

Hypothesis: Diseases in freshwater and marine systems are an important contributor to the Fraser sockeye situation

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A pathogen can be defined as an agent (e.g. virus, bacterium, fungi or parasite) that has the potential to causes disease. Whereas, disease refers to a pathological condition, that has characteristic signs, that can result from various causes including infection with pathogens. For the purposes of this discussion it is important to remember that the presence of a pathogen doesn't always mean that a disease condition exists. The factors that lead to the development of disease due to a pathogen are outlined in more detail below.

Infectious diseases are recognized as being a dominant selective force in influencing human populations; however, the role that disease plays in wildlife populations is much less understood. In fact there are relatively few examples that have demonstrated a role for infectious disease in the structuring of terrestrial and aquatic animal populations. With respect to fish, studies examining *Schistocephalus solidus* in three-spined stickleback, and viral hemorrhagic septicemia virus and *Ichthyophonus hoferi* in Pacific herring have documented population level impacts (Pennycuik 1971, Marty et al. 2010).

A diverse range of pathogens including viruses, bacteria, fungi and parasites have been shown to infect sockeye salmon. Some common pathogens of sockeye salmon are listed in Table 1. This table is not a comprehensive list of all infectious agents of sockeye salmon as more than 50 other pathogens, whose pathogenicity is not well known, have been reported from sockeye salmon in British Columbia.

Table 1. Common pathogens of sockeye salmon. Pathogens detected in the Fraser River are highlighted in green.

| | Pathogen | Disease |
|-----------|---|---|
| Bacteria | <i>Renibacterium salmoninarum</i> | Bacterial Kidney Disease (BKD) |
| | <i>Aeromonas salmonicida</i> | Furunculosis |
| | <i>Yersinia ruckeri</i> | Enteric Redmouth Disease (ERM) |
| | <i>Flavobacterium branchiophila</i> | Bacterial Gill Disease (BGD) |
| | <i>Vibrio Spp.</i> | Vibriosis |
| | <i>Pseudomonas Spp.</i> | |
| | <i>Flexibacter</i> | Columnaris disease |
| Viruses | Infectious hematopoietic necrosis virus | Infectious hematopoietic necrosis (IHN) |
| | Erythrocytic necrosis virus | Erythrocytic necrosis (ENV) |
| | Salmonid herpesvirus | |
| Parasites | <i>Parvicapsula minibicornis</i> | |
| | <i>Ichthyophthirius multifiliis</i> | Ich or white spot disease |
| | <i>Loma salmonae</i> | |

| | | |
|--------|----------------------------------|------------------------------------|
| | <i>Eubothrium salvelini</i> | |
| | <i>Myxobolus articus</i> | |
| | <i>Tetracapsula bryosalmonae</i> | Proliferative kidney disease (PKX) |
| | <i>Lepeophtheirus salmonis</i> | |
| | <i>Caligus clemensi</i> | |
| | <i>Cryptobia salmositica</i> | |
| | <i>Kudoa thyrsites</i> | |
| | <i>Myxobolus cerebralis</i> | |
| Fungus | <i>Icthyophonus hoferi</i> | |
| | <i>Phoma herbarum</i> | |

As mentioned previously the presence of a pathogen in a sockeye salmon does not necessarily equate to disease or compromised health conditions. The determinants of disease are multifactorial and whether a sockeye salmon becomes diseased depends upon complex interactions between the host, the pathogen, and the environment in which these interactions take place. Due to this complexity, it is extremely difficult to predict occurrence and severity of disease and what if any role disease plays in structuring Fraser River sockeye populations.

Based on our knowledge of infectious diseases of fish, potential impacts on Fraser sockeye salmon populations can occur directly through mortality of individuals or indirectly through changes in various performance parameters including, but not limited to, swimming ability, growth, osmocompetence and reproduction. However, quantification of these disease impacts in wild fish can be difficult and fish mortality due to disease can go unnoticed or underestimated due to the rarity of carcasses. Additionally, if the impact is indirect (i.e. infectious disease increases susceptibility to predation due to reduced swimming performance) then the roles of numerous factors may be difficult to tease apart. The impacts of infectious disease impacts can be difficult to assess because for many pathogens the relationship between ‘infection’ and ‘disease’ is unknown. Thus predicting a disease consequence based only on the observation of a pathogen is rarely possible.

