The Cohen Commission of Inquiry into the Decline of Sockeye Salmon in the Fraser River

June 2011

TECHNICAL REPORT 5C

Impacts of salmon farms on Fraser River sockeye salmon: results of the Noakes investigation

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Preface

Fraser River sockeye salmon are vitally important for Canadians. Aboriginal and non-Aboriginal communities depend on sockeye for their food, social, and ceremonial purposes; recreational pursuits; and livelihood needs. They are key components of freshwater and marine aquatic ecosystems. Events over the past century have shown that the Fraser sockeye resource is fragile and vulnerable to human impacts such as rock slides, industrial activities, climatic change, fisheries policies and fishing. Fraser sockeye are also subject to natural environmental variations and population cycles that strongly influence survival and production.

In 2009, the decline of sockeye salmon stocks in the Fraser River in British Columbia led to the closure of the fishery for the third consecutive year, despite favourable pre-season estimates of the number of sockeye salmon expected to return to the river. The 2009 return marked a steady decline that could be traced back two decades. In November 2009, the Governor General in Council appointed Justice Bruce Cohen as a Commissioner under Part I of the *Inquiries Act* to investigate this decline of sockeye salmon in the Fraser River. Although the two-decade decline in Fraser sockeye stocks has been steady and profound, in 2010 Fraser sockeye experienced an extraordinary rebound, demonstrating their capacity to produce at historic levels. The extreme year-to-year variability in Fraser sockeye returns bears directly on the scientific work of the Commission.

The scientific research work of the inquiry will inform the Commissioner of the role of relevant fisheries and ecosystem factors in the Fraser sockeye decline. Twelve scientific projects were undertaken, including:

Project	
1	Diseases and parasites
2	Effects of contaminants on Fraser River sockeye salmon
3	Fraser River freshwater ecology and status of sockeye Conservation Units
4	Marine ecology
5	Impacts of salmon farms on Fraser River sockeye salmon
6	Data synthesis and cumulative impact analysis
7	Fraser River sockeye fisheries harvesting and fisheries management
8	Effects of predators on Fraser River sockeye salmon
9	Effects of climate change on Fraser River sockeye salmon
10	Fraser River sockeye production dynamics
11	Fraser River sockeye salmon – status of DFO science and management
12	Sockeye habitat analysis in the Lower Fraser River and the Strait of Georgia

Experts were engaged to undertake the projects and to analyse the contribution of their topic area to the decline in Fraser sockeye production. The researchers' draft reports were peer-reviewed and were finalized in early 2011. Reviewer comments are appended to the present report, one of the reports in the Cohen Commission Technical Report Series.

Executive Summary

A question that has garnered considerable public attention and one that is the focus of this report is whether there is a relationship between farmed salmon production and the returns of Fraser River sockeye salmon. There are many aspects of this complex issue that need to be considered and the terms of reference for this project include four broad areas of interest (Appendix 3). These include 1) issues associated with Atlantic salmon escapees; 2) the effect of farm wastes on benthic and pelagic habitat quality, and disease issues which are partitioned in two 3) sea lice given the extensive public debate around this issue, and 4) other diseases. The last topic that will be addressed, managing and mitigating risks, will make recommendation specific to salmon farming in British Columbia with respect to Fraser River sockeye salmon.

The information contained in this report is from the analysis and synthesis of a) peer-reviewed publications and other documents including the technical reports submitted to this Commission, b) summaries and analysis of data provided to the Commission by industry and government as well as data that are publically available or provided from other sources, and c) interviews with individuals from government, industry, academia, and others (Appendix 1). The disease data provided by industry and government were extremely useful in assessing the potential impacts of salmon farming on Fraser River sockeye salmon and the assessment of the data provided in this report may help clarify some of the misconceptions that exist in the public's mind.

The debate around salmon farming is highly polarized as evidenced by the media attention it has and continues to receive, the number and tone of aquaculture related comments submitted to this Commission, and the very divergent and strongly held views expressed and advanced in some of the publications reviewed in this study. Some of the publications are highly speculative for a variety of reasons including but not limited to the absence of data from government and industry as well as assumptions used by the researchers. In some cases, the publications were deficient to the point that they were neither objective nor scientific and they generally lack credibility.

