Fisheries and Oceans Canada | Pêches et Océans Canada
Ecosystems and Oceans Science | Sciences des écosystèmes et des océans

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Science Advisory Report 2020/043

ADVICE FROM THE ASSESSMENT OF THE RISK TO FRASER RIVER SOCKEYE SALMON DUE TO *MORITELLA VISCOSA* TRANSFER FROM ATLANTIC SALMON FARMS IN THE DISCOVERY ISLANDS AREA, BRITISH COLUMBIA

Net-pen along the coast of British Columbia (photo credit: DFO).

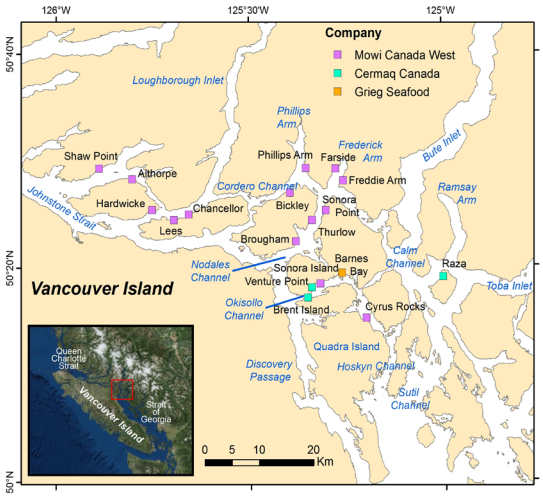

Figure 1. Location of the 18 Atlantic Salmon farms in the Discovery Islands area included in this risk assessment.

Context:

Fisheries and Oceans Canada (DFO), under the Sustainable Aquaculture Program, is committed to deliver environmental risk assessments to support science-based decision making related to aquaculture activities. The Aquaculture Science Environmental Risk Assessment Initiative was implemented to assess the risks of aquaculture activities to wild fish and the environment. The risks associated with each environmental stressor validated in the Pathways of Effects for finfish and shellfish aquaculture (DFO, 2010) will be assessed as per the Aquaculture Science Environmental Risk Assessment Framework ensuring a systematic, consistent and transparent process.

DFO's Aquaculture Management Directorate has requested CSAS advice on the risks to Fraser River Sockeye Salmon due to pathogen transfer from marine Atlantic Salmon (Salmo salar) farms located in the Discovery Islands area in British Columbia. This request supports DFO's role in the management of aquaculture in British Columbia and aligns with recommendations in the final report of the Commission of Inquiry into the Decline of Sockeye Salmon in the Fraser River, including recommendations 18 and 19 on risks to wild fish populations related to pathogen transfer from finfish farms (Cohen, 2012).

The advice is provided through a series of pathogen transfer risk assessments; this seventh risk assessment is focusing on Moritella viscosa. *The risks associated with other pathogens also known to*

cause disease on marine Atlantic Salmon farms in the Discovery Islands area will be assessed in subsequent processes.

This Science Advisory Report is from the December 3 to 5, 2019 National Peer Review Meeting on the Assessment of the risk to Fraser River Sockeye Salmon due to bacteria causing erosive lesions transfer from Atlantic Salmon farms located in the Discovery Islands area, British Columbia. Additional publications from this meeting will be posted on the Fisheries and Oceans Canada (DFO) Science Advisory Schedule as they become available.

SUMMARY

Moritella viscosa Transfer Risk Assessment

- *Moritella viscosa* released from Atlantic Salmon (*Salmo salar*) farms operating in the Discovery Islands area was assessed to pose minimal risk to Fraser River Sockeye Salmon (*Oncorhynchus nerka*) abundance and diversity under current farm practices.
- The assessment relied on 2012 to 2018 fish health data on salmon farms; and the current state of knowledge of *M. viscosa*, including fish health data surveys and studies from enhanced and wild salmon in British Columbia.
- Between 2012 and 2018, evidence of *M. viscosa* infection has been reported on Atlantic Salmon farms in the Discovery Islands area by industry, the Fish Health Audit Surveillance Program and/or as a Fish Health Event in six of seven years.
- Throughout 2012 to 2018, all evidence of *M. viscosa* on Atlantic Salmon farms in the Discovery Islands area occurred only between December and February. Fraser River Sockeye Salmon are known to migrate through this area between May and October.
- In the overall likelihood assessment, it was concluded that the likelihood that Fraser River Sockeye Salmon would become infected with *M. viscosa* released from Atlantic Salmon farms in the Discovery Islands area was extremely unlikely for both juveniles and adults because exposure was extremely unlikely given no temporal overlap between *M. viscosa* occurrences on Atlantic Salmon farms and Fraser River Sockeye Salmon migration timing. Each step of the assessment was ranked with reasonable certainty.
- The consequence assessment was not performed because the outcome of the overall likelihood assessment was extremely unlikely.
- Although there are a few sources of uncertainty related to this risk assessment, they are not expected to change the final risk estimates (outcomes of the assessment).
- If winter ulcer outbreaks occur on Atlantic Salmon farms in the Discovery Islands area during the migration window of Fraser River Sockeye Salmon, a new risk assessment would be warranted.

