agent of the disease mouth rot on farms, was the most strongly associated with active salmon farms as determined from a recent environmental-DNA study. • Population-level models based on surveillance data for 25 pathogens in Chinook, coho, and sockeye salmon identified T. maritimum as the top marine-transmitted agent consistently associated with depressed marine survival and reduced body condition • Spatial epidemiological models identify salmon farms in the Discovery Islands as the likely dominant source of *T. maritimum* infection in juvenile migratory Fraser River sockeye.	Science ADGT/Pacific	Not required ☐ Next week ☐ Week after ☐
Provide a short description of the COVID related issue. (1 sentence max.)	Provide a short overview of any issues stemming from COVID-19 that are affecting departmental operations, including interruptions to regular operations, changes in operations, delays, etc. *(4 bullets, 1 line each max. Spell out acronyms in first usage.)*		
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From: Miller-Saunders, Kristi
Sent: Wednesday, December 16, 2020 4:21 PM
To: Lowe, Carmel; Candy, John; MacDougall, Lesley
Subject: RE: Tenacibaculum findings from the SSHI
Attachments: ROCS - ADGT Tenacibaculum_KM.docx

I agree, and changed to better reflect the data at hand.

From: Lowe, Carmel
Sent: Wednesday, December 16, 2020 1:14 PM
To: Miller-Saunders, Kristi ; Candy, John ; MacDougall, Lesley
Subject: RE: Tenacibaculum findings from the SSHI

Kristi,
The first bullet is misleading as it suggests a formal risk assessment was conducted which I don't think was the case here? Please take another look/revise this.

Thanks
Carmel

From: Miller-Saunders, Kristi <Kristi.Saunders@dfo-mpo.gc.ca>
Sent: Wednesday, December 16, 2020 12:46 PM
To: Candy, John <John.Candy@dfo-mpo.gc.ca>; Lowe, Carmel <Carmel.Lowe@dfo-mpo.gc.ca>; MacDougall, Lesley <Lesley.MacDougall@dfo-mpo.gc.ca>
Subject: RE: Tenacibaculum findings from the SSHI

Sorry, I fixed a couple of typos. Use this version.

From: Candy, John <John.Candy@dfo-mpo.gc.ca>
Sent: Wednesday, December 16, 2020 12:26 PM
To: Lowe, Carmel <Carmel.Lowe@dfo-mpo.gc.ca>; Miller-Saunders, Kristi <Kristi.Saunders@dfo-mpo.gc.ca>; MacDougall, Lesley <Lesley.MacDougall@dfo-mpo.gc.ca>
Subject: RE: Tenacibaculum findings from the SSHI

Hi Carmel
We have the template and I have sent a draft for Kristi to review and modify.
John

From: Lowe, Carmel <Carmel.Lowe@dfo-mpo.gc.ca>
Sent: Wednesday, December 16, 2020 12:03 PM
To: Miller-Saunders, Kristi <Kristi.Saunders@dfo-mpo.gc.ca>; MacDougall, Lesley <Lesley.MacDougall@dfo-mpo.gc.ca>; Candy, John <John.Candy@dfo-mpo.gc.ca>
Subject: RE: Tenacibaculum findings from the SSHI

Thanks for sending this along Kristi. Can you please draft a ROCS for this and send to me before end of day (which is weekly deadline) – Tarah can provide the template if you don't have one handy.

Thanks
Carmel

From: Miller-Saunders, Kristi <Kristi.Saunders@dfo-mpo.gc.ca>
Sent: Tuesday, December 15, 2020 1:54 PM
To: MacDougall, Lesley <Lesley.MacDougall@dfo-mpo.gc.ca>; Candy, John <John.Candy@dfo-mpo.gc.ca>
Cc: Lowe, Carmel <Carmel.Lowe@dfo-mpo.gc.ca>; Paylor, Adrienne <Adrienne.Paylor@dfo-mpo.gc.ca>; Webb, Allison <Allison.Webb@dfo-mpo.gc.ca>
Subject: FW: Tenacibaculum findings from the SSHI

FYI these documents represent the results from our Tenacibaculum research that that [redacted] and I have been discussing with Zac and Derek since last September. They are relevant to our risk framework pertaining to farms in the Discovery Islands and sockeye salmon, but note that our models have revealed population-level associations with survival and condition with this agent more broadly for Chinook, coho and sockeye salmon. The briefing note document provides a lay description of our findings, while the technical summary provides a detailed description of the models and results. We will be turning this around into a peer reviewed manuscript in the new year, but wanted you to be aware of the findings well in advance.