The industry is highly regulated with very extensive requirements for monitoring, proactive and reactive intervention to resolve disease and waste issues and problems, and mandatory reporting. The volume, quality, and level of detail of the data provided to the Commission by both industry and government is impressive and I believe providing summaries of this information at an appropriate level will help build confidence in this industry with the general public. While some improvements are certainly possible and desirable, the industry generally leads the world in with respect to the management and control of disease and waste at their farm sites both through proactive policies and practices. Overall, the evidence suggests that salmon farms pose no significant threat to Fraser River sockeye salmon and that salmon farming has not contributed to the recent decline in Fraser River sockeye salmon productivity.

Key Findings

1. There is no significant correlation between farmed salmon production within the main migration path of Fraser River sockeye salmon, the waters between Vancouver Island and the mainland of British Columbia, and the returns of Fraser River sockeye salmon. No causal relationship was found between the two time series and there was no apparent plausible link between farmed salmon production which is governed by condition of licence and the returns of Fraser River sockeye that are a function of the number of fish that spawned 4 years previous as well as a variety of environmental factors.

2. There is no evidence that escaped Atlantic salmon have contributed to the decline in Fraser River sockeye salmon stocks or that escaped Atlantic salmon pose any threat to sockeye or any other salmon stocks in the Fraser River. No juvenile Atlantic salmon have ever been observed in the Fraser River and only 2 adult Atlantic salmon have been found in the Fraser area (Area 29) in the last decade.

3. There is no obvious plausible link or evidence to support a link between the deposit of waste on the sea bed or into the water column and sockeye salmon survival. The impact of waste appears to be limited to the immediate vicinity of the farms (within 30m).

4. There is no significant correlation between the number of sea lice on farmed salmon and the return of Fraser River sockeye salmon. The average number of lice (*Lepeophtheirus salmonis*) on farmed salmon has decreased from approximately 3 lice/fish in 2004 to between 1.0 lice/fish (annual mean) and 0.5 lice/fish (the April – June average - the time period when juvenile sockeye salmon are migrating past the salmon farms) in 2010.

5. The evidence suggests that disease originating from salmon farms has not contributed to the decline of Fraser River sockeye salmon. Since 2003, no outbreaks of IHN have been reported on any salmon farm. Only 1 or 2 cases (per year) of vibrio were reported on salmon farms for 5 of the 9 years between 2002 and 2010. Since 2003, the majority (29 of 38) reported cases of furunculosis were from farms on the West Coast of Vancouver Island with an average of only 1.3 cases/year on farms located in the main migration path for Fraser River sockeye salmon. Since 2003, there has been a significant decline in the number of farms reporting BKD in BC Fish Health Area 3 (the main migration route for Fraser River sockeye salmon) with an average of 6 farms per year since 2006. In 2006, 3 farms from northern Queen Charlotte Strait, 2 farms from the Broughton, and 1 farm the Sechelt area reported BKD fish health events. Of the 20 cases of BKD reported between 2007 and 2009, 17 were from farms in the Jervis/Sechelt/Salmon inlets area with only 1 farm in each of the 3 years being located within the main migration route for Fraser River sockeye salmon. Overall, the incidence of diseases in farmed salmon that would be classified as high risk to sockeye salmon is very low and do not pose a significant risk.

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Introduction

Historically, the Fraser River has been one of the most productive salmon producing rivers in the world. However, over the past two or three decades there has been a steady decline in returns of sockeye salmon (*Oncorhynchus nerka*) to the Fraser River. The decline is not unique to the Fraser as there have also been synchronous declines to sockeye salmon populations outside the Fraser (Peterman and Doner 2011) as well as significant declines for other species of salmon (Beamish et al. 2011a). Despite recent declines, the Fraser River and the Strait of Georgia are still very important rearing areas for salmon and other species as witnessed by very large returns of pink salmon (*O. gorbuscha*) to the Fraser River in 2009 (and generally since the late-1970s) and record returns of sockeye salmon to the Fraser in 2010 after near record low returns in 2009.