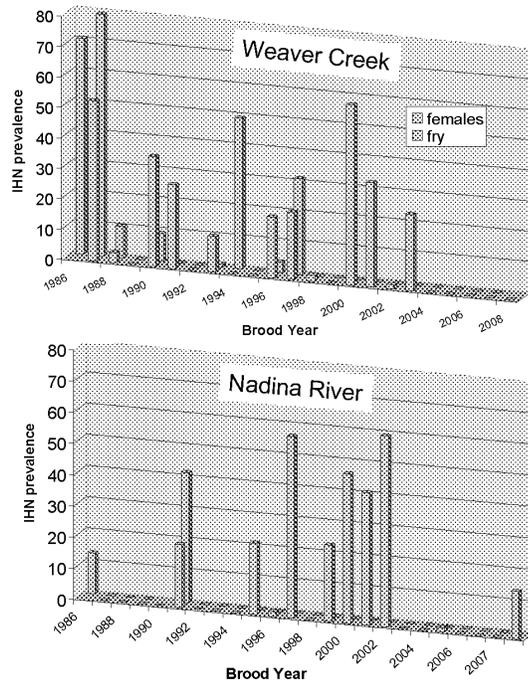
To understand and predict the role of infectious diseases in Fraser Rive sockeye population dynamics requires:

1. Long term data on the prevalence and abundance of pathogens within the various populations of sockeye throughout their life cycle.
2. For each pathogen, an understanding what conditions trigger the development of disease (e.g. pathogen load, poor environmental conditions etc.)
3. For each disease, the mortality rate and non-lethal effects of the disease in fish of various ages and under various environmental conditions.

Unfortunately much of this information does not exist for most salmonids including Fraser River sockeye.

There are three pathogens of Fraser River sockeye for which we have some data regarding prevalence and disease occurrence in various populations. This allows a limited assessment of their impact to be conducted. This report will discuss these

Figure 1. Graphs showing annual prevalence of IHNV positive spawning females (in blue) and fry (in red) sockeye salmon in Weaver Creek and Nadina River spawning channels from 1986-2009.



pathogens; infectious hematopoietic necrosis virus, *Ichthyophthirius multifiliis*, and *Parvicapsula minibicornis*, and their impact on Fraser River sockeye.

Infectious hematopoietic necrosis virus (IHNV) is an aquatic rhabdovirus that is enzootic (consistently present) in sockeye salmon populations in the Pacific Northwest of North America. The virus infects all life stages of sockeye salmon, however IHN disease is predominantly observed in fry while adult spawning sockeye although carriers of virus remain asymptomatic. Mass mortality events due to IHN disease have been reported in two lower Fraser River sockeye stocks. The first IHNV mortality event

occurred in the spring of 1973 at Chilko Lake and resulted in an estimated loss of 23.7 million fry. Subsequently, in 1987 an IHNV epizootic occurred at Weaver Creek spawning channel resulting in nearly 50% mortality (8.3 million fry died out of a total 16.8 million) of all migrating fry within days of leaving the spawning channel. Despite these significant impacts incurred in Fraser sockeye fry due to IHN disease, long-term monitoring of Nadina River and Weaver Creek spawning channels has revealed that over a 24 year period (1986-2009), IHNV prevalence varies annually within the same sockeye stock and is inconsistent between stocks (Figure 1). There is no correlation with IHNV prevalence in adults and the occurrence in fry. Additionally, the data set illustrates that the occurrence of IHN disease outbreaks in fry have not increased over the 24 year monitoring period for either Weaver Creek or Nadina River stocks (Figure 1). Our inability to detect IHNV in sockeye salmon fry from Weaver Creek and Nadina River over the past 10 (1998-2007) and 16 (1992-2007) years; respectively, suggests that IHNV is not a major contributor to the long-term decline of these two stocks.

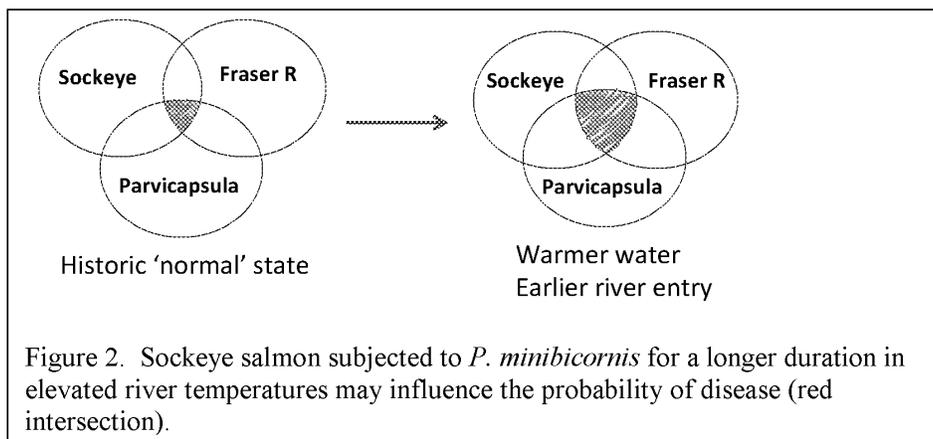
Ichthyophthirius multifiliis (ICH) is a naturally occurring freshwater ciliate protozoan that causes a disease commonly referred to as “ich” or “white spot disease”. The pathogen typically does not cause disease in sockeye salmon. However, if conditions such as warm