This risk assessment was informed by a summary of the current state of knowledge related to *Moritella viscosa* and winter ulcer (Wade and Weber, 2020). The key elements of this review are summarized below.

Characterization of *Moritella viscosa* and Winter Ulcer

- Winter ulcer is a disease caused by infection with *M. viscosa*, a bacterium found in the marine environment and commonly reported in farmed Atlantic Salmon in the Northern Atlantic Ocean.

- In BC, winter ulcer has only been reported in farmed Atlantic Salmon. However, molecular evidence of *M. viscosa* has been detected in two of 2,006 juvenile Fraser River Sockeye Salmon sampled in June, 2013. Note that this detection does not necessarily indicate infection or disease.
- Winter ulcer typically occurs when water temperatures are below 10°C.
- The evidence suggests limited horizontal transmission of *M. viscosa* between fish.
- Vaccines are available for *M. viscosa* in Atlantic Salmon which can reduce the incidences of winter ulcer.
- Between 2012 and 2018, winter ulcer was diagnosed at the farm-level in 17 of the 715 fish health audits conducted on Atlantic Salmon farms in BC. Between the end of 2011 and 2018 (excluding the years 2013 to 2015), 13 Fish Health Events were attributed to winter ulcer on Atlantic Salmon farms in BC. Between 2011 and 2018, one mortality event was attributed to winter ulcer on an Atlantic Salmon farm in BC.

INTRODUCTION

This risk assessment was conducted under the DFO Aquaculture Science Environmental Risk Assessment Initiative, implemented as a structured approach to provide risk-based science advice to further support sustainable aquaculture in Canada. Risk assessments conducted under this initiative follow a Framework adapted from international and national risk assessment frameworks (GESAMP, 2008; ISO, 2009; Mandrak et al., 2012). Details about the initiative and the framework are available on the DFO Aquaculture Science Environmental Risk Assessment Initiative webpage. Risk assessments conducted under the Initiative do not include socio-economic considerations.

This advisory report summarizes the consensus advice developed during the December 3-5, 2019 Canadian Science Advisory Secretariat (CSAS) scientific peer-review meeting that included international and national scientific experts. The information and current scientific knowledge about *M. viscosa* and winter ulcer and the risk assessment were presented in the following documents:

- Characterization of *Moritella viscosa* and winter ulcer to inform pathogen transfer risk assessments in British Columbia (Wade and Weber, 2020).
- Assessment of the risk to Fraser River Sockeye Salmon due to *Moritella viscosa* transfer from Atlantic Salmon farms in the Discovery Islands area, British Columbia (Mimeault et al., 2020).

The two supporting research documents were reviewed and used to meet the remaining objectives of the meeting, specifically:

- review the qualitative assessments of the risk to Fraser River Sockeye Salmon abundance and diversity due to *Moritella viscosa* transfer from Atlantic Salmon farms located in the Discovery Islands area;
- review the uncertainties associated with the estimation of the risk to Fraser River Sockeye Salmon abundance and diversity; and
- if risk assessment outcomes warrant, provide advice on additional measures that would reduce the risk to Fraser River Sockeye Salmon abundance and diversity due to *Moritella viscosa* transfer from Atlantic Salmon farms in the Discovery Islands area.

ANALYSIS

Characterization of *Moritella viscosa* and Winter Ulcer

The following summary highlights the key aspects of *M. viscosa* and winter ulcer relevant to the risk assessment; for more details refer to Wade and Weber (2020).