On average, more than a billion juvenile salmon (250 million sockeye, 400 million pink, 400 million chum, and 30 million coho and chinook) enter the Strait of Georgia each spring spending between 25 and 40 days (or more) in the Strait of Georgia before migrating out to sea (Beamish et al. 2010; DFO 2009; Welch et al. 2009). The estimated number of juvenile chum salmon is likely low as they are typically the most abundant species of juvenile salmon (often more abundant than all other species of salmon combined) in the juvenile salmon surveys conducted in the Strait of Georgia over the past 13 or 14 years (R. Beamish, pers. comm.). It is, however, difficult to get a more precise estimate as adult chum salmon escapement and the outmigration of juvenile chum salmon are not routinely monitored for stocks that rear in the Strait of Georgia.

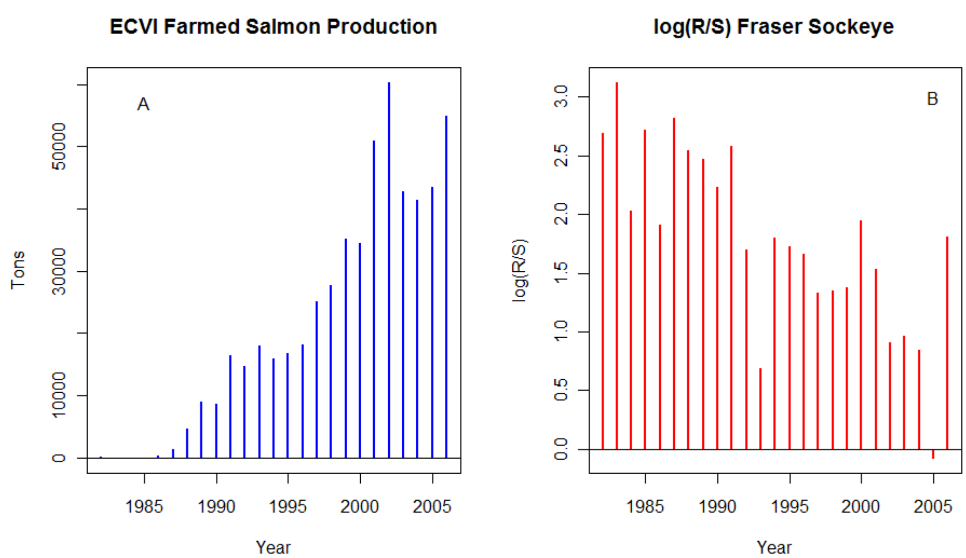
Early marine mortality is quite high for all species of juvenile Pacific salmon, on the order of 3% or more per day, and it is generally accepted that year-class strength (the number of adult salmon that will return) is largely established during this early marine period (Bax 1983; Beamish et al. 2011a; Fukuwaka and Suzuki 2002; Karpenko 1998; Parker 1964, 1968; Wertheimer and Thrower 2007; Welch et al. 2009). At that rate of mortality (3%/day), roughly half of the juvenile salmon entering the Strait of Georgia each spring (~500 million fish) die within the first 25 days after ocean entry. The question at hand is what kills 20 million juvenile Pacific salmon or more specifically 5 million juvenile sockeye salmon on average every day after they enter the Strait of Georgia? It's a question and perspective (in terms of the magnitude) to keep in mind as we consider all of the factors that may explain recent declines in Fraser sockeye.

Farm Salmon Production and Fraser River Sockeye Productivity

Of particular interest to the public is whether farmed salmon production along the main migration path of Fraser River sockeye salmon, the waters between Vancouver Island and the British Columbia mainland, has affected sockeye returns over time. The salmon farming industry in British Columbia began in the early 1980s and production from farms located in this migration corridor along the east coast of Vancouver Island (ECVI) has increased steadily since that time and over the last decade farmed salmon production has averaged about 50,000 tons per year (Figure 1A). To a very large extent, farmed salmon production is dictated by the limits specified in each farm's aquaculture licence. Environmental factors such as algae blooms and other random events can have local impacts on farm productivity but over time the potential effects of these environmental impacts have been factored into business decisions on stocking and harvesting farms as well as ongoing operational practices in order to stabilize production.

