

**From:** Miller-Saunders, Kristi  
**Sent:** Wednesday, August 3, 2022 4:51 PM  
**To:** Candy, John  
**Cc:** Chamberlain, Jon  
**Subject:** RE: Informal aquaculture request - notes\_KM.docx  
**Attachments:** Salmon diseases and parasites New Template July 29 2022\_KM.docx

Here are my revisions. It is always dismaying to see statements like “the department uses a weight of evidence approach that combined laboratory and field studies to assess risk” and then see that all of the field studies from the SSHI have been completely wiped from the document, over and over again. Why can we not be open and honest about what we know and do not know? Such a one-sided viewpoint repeatedly presented to the public and the minister.

Kristi

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**From:** Candy, John <John.Candy@dfo-mpo.gc.ca>  
**Sent:** Wednesday, August 3, 2022 10:35 AM  
**To:** Miller-Saunders, Kristi <Kristi.Saunders@dfo-mpo.gc.ca>  
**Subject:** Informal aquaculture request - notes\_KM.docx

Kristi  
Is this the one?  
Jon



## **Salmon diseases and parasites**

### **Sea lice**

Sea lice are naturally occurring parasites that have lived in coastal waters for thousands of years. While sea lice generally do not harm adult fish, high numbers of sea lice can harm very small juvenile salmon, with some variability of virulence among salmon species. There are concerns that sea lice from Atlantic salmon farms have a negative impact on wild salmon.

Ongoing efforts aim to determine the potential impacts of sea lice on wild salmon populations, including research on sea lice tolerance to various environmental conditions, interactions between sea lice and host fish, impacts of co-infections, non-chemical treatment options, and effects of different farm management strategies on sea lice levels on wild salmon. For example, a recent DFO study highlighted lower tolerance to sea lice infection of sockeye compared to size-matched Atlantic salmon.



The Department's overall management of sea lice and fish health on farms, including mitigation measures, is adaptive and will continue to be revised as new scientific information becomes available.

### Infectious Salmon Anaemia Virus (ISAV)

Infectious salmon anaemia (ISA) is a viral finfish disease which can cause high mortality in affected fish populations. The virus is not a risk to human health.

Outbreaks of ISA have been reported in Atlantic Canada on salmon farms. ~~However,~~ While there have been no reports of this disease in any wild species of fish in Atlantic Canada, there has been no directed study; given the acute nature of the disease that occurs in the ocean, where mortality of free-migrating salmon is not observable, probability of detection is low. The ISA virus has not been found-detected in the Pacific in any wild or farmed fish, despite extensive monitoring.

**Commented [MSK1]:** This statement, as originally written, is meaningless, as there are not monitoring programs for this virus or disease in wild fish that I am aware of, and it would be virtually impossible to detect even if it were. Just look at the extensive monitoring we have conducted in the Pacific, where agents of acute diseases are rarely, if ever, observed. This does not mean that these agents never infect, or in fact impact wild fish, but is an impact of live-only sampling programs.



Research is ongoing to better understand the impacts of ISA outbreaks at Atlantic Canada fish farms on wild fish.

### Tenacibaculum maritimum

Tenacibaculum maritimum is a bacterium found worldwide in several species of marine fish, in the water column, and on surfaces. Tenacibaculum maritimum causes the ulcerative disease tenacibaculosis in marine fish and salmon worldwide, but has largely been studied in cultured fish. In farmed BC Atlantic salmon BC, it can cause a unique form of tenacibaculosis disease known as mouthrot or yellow, mouth in farmed salmon, with mortality controlled by antibiotic treatment. When treated appropriately, mouthrot generally does not cause high mortality.

Mouthrot occurs commonly in BC juvenile farmed Atlantic salmon, and is the disease most often requiring antibiotic treatment on BC farms.