Winter ulcer is typically a disease of Atlantic Salmon reared in cold temperatures, usually during the winter (Lunder et al., 2000; Toranzo et al., 2005). The main aetiological agent of the disease is *M. viscosa* (Løvoll et al., 2009; Tunsjø et al., 2009; Björnsson et al., 2011; Karlsen et al., 2017a; Karlsen et al., 2017b), a bacterium that can survive and proliferate in an oligotrophic and cold environment (Tunsjø et al., 2007) and that has been isolated from cold shallow waters (Urakawa, 2014).

Winter ulcer has been reported in farmed and wild salmonids in Norway, Scotland and Iceland (summarized in Wade and Weber (2020)). In British Columbia (BC), winter ulcer was first reported on Atlantic Salmon farms in December 2011 and the Fish Health Audit and Surveillance Program started screening for *M. viscosa* in 2012. Between 2012 and 2018, winter ulcer was diagnosed at the farm-level in 17 of the 715 (2.4%) audits conducted on Atlantic Salmon farms in BC through the Fish Health Audit Surveillance Program. Between the end of 2011 and 2018 (excluding 2013 to 2015), 13 Fish Health Events were attributed to winter ulcer on Atlantic Salmon farms in BC. Between 2011 and 2018, one mortality event was attributed to winter ulcer on an Atlantic Salmon farm in BC. Refer to Wade and Weber (2020) for more details.

There are no reports of *M. viscosa* isolation or winter ulcer in wild Pacific salmon species and the disease has not been reported on Pacific Salmon farms in BC (DFO, 2019a, b, c). However, there has been molecular evidence of *M. viscosa* from two of 2,006 juvenile Sockeye Salmon samples collected in June 2013, using high-throughput microfluidics quantitative polymerase chain reaction (qPCR) (Nekouei et al., 2018).

Two phenotypic and genotypic clades of the bacterium (typical and variant) have been identified from an analysis of 40 different strains isolated from different geographic locations (Grove et al., 2010). Only the 'variant' form has been isolated from Canadian farmed Atlantic Salmon, without further identification of where the fish were sampled (Grove et al., 2010). There is evidence of strain-specific geographical distribution of the bacterium. For instance, Eastern Canadian isolates of *M. viscosa* have been associated with skin ulcer disease in temperatures above 10°C (MacKinnon et al., 2019).

Infection with *M. viscosa* resulting in winter ulcer in BC appears similar to those described in farmed Atlantic Salmon in Norway, Scotland and Iceland, with an onset at temperatures <8-10°C, recovery or no incidence of infection at temperatures >10°C, superficial wounds, and the isolation of *M. viscosa* (Lunder et al., 1995; Benediktsdóttir et al., 1998; Bruno et al., 1998).

There is little known about the epidemiology of winter ulcer in BC and most of the available information on the outbreaks arise from studies in other countries, especially Norway. Transmission pathways among farmed fish are still unknown (Lunder et al., 1995; Burnley, 2011).

In Norway, co-infection with other bacteria is common, particularly *Tenacibaculum* spp. and *Aliivibrio wodanis* (Olsen et al., 2011; Karlsen et al., 2014). Cumulative mortality in Norwegian outbreaks is most commonly reported at approximately 10% (Lunder et al., 1995; Olsen et al.,

2011) but has been reported as high as 40% (Hoffman et al., 2012). To date, no studies have been conducted to describe the virulence of *M. viscosa* strains from BC Atlantic Salmon.

There are several important knowledge gaps related to BC strains of *M. viscosa* and the epidemiology of winter ulcer in BC including: natural reservoirs and vectors; transmission pathways; susceptibility of different Pacific salmon species; environmental and biological factors contributing to infection and disease development; and applicability of results from studies conducted on Atlantic Salmon on the East Coast of Canada.

Moritella viscosa Transfer Risk Assessment

The risks to Fraser River Sockeye Salmon abundance and diversity due to *M. viscosa* transferred from Atlantic Salmon farms operating in the Discovery Islands area (see Figure 1) were assessed under current health management practices.

Current fish health management practices include regulatory requirements (e.g., Salmonid Health Management Plan (SHMP) and accompanying proprietary Standard Operating Procedures (SOPs) and regulations of the movement of live fish) and additional voluntary industry practices (e.g., surveillance and testing, use of nursery sites, vaccination).