Over the same period of time, Fraser River sockeye salmon productivity as measured by the average number of salmon returning (recruits), R, per salmon that spawned four years earlier, S, has decreased steadily (Figure 1B). For a variety of reasons, it is typical to examine the natural logarithm of recruits per spawner rather than the ratio 'R/S' as a mathematical model developed by Dr. William E. Ricker incorporates log(R/S) as a component and the 'Ricker model' is often used to model salmon productivity (Noakes 1988; Noakes et al. 1990; Peterman and Doner 2011; Ricker 1954). Positive values of log(R/S) imply that more salmon returned than spawned 4-years earlier (i.e. the ratio R/S > 1) and larger values of log(R/S) mean that the stock is more productive. The negative log(R/S) for the 2005 brood year (Figure 1B) means that fewer salmon returned in 2009 (the progeny) than spawned in 2005 (the parent stock).

Figure 1. Time series plots of farmed salmon production (tons) from farms located on the east coast of Vancouver Island (A) and the brood year log(R/S) (productivity index) for sockeye salmon (all runs combined) returning to the Fraser River, British Columbia (B). The log(R/S) for the 2005 brood year was negative (B) as fewer sockeye salmon return to the Fraser in 2009 than spawned in 2005. (Data from Korman 2011).



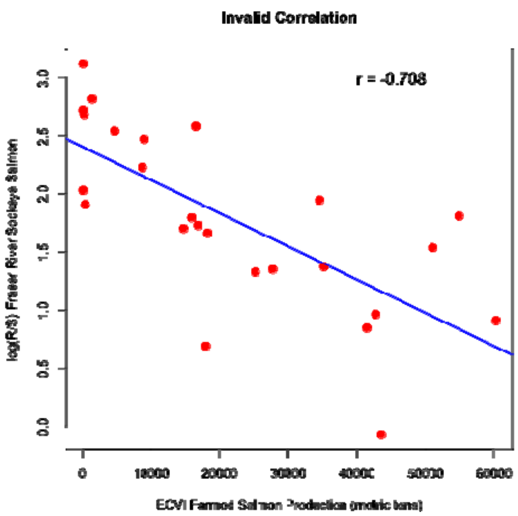
The relationship between farmed salmon production and Fraser River sockeye productivity could be examined a number of ways and different aspects of this issue will be considered later in this paper. An obvious question and starting point is whether farmed salmon production from the

ECVI (Figure 1A) is correlated with sockeye salmon productivity over the same time period (Figure 1B). There are several important points to consider when examining these data to see if a potential causal relationship exists. First, as noted earlier farmed salmon production is largely a function of the limits established in the aquaculture licence for each farm with environmental factors playing little or no role in the long-term trend and typically a very minor role (certainly in comparison to wild stocks) in year-to-year variation in production. Conversely, environmental factors (both freshwater and marine) likely play a substantial role in determining the annual productivity of sockeye salmon as well as the long-term trend in production (Beamish and Noakes 2002). Thus, there is no apparent common underlying driving force (environmental factor) that would tend to make the two time series (farmed salmon production and Fraser River sockeye salmon productivity) behave in a similar or opposite fashion (direction). Considerable care should be taken in such cases to avoid spurious or nonsensical correlations.

These are also time series data (observations recorded sequentially in time) and it is likely, especially for farmed salmon production, that farmed salmon production in any particular year is correlated with production in previous years. For instance, farmed salmon production in 2000 is likely highly correlated with farmed salmon production in 1999 since one of the goals of the salmon farming industry is to provide a stable supply of salmon for their domestic and export markets. Likewise, log(R/S) may also be autocorrelated (i.e. sequential values of log(R/S) are correlated) since there is an overlap of sockeye salmon year-classes in both their freshwater and marine habitats and persistent climate patterns may result in similar ocean (and freshwater) survival for sequential brood years. The autocorrelation in each time series must be accounted for (removed) before the cross-correlation between the two series (farmed salmon production and sockeye salmon productivity, in this case) is estimated in order to avoid spurious correlations (see for example Box and Jenkins 1976; El-Gohary and McNames 2007; Hipel et al. 1985; Hipel and McLeod 2005; Granger and Newbold 1977). Otherwise, the results of the statistical test (in this case, the cross-correlation between the two time series) including the estimated significance and subsequent interpretations are invalid. Likewise, if both time series exhibit strong trends (or cycles) in the data this will also result in spurious cross-correlations and the trends must also be accounted for before the cross-correlations are estimated (Figures 1A and 1B).