Happy to discuss further.
Thanks,

Kristi

Kristi Miller-Saunders, PhD
Head, Molecular Genetics
Pacific Biological Station
3190 Hammond Bay Rd
Nanaimo BC V9T 6N7
250-756-7155
Kristi.Saunders@dfo-mpo.gc.ca

From: [redacted]
Sent: Tuesday, December 15, 2020 1:38 PM
To: Waddington, Zac <Zac.Waddington@dfo-mpo.gc.ca>; Price, Derek <Derek.Price@dfo-mpo.gc.ca>
Cc: Miller-Saunders, Kristi <Kristi.Saunders@dfo-mpo.gc.ca>
Subject: Tenacibaculum findings from the SSHI

Hi Zac and Derek (Kristi cc'd),

Further to our ongoing conversations about *Tenacibaculum maritimum* on salmon farms and its potential transfer to and impacts on wild salmon, I've prepared the attached briefing note and technical summary, based on relevant findings from the SSHI.

Hopefully these clarify a few more details. The technical document also contains a summary of the population-level associations I mentioned in a past email, between T. maritimum infection and reduced survival or body condition in Chinook, coho, and sockeye. (Please note: the information in this document corrects a number of minor errors in the summary email I sent a few days ago.)

As always, I'm happy to discuss further once you've had a chance to read these.

Best regards, **s.19(1)**

[redacted]

s.19(1)

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Weekly Input: Briefing Note To Minister & MinO Briefing Schedule – December 2, 2020			Secret
Issue	**Key Information**	**Lead Sector / Region**	**Mino Briefing Request**
Provide a short description of the issue. *(1 sentence max.)* Association of bacterial infection (*T. maritimum*) fish farms and migration of Fraser River Sockeye	Provide a short overview of the issue: what is it; why is this coming forward now (e.g. what is the departmental implication); key dates; actions taken or planned by the Department (including but not limited to the drafting of memorandum, meetings with stakeholders or other government officials). If a MINO briefing is requested, indicate why one is needed now. *(4 bullets, 1 line each max. Spell out acronyms in first usage.)*		Is your Sector / Region requesting a MINO briefing?
	• There is recent and new evidence that farmed salmon in the Discovery Islands is the dominant source of transmission of a pathogen negatively impacting survival of migratory sockeye salmon. • Of 39 agents tested, *Tenacibaculum. maritimum*, the causative agent of the disease mouth rot on farms, was the most strongly associated with active salmon farms as determined from a recent environmental-DNA study. • Population-level models based on surveillance data for 25 pathogens in Chinook, coho, and sockeye salmon identified T. maritimum as the top marine-transmitted agent consistently associated with depressed marine survival and reduced body condition in all three species. • Spatial epidemiological models identify salmon farms in the Discovery Islands as the likely dominant source of *T. maritimum* infection in juvenile migratory Fraser River sockeye.	Science ADGT/Pacific	Not required ☐ Next week ☐ Week after ☐
Provide a short description of the COVID related issue. (1 sentence max.)	Provide a short overview of any issues stemming from COVID-19 that are affecting departmental operations, including interruptions to regular operations, changes in operations, delays, etc. *(4 bullets, 1 line each max. Spell out acronyms in first usage.)*		
	• • • •		

From: MacDougall, Lesley
Sent: Wednesday, December 16, 2020 4:59 PM
To: McLeod, Patricia; Sullivan, Tarah
Cc: Lowe, Carmel
Subject: ROCS - ADGT Tenacibaculum_KM3.docx
Attachments: ROCS - ADGT Tenacibaculum_KM3.docx