Tenacibaculum maritimum causes tenacibaculosis, an ulcerative disease resulting in body sores and fraying of gills and fins. Tenacibaculosis occurs, in all Pacific salmon

**Commented [MSK2]:** Are there actually studies on wild fish? Can we back this statement up with evidence that there have been directed studies?

**Commented [MSK3]:** eDNA detections in the water column is absolutely strongest near farms.



species cultured in sea pens worldwide. In the 1990's, this disease decimated the Chinook farm industry in California, although it has not been commonly documented on Chinook farms in the brackish waters of Clayoquot sound. Farming of Chinook salmon in California was curtailed by the inability to control tenacibaculosis-caused mortalities in the 1990s. It has been identified twice in farmed Chinook salmon, over a decade ago. While

Recent research has confirmed the presence of the bacterium on juvenile wild salmon species, and models based on a decade of infection data has revealed that this bacterium is consistently associated with ocean survival and relative weight of salmon condition across Chinook, coho and sockeye salmon. Tenacibaculum levels in the water column are concentrated around active farms, and a recent study showed that fFarms in the Discovery Islands werehave been -also identified as a key transmission risk to migrating Fraser River sockeye salmon. presence of disease in wild fish has not been reported in the Pacific Northwest. Dedicated studies have not



~~been carried out to assess the presence of the disease in wild salmon species.~~

DFO reviews new scientific evidence as it becomes available, and can implement adaptive management measures and reconsider their findings pertaining to risk.

### Piscine orthoreovirus (PRV)

Piscine orthoreovirus (PRV) is a widely distributed virus that is commonly found on farmed salmon and has ~~also~~ been detected at generally lower levels on wild Pacific salmon species. The virus is not a risk to human health.

Infections with PRV result in different outcomes depending on the variant, host species, and the environment. In farmed Atlantic salmon, PRV ~~has caused~~ Heart and Skeletal Muscle Inflammation (HSMI), with broad-scale impacts on farms in Norway and Chile. HSMI has also been observed in Canada, but appears less impactful. in Norway and has been associated with HSMI-like disease in Canada.

**Commented [MSK4]:** Note that in specific areas in the winter period, it can rise to >50% in Chinook salmon.

**Commented [MSK5]:** The disease is not HSMI-like, it is HSMI, but when you combine the prevalence on farms, and the challenge data, it appears less impactful; but the demonstration that the virus can and does cause the pathological lesions diagnostic of the disease is confirmed.



In farmed Chinook salmon, PRV ~~has infection been associated~~ is associated with a jaundice and anemia disease, with similar pathological lesions in association with PRV infection occurring in wild Chinook salmon. Similar jaundice and anemia related diseases caused by various strains of PRV have also been described in Pacific salmon species in Japan, Norway and Chile. Importantly, population-level associations with ocean survival and condition of fish during their first winter at sea have been observed ~~demonstrated~~ for Chinook and coho salmon. Moreover, epidemiological models show that open net salmon farms are strongly associated with transmission of PRV to wild BC Chinook and coho salmon.

DFO scientists, in collaboration with other researchers, are addressing concerns about ~~potential transmission risks~~ of PRV between wild and farmed and wild salmon and its factors influencing its ability to cause disease in Atlantic and Pacific salmon.

Scientists in my Department use a weight of evidence approach, including information from lab

**Commented [MSK6]:** We know that "PRV" causes disease in Pacific and Atlantic salmon worldwide, what we don't know is what additional factors contribute to the development and impacts of disease.

**Commented [MSK7]:**

**Commented [MSK8R7]:** Mortality has NEVER been demonstrated in laboratory challenges with PRV, so this is not a meaningful statement. I would delete this entire paragraph, because the fact of the matter is that DFO has largely used laboratory studies as the sole piece of information to inform risk and to negate all field-based findings.



~~experiments and field surveys, to study the transmission and virulence of PRV to address potential impacts. To date, PRV infections of farmed Atlantic salmon in Pacific Canada are of low virulence and cause little to no mortality.~~

As PRV research evolves, DFO will continue to consider the growing base of evidence in risk assessment and decision-making to protect Canada's marine resources.