The example or question at hand is a good case in point. If you naïvely estimate the correlation between farmed salmon production from farms on the ECVI (Figure 1A) and log(R/S) for Fraser River sockeye salmon (Figure 2) with no adjustment for trend or autocorrelation, then you would incorrectly conclude that the two time series are negatively correlated ($r = -0.708$; Figure 2). In this case, the correlation and the implied negative relationship between the two time series are completely spurious due to the fact that the two time series are both autocorrelated and have significant trends and these have not been explicitly accounted for in the analysis. In order to correctly estimate the cross-correlation between the two time series, the autocorrelations and trends need to be removed from each time series. The process is called pre-whitening and is common practice in time series analysis (see for example Box and Jenkins 1976; Granger 1969; Haugh 1976; Haugh and Box 1977; Hipel and McLeod 2005; McLeod 1979).

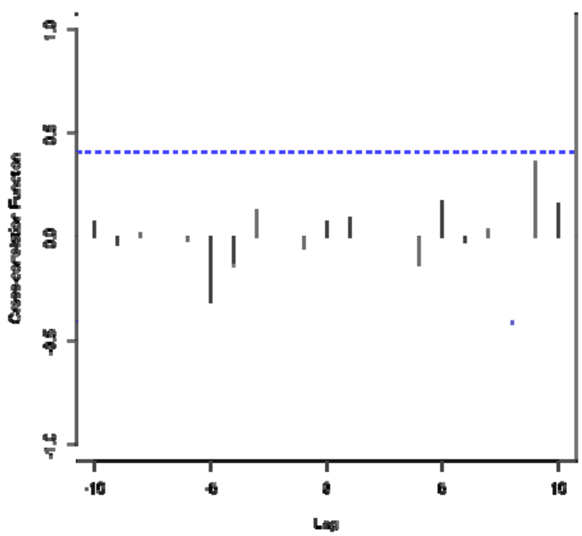
Figure 2. Statistically invalid (naïve) correlation between farmed salmon production for farms located on the east coast of Vancouver Island and log(R/S) for Fraser River sockeye salmon (all runs combined) returns. The large spurious negative correlation (r = -0.708) and the conclusion that there is a significant relationship is the result of not removing the autocorrelation and trend in either the farmed salmon or sockeye log(R/S) time series. (Data from Korman 2011).



Quite a different picture arises if the trends and autocorrelations in the data are dealt with in an appropriate fashion. The farmed salmon production for the ECVI is significantly autocorrelated with the correlation between sequential observations being about 0.85 (Figure I, Appendix 2). That is, farmed salmon production in year 't' is about 0.85 times the production in year 't-1' plus some random component. In time series with an obvious linear trend and significant autocorrelation (the situation we are faced with in this instance), differencing the series will often sufficiently pre-whiten the series (remove the trend and autocorrelation) for subsequent analysis and this turned out to be the appropriate approach in this case (Figure I, Appendix 2). Differencing the series allows you to look at year to year changes in the time series while removing the trend. Fraser River sockeye productivity was also autocorrelated but not as much as farmed salmon production. The lag-1 autocorrelation for the log(R/S) time series was 0.55 which is statistically different from 0 (Figure II, Appendix 2). The log(R/S) time series was pre-whitened by fitting a first-order autoregressive model to the data and the residuals from that model and the residuals from the differenced time series of farmed salmon production were then used to correctly estimate the cross-correlation between the two series (Figure 3).

The large-sample variance for the sample cross-correlations is used to test for significant correlations and is approximately 1/n where 'n' is the number of observations or years of data (25 in this case) in the time series (McLeod 1979). The approximate 95% confidence interval for the sample cross-correlation would then be about ± 0.40 in this case (the two dashed lines in Figure 3). However, because of the small sample size the confidence intervals for the cross-correlations at the larger lags would be wider since fewer data (years) are available to estimate the cross-correlation. At lag ±8, for instance, the approximate 95% confidence interval would be about ±0.55 since only 13 observations (years of data) are used to estimate the cross-correlation. Thus, based on this analysis, there is no significant correlation between farmed salmon production on the ECVI and the productivity of Fraser River sockeye salmon as measured by log(R/S) at any lag using a 5% (α=0.05) significance level (Figure 3). In light of the disease information from the farms which will be discussed in much greater detail later in this report, this is really not a surprising result since there is no obvious causal link (underlying factor) that would tend to increase farm production (which is governed by condition of licence) and decrease sockeye salmon productivity. This issue (plausible links) will be revisited when the issue of disease is considered in more detail in later sections of this report.