Follow Up Flag: Follow up
Flag Status: Completed

Hi Trish and Tarah – a revised late ROCS for the meeting today.
Lesley

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Weekly Input: Briefing Note To Minister & MinO Briefing Schedule – December 2, 2020			Secret
Issue	**Key Information**	**Lead Sector / Region**	**Mino Briefing Request**
Provide a short description of the issue. *(1 sentence max.)* Association of bacterial infection (*T. maritimum*) fish farms and migration of Fraser River Sockeye	Provide a short overview of the issue: what is it; why is this coming forward now (e.g. what is the departmental implication); key dates; actions taken or planned by the Department (including but not limited to the drafting of memorandum, meetings with stakeholders or other government officials). If a MINO briefing is requested, indicate why one is needed now. *(4 bullets, 1 line each max. Spell out acronyms in first usage.)*		Is your Sector / Region requesting a MINO briefing?
	• A recent study describes recent and new evidence that farmed salmon in the Discovery Islands is a dominant source of transmission of a pathogen negatively impacting survival of migratory sockeye salmon. • Of 39 agents tested in a recent environmental-DNA study, *Tenacibaculum. maritimum*, the causative agent of the disease mouth rot on farms, was the agent whose detection was most strongly associated with active salmon farms. • Population-level models based on surveillance data for 25 pathogens in Chinook, coho, and sockeye salmon identified T. maritimum as the top marine-transmitted agent consistently associated with depressed marine survival and reduced body condition in all three species. • Spatial epidemiological models identify salmon farms in the Discovery Islands as the likely dominant source of *T. maritimum* infection in juvenile migratory Fraser River sockeye.	Science ADGT/Pacific	Not required ☐ Next week ☐ Week after ☐
Provide a short description of the COVID related issue. (1 sentence max.)	Provide a short overview of any issues stemming from COVID-19 that are affecting departmental operations, including interruptions to regular operations, changes in operations, delays, etc. *(4 bullets, 1 line each max. Spell out acronyms in first usage.)*		
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From: Lowe, Carmel
Sent: Wednesday, December 16, 2020 5:04 PM
To: MacDougall, Lesley
Subject: FW: ROCS - ADGT Tenacibaculum_KM.docx
Attachments: ROCS - ADGT Tenacibaculum_KM.docx

Not sure if you got this?

From: Lowe, Carmel
Sent: Wednesday, December 16, 2020 1:43 PM
To: Candy, John ; MacDougall, Lesley
Subject: ROCS - ADGT Tenacibaculum_KM.docx

Both,

Can you please take another look at this – the title seems a very POOR descriptor of the bullets. Also – it would seem important to me to clarify that the results are not yet published/peer reviewed.

Carmel

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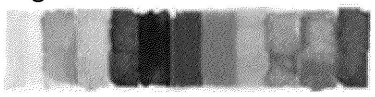
From: Sullivan, Tarah
Sent: Wednesday, December 16, 2020 5:05 PM
To: Lowe, Carmel
Subject: RED HOT URGENT - Science ROC submission for today
Attachments: ROCS- December 16- Science Submission.docx

Follow Up Flag: Follow up
Flag Status: Completed

Hi Carmel-
I have worked to ensure that the last minute ROCs request that Science received was included. This needs your immediate approval to move forward for this afternoons meeting.

Thank you,
Tarah Sullivan
A/Executive Assistant to the,
Regional Director of Science



Positive Space Ambassador
Pronouns: She, Her
250-802-4303
Or Contact via TEAMs

Weekly Input: Briefing Note To Minister & MinO Briefing Schedule – December 16, 2020