water, reduced flows, and adult crowding exist then disease can occur due the development of high numbers of this pathogen. Such disease events have been documented in Fraser and Skeena River sockeye salmon and have resulted in severe pre-spawn mortalities of up to 80% (Table 2). However, as with IHN disease, ICH disease prevalence has been inconsistent and varies between stocks. Additionally, the frequency of ICH epizootic disease events at Weaver Creek and Nadina River have not increased since 1990, suggesting that ICH disease is not a major factor contributing to the long term decline of these two stocks.

Table 2. Years in which *Ichthyophthirius multifiliis* was associated with elevated pre-spawning mortality at various sockeye spawning channels

| Watershed | Spawning Channel | Year of epizootic | Pre-spawning losses |
|--------------|------------------|------------------------------------|---------------------|
| Fraser River | Weaver Creek | 1995 | 30% |
| | Nadina River | 1978, 1987, 1995, 2008 | 25-70% |
| Skeena River | Fulton River | 1994, 1995, 1997, 2000, 2001, 2009 | 35-80% |

Parvicapsula minibicornis is a myxozoan parasite that is enzootic in Fraser River sockeye stocks. Surveys for the parasite has revealed that transmission occurs at or near the river estuary and that adults and juvenile salmon become infected with the parasite as they migrate through this area. In adult salmon, the prevalence and severity of infection is affected by time and temperature, such that migrating sockeye holding in the river under elevated river temperatures are at higher risk of more severe infections (Figure 2). Severe *P. minibicornis* infections may interfere with renal osmoregulatory function and



increase the probability of pre-spawning mortality. However, assigning a clear negative impact due to this parasite is difficult, as severe *P. minibicornis* infections are also

evident in successfully spawning fish. There are no data on the severity of infection of juvenile sockeye in marine waters with *Parvicapsula*. In the absence of information regarding the relationship between *Parvicapsula* infection and disease in sockeye salmon, its contribution to migratory behaviour and/or high mortality remains unknown. Additionally, the lack of historical *P. minibicornis* infection data makes it difficult to understand the significance of present day observations.

In summary, pathogens are a natural component of all ecosystems and not all infections lead to disease. Often enzootic pathogens are ‘well-adapted’ in that they do little to harm their host, however, the incidence and severity of disease from such pathogens may increase if abnormal conditions and/or adverse factors (“stressors”) occur. Epizootic disease events caused by IHNV and ICH have resulted in sporadic and significant mortality events in populations of Fraser River sockeye populations in that millions of fish suffered mortality. Long term monitoring, since 1986, of IHNV and ICH in Weaver Creek and Nadina River sockeye has indicated that no increase in the prevalence of IHN or white spot disease in these populations. Our data suggests that neither IHNV nor ICH are solely responsible for the long-term declines of these stocks.

It should be noted that only very limited information is available concerning the numerous other enzootic pathogens listed in Table 1. It is therefore not possible to comment on any potential effect of these on Fraser River sockeye salmon. To ascertain disease impacts of enzootic pathogens, it is necessary to study their long-term effect on growth, reproduction and survival of sockeye salmon. Currently, there is insufficient fish health data to predict what, if any, role disease has played in the long-term decline of Fraser River sockeye.

Research efforts aimed at determining the prevalence and abundance of pathogens, through comprehensive health assessments for multiple Fraser River sockeye stocks, are required. Additionally, health assessments need to investigate multiple sockeye salmon life-stages, in particular the marine phase. Research is also required to better understand the relationship between infection and disease, especially the role of unfavorable environmental conditions in influencing disease occurrence. Lastly, disease impacts need to be incorporated into fisheries models.

References:

Marty, GD, Hulson, PJF, Miller, SE, Quinn, TJ, Moffitt, SD, and Merizon, RA. (2010) Failure of population recovery in relation to disease in Pacific herring. *Dis Aquat Org* Vol. 90: 1-14

Pennycuik, L. (1971) Quantitative effects of three species of parasites on a population of Three-spined sticklebacks, *Gasterosteus aculeatus*. *J Zool.* 165: 143-162