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## **Background**

### Sea Lice

- Sea lice are naturally occurring parasitic copepods that have lived in coastal waters for thousands of years. Wild salmonids (adult and juvenile) and non-salmonids host sea lice but the levels vary with fish species, age of fish, environmental conditions, location and temporally (seasonally/annually/daily) as well as with sea lice species.
- Salmon stocked into marine cages are initially free of sea lice, but may acquire sea lice infestations from wild marine fish or from other farmed fish in the area. The result is that many salmon farming areas experience some level of sea lice infestations.
- Serious fish health issues can occur when salmon are heavily infected by sea lice. This is especially true for farmed Atlantic salmon in the Atlantic provinces, and low tolerance has recently been demonstrated in sockeye salmon in the Pacific. Sea lice feed on the skin and associated mucus, and when present in high numbers their feeding activities can lead to the development of open wounds. Damage caused by sea lice feeding may increase the opportunity for infection with pathogens, cause osmotic and other stress, and can ultimately lead to the death of the host. In BC, disease impacts resulting from sea lice infestations are mainly known to occur on salmon farms when infestation rates are extremely high, but all salmon species are likely vulnerable, as demonstrated from a more global perspective.
- Transmission of sea lice between and within wild fish populations and salmon farms is known to occur; however, the dynamics of transmission of sea lice between and within wild fish populations and salmon farms will depend on a multitude of environmental and biological factors, and will be site and time-dependent. The period of outmigration of juvenile wild salmon represents the period of highest risk of sea lice infestation to wild salmon.



- Across Canada, sea lice on farmed salmon are typically managed through harvesting, topical pesticides, in-feed medications and a variety of other non-chemical treatments. ~~In recent years, mechanical removal of lice has been applied. Licensed veterinarians use in-feed drugs, authorized for use by Health Canada's Veterinary Drugs Directorate, and pesticides, registered for use by the Pest Management Regulatory Agency within Health Canada, to treat fish at aquaculture sites. Veterinarians consider a variety of site-specific information to determine the appropriate prescription for maintaining the health of farmed fish. Resistance to anti-parasite drugs has been a common issue in sea lice control in aquaculture farms worldwide, and the decrease in efficacy of this treatment has, in recent years, spread to areas of the BC coast. As a result, more and more the industry has employed mechanical removal to control lice levels on farms, but these treatments can be stressful on the fish and can result in spikes in mortality and vulnerability to opportunistic diseases. In recent years, mechanical removal of lice has been applied as resistance to chemical treatments has risen. Drug resistance has developed everywhere in the world salmon are farmed, but is a relatively recent occurrence in BC.~~
- DFO scientists have undertaken more than 15 years of intensive research to improve our knowledge and understanding of sea lice biology. Ongoing research efforts aim to determine the potential impacts of sea lice to wild salmon populations including modeling sea lice infections on wild salmon under various farm sea lice management regimes, sea lice tolerance to various environmental conditions, host-parasite interactions, impacts of co-infections, and non-chemical treatment options.

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Infectious Salmon Anaemia Virus (ISAV)