Issue	Key Information	Lead Sector / Region	Mino Briefing Request
Provide a short description of the issue. *(1 sentence max.)* Association of bacterial infection (*T. maritimum*) fish farms and migration of Fraser River Sockeye	Provide a short overview of the issue: what is it; why is this coming forward now (e.g. what is the departmental implication); key dates; actions taken or planned by the Department (including but not limited to the drafting of memorandum, meetings with stakeholders or other government officials). If a MINO briefing is requested, indicate why one is needed now. *(4 bullets, 1 line each max. Spell out acronyms in first usage.)*		Is your Sector / Region requesting a MINO briefing?
Vancouver Pile Driving v Her Majesty the Queen (HMTQ) Settlement Offer	• The Crown (CHS) was a third party to this litigation resulting from the striking of the Golden Ears Bridge by a crane on a barge owned by Vancouver Pile Driving. • The Plaintiff, VanPile, [redacted] • A Trial Management Conference (TMC) on the above file is scheduled for next Thursday, December 17 at 9:00 am PST before Justice Strickland. The TMC will give the trial judge a chance to understand and organize the case for trial, and potentially narrow the issues as the plaintiff has already settled with the original defendant (tug owner Gisbourne Marine Services). Trial is scheduled to commence 22 Feb, 2021. • [redacted] •	Pacific	Not required ☒ Next week ☐ Week after ☐
	• A recent study describes recent and new evidence that farmed salmon in the Discovery Islands is a dominant source of transmission of a pathogen negatively impacting survival of migratory sockeye salmon. • Of 39 agents tested in a recent environmental-DNA study, *Tenacibaculum. maritimum*, the causative agent of the disease mouth rot on farms, was the agent whose detection was most strongly associated with active salmon farms. • Population-level models based on surveillance data for 25 pathogens in Chinook, coho, and sockeye salmon identified T. maritimum as the top marine-transmitted agent consistently associated with depressed marine survival and reduced body condition in all three species. • Spatial epidemiological models identify salmon farms in the Discovery Islands as the likely dominant source of *T. maritimum* infection in juvenile migratory Fraser River sockeye.	Science ADGT/Pacific	Not required ☐ Next week ☐ Week after ☐
Provide a short description of the COVID related issue. (1 sentence max.)	Provide a short overview of any issues stemming from COVID-19 that are affecting departmental operations, including interruptions to regular operations, changes in operations, delays, etc. *(4 bullets, 1 line each max. Spell out acronyms in first usage.)*		

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Weekly Input: Briefing Note To Minister & MinO Briefing Schedule – December 16, 2020			Secret
Issue	**Key Information**	**Lead Sector / Region**	**Mino Briefing Request**
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From: MacDougall, Lesley
Sent: Wednesday, December 16, 2020 5:20 PM
To: Sullivan, Tarah; Lowe, Carmel; McLeod, Patricia
Cc: Candy, John
Subject: ROCS - ADGT Tenacibaculum_KM3 (002).docx
Attachments: ROCS - ADGT Tenacibaculum_KM3 (002).docx

Follow Up Flag: Follow up
Flag Status: Completed

Hello - apologies – further changes made.

Lesley

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Weekly Input: Briefing Note To Minister & MinO Briefing Schedule – December 2, 2020			**Secret**
Issue	**Key Information**	**Lead Sector / Region**	**Mino Briefing Request**
Provide a short description of the issue. *(1 sentence max.)* Unpublished results from Strategic Salmon Health Initiative propose link between Discover Island farms and bacterial infection (*T. maritimum*) in Fraser sockeye and other salmon species.	Provide a short overview of the issue: what is it; why is this coming forward now (e.g. what is the departmental implication); key dates; actions taken or planned by the Department (including but not limited to the drafting of memorandum, meetings with stakeholders or other government officials). If a MINO briefing is requested, indicate why one is needed now. *(4 bullets, 1 line each max. Spell out acronyms in first usage.)*		Is your Sector / Region requesting a MINO briefing?
	• Currently unpublished epidemiological models identify salmon farms in the Discovery Islands as the likely dominant source of *T. maritimum* infection in juvenile migratory Fraser River sockeye • In a recent environmental-DNA study, the detection of *Tenacibaculum. maritimum*, the causative agent of the disease mouth rot on farms, was the agent most strongly associated with active salmon farms. • Population-level models based on surveillance data for 25 pathogens in Chinook, coho, and sockeye salmon identified *T. maritimum* as the top marine-transmitted agent consistently associated with depressed marine survival and reduced body condition in all three species. • Results are beginning to be developed into primary publications.	Science ADGT/Pacific	Not required ☐ Next week ☐ Week after ☐
Provide a short description of the COVID related issue. (1 sentence max.)	Provide a short overview of any issues stemming from COVID-19 that are affecting departmental operations, including interruptions to regular operations, changes in operations, delays, etc. *(4 bullets, 1 line each max. Spell out acronyms in first usage.)*		
	• • • •		

From: Lowe, Carmel
Sent: Wednesday, December 16, 2020 5:31 PM
To: Sullivan, Tarah
Cc: MacDougall, Lesley
Subject: ROCS - ADGT Tenacibaculum_KM3 (002).docx
Attachments: ROCS - ADGT Tenacibaculum_KM3 (002).docx

Thanks Lesley. Tarah - I approve this version for submission thanks!