The risk assessment relied on the current state of knowledge of *M. viscosa* and was informed by 2012 to 2018 fish health data on Atlantic Salmon farms in the Discovery Islands area (i.e., data provided by the industry, results from the Fish Health Audit and Surveillance Program, Fish Health Events and mortality events). The risk assessment followed three main steps being a likelihood assessment, a consequence assessment and an estimation of risk.

Likelihood Assessment

The likelihood assessment was conducted through four sequential assessments: farm infection, release, exposure and infection assessments. Each step of the likelihood assessment assumes that current management practices on Atlantic Salmon farms are followed and maintained. The main considerations and conclusions of each step are reported here.

Farm infection assessment

The farm infection assessment determined the likelihood that farmed Atlantic Salmon infected with *M. viscosa* are present on one or more farms in the Discovery Islands area in a given year.

In Canada, vaccination for the prevention of winter ulcer is a common practice by the industry in BC.

Between 2012 and 2018, industry detected molecular evidence of *M. viscosa* in two years on Atlantic Salmon farms in the Discovery Islands area. In the same period, fish health audits reported the isolation of *M. viscosa* (or *Moritella* sp.) in four different years, the diagnoses of ulcerative dermatitis though histology in two different years, and the diagnosis of winter ulcer at the farm-level in one year. Finally, between 2012 and 2018, one Fish Health Event attributed to winter ulcer was reported on an Atlantic Salmon farm in the Discovery Islands area. The disease was not attributed to mortality events on Atlantic Salmon farms in the Discovery Islands area.

Overall, between 2012 and 2018, *M. viscosa* was detected from individual fish or winter ulcer was diagnosed at the farm level on at least one Atlantic Salmon farm in the Discovery Islands area in six of the last complete seven years. It was, therefore, concluded with reasonable certainty that, in any given year, the likelihood of farmed Atlantic Salmon infected with *M.*

viscosa are present on one or more Atlantic Salmon farms in the Discovery Islands area is very likely under the current farm management practices.

Release assessment

The release assessment determined the likelihood that any *M. viscosa* would be released from an Atlantic Salmon farm located in the Discovery Islands area into an environment accessible to Fraser River Sockeye Salmon assuming Atlantic Salmon infected with the bacterium are present on at least one farm. Two potential release pathways were considered: release through infected farmed Atlantic Salmon; and mechanical vectors (e.g., personnel, visitors and wildlife) and fomites (e.g., farm equipment and vessels).

Despite the limited evidence of shedding and horizontal transmission (i.e., spread from fish to fish) of *M. viscosa* under experimental conditions, it was concluded with reasonable certainty that the bacterium is extremely likely to be released from an infected Atlantic Salmon farm into the marine environment.

As part of licence requirements, biosecurity and biocontainment practices are specified in Salmonid Health Management Plans and associated SOPs. Low levels of operational deficiencies related to fish health on Atlantic Salmon farms in the Discovery Islands area have been documented in DFO's Fish Health Audit and Surveillance Program and summarized by Wade (2017), it was, therefore, concluded with reasonable certainty that the likelihood of release through vectors or fomites is unlikely under the current fish health management practices.

The overall likelihood of release was obtained by adopting the highest likelihood of the release pathways. Therefore, it is extremely likely that *M. viscosa* would be released from an infected Atlantic Salmon farm.

Exposure assessment

The exposure assessment determined the likelihood that at least one Fraser River Sockeye Salmon would be exposed to *M. viscosa* in a given year assuming that the bacterium was released from at least one Atlantic Salmon farm in the Discovery Islands area. Two exposure groups were considered: juvenile and adult Fraser River Sockeye Salmon.

The exposure assessment examined whether winter ulcer on Atlantic Salmon farms occurred during the same time period that Fraser River Sockeye Salmon migrate through the Discovery Islands area.

Between 2012 and 2018, evidence of *M. viscosa* (i.e., molecular detection of the bacterium, culture isolation of the bacterium, identification of ulcerative dermatitis through histology, or winter ulcer diagnoses) on Atlantic Salmon farms in the Discovery Islands area were reported in the months of December, January and February.

Juvenile lake-type Fraser River Sockeye Salmon migrate through the Discovery Islands area from approximately mid-May to mid-July, while returning adults migrate through the area from approximately late-June to early-October (reviewed in Grant et al. (2018)). To account for annual variations in migration timing, it was assumed that juveniles could be present in the Discovery Islands area from the beginning of May through the end of July. Similarly, for returning adults, it was assumed that adult Sockeye Salmon could be present in the Discovery Islands area from the beginning of June through to the end of October.