- Infectious salmon anaemia (ISA) is a reportable disease listed under the federal *Health of Animals Act*, promulgated by the Canadian Food Inspection Agency (CFIA). Infection with the virus can result in death rates of up to 90 per cent in the affected farmed finfish populations. However, only some strains of the virus cause disease and potentially kill finfish. Most of the virus strains identified in the Atlantic region do not lead to disease or death.
- Outbreaks of this disease have been reported in Atlantic Canada on salmon fish farms since 1996. There have been concerns expressed in the past on the potential impact of these outbreaks on wild salmon stocks. To date, there have been no reports of any wild species of fish in Atlantic Canada being diseased.
- Although outbreaks of ISA occur in farmed Atlantic salmon, other fish species have been experimentally infected without showing clinical signs of the disease. Most Pacific salmon and rainbow trout are resistant to the disease.
- ISA has been tested for routinely in BC for over a decade, and has never been found. It is not considered to be endemic.
- Fisheries and Oceans Canada (DFO) works in collaboration with the CFIA to deliver the National Aquatic Animal Health Program to protect Canada's aquatic animal's resources and productivity by reducing the potential for the introduction and spread of aquatic animal diseases. DFO provides the diagnostic testing, research and science advice in support of CFIA's regulatory role.
- Over the years, DFO's Science sector has undertaken scientific research characterizing ISA and improving detection methods, and continues to further investigate factors affecting Atlantic salmon susceptibility to ISA, and sub-lethal effects of the virus on salmon. This research will improve our understanding of the impacts of aquaculture ISA outbreaks on wild fish, but given the acute nature of the disease that occurs in the ocean, where mortality of free-migrating salmon is not observable, probability of detection is low. The ISA virus has not been detected in the Pacific in any wild or farmed fish, despite extensive monitoring.

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Tenacibaculum maritimum

- *T. maritimum* is a bacterium with global distribution that occurs naturally in the marine environment, including at elevated levels near active salmon farms, and has been found on fish surfaces with and without signs of disease. It is especially concentrated in water around active salmon farms commonly found in the ocean in coastal British Columbia (BC).

**Commented [MSK9]:** Where are the "data" that it is commonly found in the "ocean" in BC? I don't know of any such studies. Lots of studies detecting it in fish—but I don't see anything but studies coming out of my lab that have looked at ocean water. We need to be factual here, not arm waving.



- The bacterium causes tenacibaculosis in a number of marine fish, including Pacific salmon. In BC, under the right conditions, the bacterium may cause a unique form of version of tenacibaculosis disease called "mouthrot" or "yellow mouth" in farmed Atlantic salmon.
- Tenacibaculosis has been documented in farmed Pacific salmon worldwide, including severe outbreaks in netpen reared Chinook salmon in California, but has not been extensively noted in BC farmed Chinook, largely cultured in low salinity brackish environments.
  - Mouthrot is currently the most treated disease in BC farmed Atlantic salmon, mostly impacting fish soon after ocean transfer. Mortality levels can be controlled with antibiotic treatment.
- A 2021 Canadian Science Advisory Secretariat (CSAS) peer reviewed risk assessment determined that *T. maritimum* attributable to Atlantic salmon farms in the Discovery Islands area poses minimal risk to Fraser River sockeye salmon abundance and diversity under the current farm practices.
- Subsequent to the DFO risk assessment, two studies published in 2022 have confirmed the presence of the bacterium on juvenile wild salmon species, and models based on 10 years of data across two dozen infectious agents found Tenacibaculum showed among the strongest, most consistent associations with population-level variance in salmon survival and relative weight for Chinook, coho, and sockeye salmon in the ocean. Moreover, a different study showed that the probability of detecting the agent *Tenacibaculum maritimum* in sockeye salmon is elevated as fish pass by Discovery Island farms. *T. maritimum* spillover effects from farms have also been demonstrated based on detections of the bacterium in the water column, which show the highest rates of detection near active farms.
- These studies provide the most compelling evidence that Tenacibaculum may pose a risk to wild Pacific salmon, although they did not directly study the disease tenacibaculosis in wild fish. However, the study authors recommend a precautionary approach to managing wild/farmed interactions given that disease caused by *T. maritimum* is commonly observed in farmed Atlantic and Pacific salmon around the world.
- As stipulated in the CSAS Risk Assessments, as research on *Tenacibaculum maritimum* and other assessed agents evolves, DFO will consider the growing base of evidence in risk assessment and decision making to protect Canada's marine resources. Continuing research on *T. maritimum* helps to improve our understanding of the bacterium and its disease effects; the Department will continue to consider the growing base of evidence in their decision-making.