Carmel

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From: Lowe, Carmel
Sent: Wednesday, December 16, 2020 6:47 PM
To: Yook, Alena; Calla, Karen
Cc: Sullivan, Tarah
Subject: RE: ROCS - Dec 16, 2020
Attachments: ROCS - ADGT Tenacibaculum_KM3 (002).docx

Oops sorry – we had completed a draft (attached) – guess it got lost crossing the pond! Karen – sorry to have put work on your plate!

Alena – please use the attached version.

Carmel

From: Yook, Alena
Sent: Wednesday, December 16, 2020 3:41 PM
To: Lowe, Carmel
Cc: Sullivan, Tarah
Subject: ROCS - Dec 16, 2020

Hi Carmel,

Karen Calla started a draft for your second submission for ROCS from Dec 16, 2020. Please make necessary changes/edits to this document and re-submit to me by tomorrow, Dec 17 at 11AM.

PS – you can ignore the formatting issues, etc. I will be fixing them up before submitting to Andy tomorrow.

Thank you!

Alena Yook
A/Correspondence Co-ordinator Fisheries Management
Fisheries and Oceans Canada | Government of Canada
alena.yook@dfo-mpo.gc.ca | Tel: 236.330.5682

A/Coordonateur de la correspondance de la gestion des pêcheries
Pêches et Océans Canada | Gouvernement du Canada
alena.yook@dfo-mpo.gc.ca | Tel : 236.330.5682

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From: Lawrie, Kirsten
Sent: Friday, December 18, 2020 6:30 PM
To: Reid, Rebecca
Subject: FOR APPROVAL: ROCS - Dec 16, 2020
Attachments: FM RD Approved - ROCS - Dec 16, 2020.docx

For your review and approval:

1. Dec 16th ROCS

Signature Type: Email Approval
Due: COB Dec 18

Topics included:

- Increasing tensions from stakeholders and First Nations within the Northern Shelf Bioregion Marine Protected Area (MPA) Network Planning Process
- Bligh Island Nootka Sound Marine Oil Spill Incident Response
- Elliot Creek/Southgate River Landslide
- Big Bar Landslide Response: update
- Unpublished Results from Strategic Salmon Health Initiative Propose Link Between Discovery Island Farms and Bacterial Infection (Tenacibaculum maritimum (T. maritimum)) in Fraser Sockeye and Other Salmon Species
- Release of the Draft 2020-21 Crab Integrated Fisheries Management Plan (IFMP)
- The Haida Nation has expressed concern to DFO about a "super trawler" operating off the north coast of Haida Gwaii.

Kirsten Lawrie
A/Executive Assistant to the Regional Director General| Assistante Exécutive à la Directrice Générale Régionale, p.i.
Fisheries and Oceans Canada - Pacific Region| Pêches et Océans Canada - Région du Pacifique
kirsten.lawrie@dfo-mpo.gc.ca | 236-334-0263

Weekly Input: Briefing Note To Minister & MinO Briefing Schedule – December 16, 2020