Between 2012 and 2018, there was no evidence of temporal overlap between migrating Fraser River Sockeye Salmon and *M. viscosa* infections on Atlantic Salmon farms in the Discovery Islands area. It was, therefore, concluded with reasonable certainty that it is extremely unlikely that at least one juvenile or adult Fraser River Sockeye Salmon would be exposed to *M. viscosa* attributable to Atlantic Salmon farms located in the Discovery Islands area.

Infection assessment

Given that infection is dependant on exposure, an infection assessment was not performed as it is extremely unlikely that Fraser River Sockeye Salmon would be exposed to *M. viscosa* attributable to Atlantic Salmon farms in the Discovery Islands area. Consequently, without exposure, there will be no chance for infection to occur.

Overall likelihood assessment

Table 1 summarizes the likelihood assessment. Overall, it was concluded that the likelihood that Fraser River Sockeye Salmon would become infected with *M. viscosa* released from Atlantic Salmon farms in the Discovery Islands area is extremely unlikely for both juvenile and adult Fraser River Sockeye Salmon. This conclusion was driven by the likelihood of exposure, which was determined to be extremely unlikely given no temporal overlap between migrating Fraser River Sockeye Salmon (May to October) and the evidence of infection with *M. viscosa* or winter ulcer (December to February) on Atlantic Salmon farms in the Discovery Islands area.

Uncertainties for each step in the likelihood assessment are not combined but are rather reported separately for clarity and transparency.

Table 1. Summary of the likelihood and uncertainty rankings for the likelihood assessment of the Moritella viscosa *risk assessment. Descriptions of the uncertainties can be found with each likelihood assessment steps; uncertainties are not combined. Estimates are reported in white cells and likelihood combination results are reported in shadowed cells under the "Rankings" column.*

Step		**Ranking**	
Farm infection assessment	**Likelihood *(uncertainty)***	Very likely *(reasonable certainty)*	
Release assessment	**Release pathways**	**Farmed Atlantic Salmon**	**Mechanical vectors and fomites**
	Likelihood *(uncertainty)*	Extremely likely *(reasonable certainty)*	Unlikely *(reasonable certainty)*
	Combined likelihood	Extremely likely	
Exposure assessment	**Exposure groups**	**Fraser River Sockeye Salmon (juveniles and adults)**	
	Likelihood *(uncertainty)*	Extremely unlikely *(reasonable certainty)*	
Infection assessment	**Likelihood *(uncertainty)***	Not performed	
Overall likelihood for each exposure group (combination of all four steps)		Extremely unlikely	

Consequence Assessment

Given that the consequence is dependant on infection, a consequence assessment was not performed because it was extremely unlikely that Fraser River Sockeye Salmon would be infected with *M. viscosa* attributable to Atlantic Salmon farms in the Discovery Islands area. Without infection, no consequences to the abundance and diversity of Fraser River Sockeye Salmon attributable to Atlantic Salmon farms in the Discovery Islands area are expected.

Risk Estimation

The estimated risks to the abundance and diversity of Fraser River Sockeye Salmon are based on the results of the likelihood and consequence assessments. Risk matrices were developed, in Mimeault et al. (2017), and are aligned with relevant scales of consequences for DFO fisheries management and policy purposes, existing policy and current management risk tolerances relevant to the risk assessment.

Given the lack of temporal overlap between Fraser River Sockeye Salmon and evidence of *M. viscosa* on Atlantic Salmon farms in the Discovery Islands area, there is no risk (minimal risk) to the abundance and diversity of Fraser River Sockeye Salmon as a result of *M. viscosa* infection attributable to Atlantic Salmon farms in the Discovery Islands area under the current farm practices.

Sources of Uncertainty

Sources of uncertainty related to this risk assessment are limited to: (i) variability and knowledge gaps about the precise migration routes of lake-type Fraser River Sockeye Salmon through the Discovery Islands area; (ii) knowledge gaps about horizontal transmission and the

shedding rates from *M. viscosa*-infected Atlantic Salmon; and (iii) knowledge gaps about the level of susceptibility of Sockeye Salmon to *M. viscosa*.