**Commented [MSK10]:** Why has all of the SSHI data been wiped out of this document yet again? So much for weight of evidence approach.

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Piscine orthoreovirus (PRV)

- PRV is a virus that commonly infects farmed Atlantic and Chinook salmon in BC, but has been detected at relatively lower prevalence across all Pacific salmon species in BC.
- There are three main genogroups of PRV (PRV-1, -2, and -3). Analyses of PRV-1 genomes concluded that the PRV-1 variants found in the North Pacific Ocean and Chile are genetically distinct from each other but are related, being descendants from the North Atlantic Ocean variant.
- PRV-1a clearly originates from Norway, but has been detected in the North Pacific Ocean over the past 30 years, consistent with sequence-based epidemiological studies that date the original introduction of PRV-1a to around 30-40 years ago. PRV-1a detections among wild Pacific salmon vary by species, with an overall prevalence of about 4.7% (juvenile and adults combined). Observed prevalence in free-ranging Chinook salmon sampled off the west coast of Vancouver Island in the fall and winter periods can exceed 30%.
- Similar to all pathogens, an infection with PRV does not necessarily equal disease. In B.C., nearly all farmed Atlantic salmon reared in marine net pens become infected with PRV-1a prior to harvest yet the disease Heart and Skeletal Muscle Inflammation (HSMI) caused by PRV was not specifically

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diagnosed until the Strategic Salmon Health Initiative identified it on a farm in 2015. There has only been only one other farm-level diagnosis of HSMI, but as the diagnostic criteria used in BC are more stringent than other parts of the world, and the disease is not reportable, it is difficult to establish the relative prevalence of this disease with farms in other countries, although it is considered to be more rare than in Norway or Chile, where it can be observed across a large proportion of farms. An infection with PRV-1 does not equal disease.

- In Norway, and most recently Chile, most farmed Atlantic salmon are expected to become PRV-1 positive, while only some develop disease (that is Heart and Skeletal Muscle Inflammation (HSMI) in farmed Atlantic salmon). This is the most common disease in farmed Norwegian salmon impacting hundreds of farms per year.
- In Canada, PRV-1 is also highly prevalent on farms, and there is an ongoing debate as to whether HSMI has ever been present. Two cases of HSMI-like symptoms have been reported to date, but unlike Norway, this disease could not be transmitted to native fish in a laboratory setting.
- Disease manifestations relating to PRV infection described in Atlantic and Pacific salmon differ in the degree of inflammatory response vs anemia and necrotic lesions. BC farmed Chinook salmon with high levels of PRV show the same jaundice and anemia related disease manifestation as observed in farmed coho salmon and rainbow trout infected with various PRV strains in other parts of the world. Moreover, wild Chinook salmon with high levels of PRV infection show the same early pathological lesions that lead to jaundice disease, and associations with population-level impacts on survival have been demonstrated for Chinook and coho salmon. Salmon condition is also impacted by PRV infection in Chinook salmon.
- A recently published study showed that probability of infection in Chinook was elevated with exposure to active salmon farms, and sequence-based epidemiology showed that farmed and wild salmon carry many of the same variants of the virus, consistent with active transmission.
- Due to concerns over the introduction of PRV into marine ecosystems via smolt transfer from hatcheries, The Department conducted a two-year survey with support from both private and First Nations diagnostic laboratories, which began in August 2019, to screen freshwater aquaculture hatcheries for the presence of both native and non-native strains of PRV in order to inform regulatory decision making.
- While field-based studies have demonstrated associations between PRV infections and impact of the variant currently present in BC (PRV-1a), DFO is collaborating with the CFIA on a joint risk assessment of the potential impacts on wild and farmed salmon of the entry and establishment of additional PRV variants that are not endemic currently present into BC waters.

**Commented [MSK11]:** Note that there will be more diagnostic cases reported soon.

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