Issue	Key Information	Lead Sector / Region	Mino Briefing Request
Provide a short description of the issue. *(1 sentence max.)*	Provide a short overview of the issue: what is it; why is this coming forward now (e.g. what is the departmental implication); key dates; actions taken or planned by the Department (including but not limited to the drafting of memorandum, meetings with stakeholders or other government officials). If a MINO briefing is requested, indicate why one is needed now. *(4 bullets, 1 line each max. Spell out acronyms in first usage.)*		Is your Sector / Region requesting a MINO briefing?
Increasing tensions from stakeholders and First Nations within the Northern Shelf Bioregion Marine Protected Area (MPA) Network Planning Process	• On November 6, 2020, the Network Committee (the trilateral collaborative governance body overseeing the network planning process) accepted recommendations from the Reconciliation Framework Agreement Solutions Table process regarding scope of the Network Action Plan (i.e., the final deliverable of the process) and timelines for its completion. • Subsequently the MPA Technical Team (MPATT) (the trilateral collaborative technical working group developing the network plan) has been planning to revise the current network scenario in consideration of First Nation, stakeholder, and partner input, beginning early January 2021. It is anticipated this second draft scenario will be discussed with stakeholders in March 2021 and again in Fall 2021 during public consultations. • A webinar with stakeholders was held December 15, 2020 wherein MPATT appraised stakeholders of these latest developments and updated them on how their input has and will be considered in revising the network scenario, and opportunities for their engagement. • On December 14, 2020 the Area A Crab sector indicated their frustration that their input was not accepted and indicated their withdrawal from the process. They had requested for increased stakeholder participation in decision-making and for the process to adopt a consensus-based approach that would include stakeholders. • This expectation for increased stakeholder involvement runs counter to the signals increasingly given by First Nations partners, in that they view the process as having entered a Government to Government to Government negotiation stage and are concerned additional stakeholder engagement will undermine their aspirations, which are very much oriented to advancing fisheries management interests and claims in their territories under the frame of the MPA network planning process.	Ecosystem Management Branch - Pacific	Not required ☒ Next week ☐ Week after ☐
Bligh Island Nootka Sound Marine Oil Spill Incident Response	• On December 3, 2020, a National Incident Notification Program (NINP) alert from Canadian Coast Guard (CCG) was reported for a historic wreck (M/V Scheidyk) releasing oil (Bunker C) from Zuciarte Channel near Bligh island (Pacific Fisheries Management Area 25-15) in Nootka Sound. • An Incident Command Post (ICP) is in place. The ICP is led by a Unified Command with a representative from CCG; British Columbia (BC) Ministry of Environment, and Muchalaht First Nations. An Environmental Unit (EU) is led by Environment and Climate Change Canada. A Joint Information Centre has been established for regular updates: http://www.spillresponsebc.ca/ • Fisheries and Oceans Canada (DFO)'s Planning for Integrated Environmental Response (PIER) program is coordinating DFO's response through the EU with the Marine Mammal Unit (MMU) deployed with Conservation & Protection (C&P) to lead mammal surveys and response strategies. • Sampling and Shoreline Clean up plans are being finalized. DFO PIER, Science, C&P, and the MMU are actively engaged for the coming weeks while a longer term strategy supported by contractors is confirmed.	Ecosystem Management Branch - Pacific	Not required ☒ Next week ☐ Week after ☐

Weekly Input: Briefing Note To Minister & MinO Briefing Schedule – December 16, 2020

Issue	Key Information	Lead Sector / Region	Mino Briefing Request
Elliot Creek/Southgate River Landslide	• A landslide occurred on Elliott Creek above the convergence of Elliott Creek and the Southgate River. The Southgate River flows into Bute Inlet (Fisheries Area 13) which is a mainland inlet northeast of Campbell River. • The slide likely occurred on November 28, 2020 when seismic activity was noted in the area. DFO received early reports on December 11, 2020. • A local charter patrolmen reported that debris from the slide likely significantly impacted coho habitat, the 2020 chum spawn and damaged chinook and chum habitat, as well as shellfish stocks at the head of the inlet. • The slide has not blocked Southgate River water flows and appears to be a natural event caused by glacial de-buttressing. • DFO has not assessed the situation yet but is planning a response and gathering information. • Homalco Nation is very concerned and may declare a state of emergency for this system and are seeking assessment, monitoring, remediation, and rebuilding funds. • The province of BC and Homalco are making plans to assess the site. • Media requests have been received and media lines are being developed. • A coordination call with Homalco, DFO, and the province of BC is planned for December 21, 2020	South Coast Area - Pacific	Not required ☒ Next week ☐ Week after ☐
Big Bar Landslide Response: update	• Media interest and interview requests have continued following the permanent fishway announcement; coverage has been positive. • Kiewit is pushing to mobilize its staff and commence additional winter work on January 4, 2021; DFO and Public Services and Procurement Canada (PSPC) are focussed on securing the necessary regulatory permits to move forward. • DFO and PSPC are expecting to receive additional pricing proposals and installation plans from Kiewit for the permanent fishway by December 21, 2020.	Big Bar - Pacific	Not required ☒ Next week ☐ Week after ☐
Unpublished Results from Strategic Salmon Health Initiative Propose Link Between Discovery Island Farms and Bacterial Infection (*Tenacibaculum maritimum (T. maritimum)*) in Fraser Sockeye and Other Salmon Species	• Currently unpublished epidemiological models identify salmon farms in the Discovery Islands as the likely dominant source of *T. maritimum* infection in juvenile migratory Fraser River sockeye. • In a recent environmental-DNA study, the detection of *T. maritimum*, the causative agent of the disease mouth rot on farms, was the agent most strongly associated with active salmon farms. • Population-level models based on surveillance data for 25 pathogens in Chinook, coho, and sockeye salmon identified *T. maritimum* as the top marine-transmitted agent consistently associated with depressed marine survival and reduced body condition in all three species. • Results are being prepared for submission to an international science journal.	Science - Pacific	Not required ☒ Next week ☐ Week after ☐