The risk estimates of this assessment are, however, not sensitive to these uncertainties (i.e., they are not expected to change the final risk estimates (outcomes of the assessment)) given the lack of evidence of temporal overlap between *M. viscosa* infection on Atlantic Salmon farms and the presence of migratory Fraser River Sockeye Salmon in the Discovery Islands area.

CONCLUSIONS

Characterization of *Moritella viscosa* and winter ulcer

Winter ulcer on Atlantic Salmon farms in BC was first reported by the industry in 2011 and the Fish Health Audit and Surveillance Program started screening for the causative agent, *M. viscosa,* in 2012.

Between 2012 and 2018, winter ulcer was diagnosed at the farm-level in 17 fish health audits conducted on Atlantic Salmon farms in BC. Between the end of 2011 and 2018 (excluding the years 2013 to 2015), 13 Fish Health Events have been attributed to winter ulcer on Atlantic Salmon farms in BC. Between 2011 and 2018, one mortality event has been attributed to winter ulcer on an Atlantic Salmon farm in BC.

To date, there is no evidence of winter ulcer in Pacific salmon species in BC, but one study reported the molecular detection of the bacterium in two juvenile Sockeye Salmon using high-throughput microfluidics qPCR.

Most of available information on the disease and pathogen are from studies conducted on farmed Atlantic Salmon in Norway and Iceland. In the literature, most reports of winter ulcer or *M. viscosa* in salmonids are in Atlantic Salmon and sea farmed Rainbow Trout.

Given to the paucity of winter ulcer and *M. viscosa* literature specific to Atlantic Salmon cultured in BC, surrogate information from studies conducted elsewhere were considered. Infection with *M. viscosa* resulting in winter ulcer in BC appears similar to those described in farmed Atlantic Salmon in Norway, Scotland and Iceland. The basic characteristics of the disease and infection are similar in these two regions: onset at temperatures below 8-10^{o}C, recovery or no incidence of infection at temperatures > 10^{o}C, superficial wounds, and the isolation of *M. viscosa*. It was, therefore, reasonable to use the results from studies conducted on these strains of Atlantic Salmon in the absence of BC specific data. Utilizing disease and infection data from the east coast of Canada appeared less relevant to the BC context because the onset of disease and its epidemiology are markedly different from the reported cases in BC.

Moritella viscosa Transfer Risk Assessment

The assessment concluded that *M. viscosa* attributable to Atlantic Salmon farms in the Discovery Islands area poses minimal risk (no risk) to Fraser River Sockeye Salmon abundance and diversity under the current farm practices.

The attribution of the minimal risk was mainly influenced by the extremely unlikely exposure of Fraser River Sockeye Salmon to *M. viscosa* attributable to Atlantic Salmon farms in the Discovery Islands area given the lack of temporal overlap between Fraser River Sockeye Salmon migration timing and *M. viscosa* infections on Atlantic Salmon farms in the Discovery Islands area.

There are sources of uncertainty related to this risk assessment; the conclusions are, however, not sensitive to these uncertainties given the lack of evidence of temporal overlap between *M. viscosa* infection on Atlantic Salmon farms and Fraser River Sockeye Salmon in the Discovery Islands area. However, if winter ulcer outbreaks were to be reported between May and October on Atlantic Salmon farms in the Discovery Islands area, this risk assessment would have to be revised.

RECOMMENDATION

- If winter ulcer outbreaks on Atlantic Salmon farms in the Discovery Islands area begin to overlap with migrations of Fraser River Sockeye Salmon, this risk assessment would have to be revised.

OTHER CONSIDERATIONS

The considerations below should be considered in all fish pathogen transfer risk assessments in the Discovery Islands area.

- The long-term impacts of changing climatic conditions on the bacteria, farmed salmon and wild salmon will need to be better understood and investigated.
- The Discovery Islands area is not the only area along the migration route of Fraser River Sockeye Salmon where Atlantic Salmon farms are located.

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SOURCES OF INFORMATION

This Science Advisory Report is from the December 3-5, 2019 National Peer Review Meeting on the Assessment of the risk to Fraser River Sockeye Salmon due to bacteria causing erosive lesions transferred from Atlantic Salmon farms located in the Discovery Islands area, British Columbia. Additional publications from this meeting will be posted on the Fisheries and Oceans Canada (DFO) Science Advisory Schedule as they become available.

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