Figure 3. Cross-correlation function for the pre-whitened time series: first-order differenced farmed salmon production and the residuals from the AR(1) model fitted to the log(R/S) data for sockeye salmon returning to the Fraser River. There are no significant correlations for either positive or negative time lags between farmed salmon production and Fraser River sockeye salmon productivity (log[R/S]). (Data from Korman 2011)



Considerable caution should be taken when products, ratios or other functions of time series (or variable) are used to test potential causal relationships. Connors (2011), for instance, combined several variables in a pairwise fashion in a nonlinear model to test for relationships with Fraser River sockeye salmon production. There are, however, several significant problems with his assumptions, methods, analyses, and conclusions (discussed below). For instance, Connors (2011) found no significant relationship between farmed salmon production and Fraser River sockeye salmon productivity, no significant relationship between pink salmon abundance in the

North Pacific and Fraser River sockeye production but he did identify a significant negative relationship between winter sea surface temperature (SST) and Fraser River sockeye salmon productivity. Conducting multiple pair-wise comparisons increases the likelihood of spurious correlations and combining series that are significantly correlated (such as SST) with other variables that are not significantly correlated may result in wrongly assigning relationships to other variables (pink salmon or farmed salmon production in this case) when none exists.

While Ruggerone and Nielsen (2004) may have been the motivation for Connors (2011) to only considering pink salmon in his analysis, it is much more reasonable to consider the relationship between sockeye, pink, and chum abundance in the North Pacific and Fraser River sockeye productivity. There is strong evidence that sockeye, pink, and chum salmon have a very high overlap at the trophic level and there is likely to be negative interactions among these species through competition (Johnson and Schindler 2008; Kaeriyama et al. 2004; Ruggerone and Nielsen 2004; Satterfield and Finney 2002). There is also evidence that pink and chum production (as indexed by catch) in the North Pacific has responded to shifts in ocean conditions in a synchronous fashion with the reverse pattern of changes (shifts) being observed for sockeye salmon (Noakes and Beamish 2009). Pink and chum salmon have similar levels of production over the last 20 years (average annual catches of 351.9×10^3 t for pink salmon and 313.3×10^3 t for chum salmon) and sockeye salmon production (average annual catch of 152.1×10^3 t) has also been substantial over the same period (Irvine et al. 2009; Noakes and Beamish 2011). If competitive interactions at the trophic level are of interest, then biomass (using catch as a surrogate) rather than the number of fish is also likely to be a much better variable to consider since it more accurately reflects the resources (primary productivity) required to sustain the system. It does not make sense to consider pink salmon abundance only given the significant trophic overlap for the three species (sockeye, pink, and chum salmon) and particularly when no significant relationship was found between the abundance of pink salmon in the North Pacific and Fraser River sockeye salmon production when they were considered independently.

The systematic combination of the factors into models to test for significant relationships is also troublesome particularly when no relationship was found between Fraser River sockeye salmon productivity and two of the time series (pink salmon abundance and farmed salmon production) when they were examined independently. Just as spurious correlations can be common in linear models (for example, the naïve and spurious correlation between farmed salmon production and Fraser River sockeye salmon productivity identified in this paper, Figure 2), Lee et al. (2005) demonstrated that nonlinear estimation procedures and tests can also wrongly indicate that two independent random walks (time series) have a significant nonlinear relationship and that these spurious nonlinear relationship become stronger as the sample size increases. Autocorrelation in one or more of the time series (likely present in all of the 4 time series considered by Connors) may also increase the likelihood of finding a spurious nonlinear relationship similar to the linear case (see Figure 3 and Appendix 2 of this report). Testing multiple pair-wise comparisons also greatly increases the likelihood of finding spurious correlations and wrongfully concluding there is an association between two or more variables when none exists.