Weekly Input: Briefing Note To Minister & MinO Briefing Schedule – December 16, 2020

Issue	Key Information	Lead Sector / Region	Mino Briefing Request
Release of the Draft 2020-21 Crab Integrated Fisheries Management Plan (IFMP)	• DFO and central coast First Nations (Heiltsuk, Kitasoo/Xai'Xais, Nuxalkt, and Wuikinuxv) have worked within a collaborative governance model to examine options for improving Food, Social, and Ceremonial (FSC) access to crab. This lead to a joint recommendation to decision makers in which commercial and recreational crab fishing closures are proposed in 17 sites to support FSC access. • These proposed area closures will be included in the draft 2020-21 Crab IFMP which was released on December 16, 2020 for a 40 day comment period. • Recreational and commercial harvesters have expressed strong opposition to the proposed closures. The release of the draft IFMP is expected to invite further reaction from these sectors which may result in correspondence to senior departmental officials. • Consultation with stakeholders continues on the specific areas which have been recommended by the Central Coast Collaborative Crab Management Process Steering Committee for closure to recreational and commercial crab fishing. A decision by the Pacific Regional Director General on approval of the 2020-21 Crab IFMP and the closures is expected in February 2021.	Fisheries Management – Pacific	Not required ☒ Next week ☐ Week after ☐
The Haida Nation has expressed concern to DFO about a "super trawler" operating off the north coast of Haida Gwaii.	• The Vice President of the Council of the Haida Nation, Trevor Russ, contacted the Pacific Region Regional Director General on December 15, 2020 expressing concern about the impacts the trawler may have on species that are important to community needs in an area he stated is important for community fishing. • The vessel of concern is a commercially licensed groundfish trawl vessels, and one of the largest commercial vessels on the Pacific coast, at 56 metres in length. Its size is likely part of the reason it is attracting attention. • The groundfish trawl fishery is tightly managed, with 100 per cent at sea and dockside monitoring and numerous area closures around Haida Gwaii to reduce harvesting pressure on localized stocks of fish, minimize the catch of juvenile Halibut, and provide improved access to FSC fisheries for First Nations. The vessel appears to have left the area since Mr. Russ's inquiry. • Regional officials are setting up a meeting with Haida officials to discuss their concerns.	Fisheries Management - Pacific	Not required ☒ Next week ☐ Week after ☐
Provide a short description of the COVID related issue. (1 sentence max.)	Provide a short overview of any issues stemming from COVID-19 that are affecting departmental operations, including interruptions to regular operations, changes in operations, delays, etc. *(4 bullets, 1 line each max. Spell out acronyms in first usage.)*		
	• • • •		

From: Marquis, Paul <Paul.Marquis@justice.gc.ca>
Sent: Monday, December 21, 2020 11:14 AM
To: Lowe, Carmel
Cc: MacDougall, Lesley; Moore, Wayne
Subject:
Attachments:

Hi Carmel,

PM

From: Lowe, Carmel
Sent: December 14, 2020 2:50 PM
To: Marquis, Paul
Cc: MacDougall, Lesley ; Moore, Wayne
Subject:

Hi Paul,

Regards
Carmel
Carmel Lowe, Ph.D.
Regional Director Science | Directrice régionale des sciences
Fisheries and Oceans Canada | Pêches et Océans Canada
Pacific Biological Station | Station biologique du Pacifique
3190 Hammond Bay Rd, Nanaimo, BC, Canada V9T 6N7
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s.21(1)(a)
s.21(1)(b)
s.23

Subject: [redacted]

[redacted]

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s.21(1)(a)
s.21(1)(b)
s.23

Pages 210 to / à 244

are withheld pursuant to section

sont retenues en vertu de l'article

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of the Access to Information Act

de la Loi sur l'accès à l'information