While combining two time series in a model was done to capture any potential synergistic relationships, Connors (2011) does not present a compelling case for the comparisons he considered. For example, the implicit assumption in Connors' (2011) analyses is that the magnitude or level of disease in farmed fish (specifically the 'high risk` diseases and/or the number of sea lice on farm fish) is proportional to farmed salmon production. This assumption is clearly not supported by the data as Korman (2011) identified a declining trend in the number of 'high risk' diseases as well as the number of sea lice on farmed salmon between 2003 and 2010 – a period when farmed salmon production was actually increasing (Figure 1). Also, the wide spread use of vaccines (farmed salmon are now routinely vaccinated for furunculosis, vibrio, and IHN; P. McKenzie, S. Saksida, pers. comm.), changes in husbandry practices, and changes in handling (such as no longer live hauling fish) has also substantially reduced disease problems in the industry compared to the 1980s and 1990s and the decline is evident in the data including a substantial decrease in the percent mortality of 'fresh silver' salmon (Korman 2011 and Table 8 this report). Connors (2011) also found no significant relationship between any of the 'high risk' diseases and/or the number of sea lice on farmed salmon and Fraser River sockeye salmon returns so there is simply no reasonable basis to assume 'disease' is proportional to production and good evidence that the opposite is actually true (Korman 2011).

It is also important to note that between 2003 and 2007 (2002 data are only partial) that 74% (136 of 183 cases; Korman 2011) of the 'high risk' diseases reported by industry were for BKD so in essence any potential link to 'high risk' diseases is based almost entirely on this one disease agent. This issue is dealt with that in more detail later in this report. Not surprisingly, Connors (2011) found that data from the 2005 brood year (the 2009 returns) exerted a high degree of leverage (that observation significantly influenced the results) and it would by itself tend to exaggerate any negative association. Also, Connors (2011) elected not to include data from the record 2010 return of Fraser River sockeye salmon in his analysis for a variety of reasons. Like 2009, I would fully expect the 2010 return data would exert significant positive leverage that would tend to reduce the association between and among the various factors.

There is also not compelling or strong evidence of significant disease transfer from salmon farms to wild or hatchery fish (BKD being a case in point) given the high incidence of these diseases found in all species of Pacific salmon (Kent et al. 1998; Noakes et al. 2000; Rhodes et al. 2006). For instance, BKD infection rates for wild and hatchery Pacific salmon ranged up to 60% for chinook and 40% for coho salmon, about 6 or 7% for sockeye and chum salmon, respectively, and up to 25% for pink salmon (Kent et al. 1998; Rhodes et al. 2006). Given these high levels of natural infection, there is no easy way to establish the source of infection unless there is evidence of disease in a hatchery or particular stream. This clearly highlights the danger of simply scaling or using farmed salmon production as an index of disease when dealing with disease agents, such as BKD and many others, which are so prevalent and wide spread (Kent et al. 1998).

Connors (2011) also found a significant relationship with SST and Fraser River sockeye salmon productivity. This isn't surprising as other studies have also demonstrated links between SST and salmon production (for example Mantua et al. 1997) although SST is almost certainly just a proxy for other factors that are governing salmon production. However, by combining SST with other time series, a significant relationship may be wrongfully assigned the other variable when none actually exists. The relationship may be (and quite likely is) solely with SST with the other factor or variable being completely unrelated. None of the combinations examined by Connors (2011, Table 6) were statistically significant (even before adjustments for multiple comparisons) so the discussion about possible links is simply unwarranted speculation.

Atlantic Salmon Escapes

Attempts to establish self-sustaining anadromous runs of Atlantic salmon (*Salmo salar*) in the Pacific Northwest date back to the early 1900s but despite the release of large numbers of fish over several years these efforts were unsuccessful (Anonymous 1997). The reasons for these early failures are not clear but they are most likely the result of a combination of environmental and ecological factors rather than a single cause. While the precise reasons are unknown, some general observations regarding the potential for Atlantic salmon colonization now or in the future are certainly possible given experiences from the past and lessons learned elsewhere.

From a habitat perspective, conditions were likely much more favourable in the past for both Pacific and Atlantic salmon particularly in areas closer to larger cities and towns as well as in regions that have experienced others forms of development (Gregory and Bisson 1997). Since Atlantic and Pacific salmon share similar life histories and both require high quality freshwater and marine habitat in order to survive, the degradation in habitat that has occurred over time would not preferentially favour either species. If environmental conditions (and subsequently salmon habitat) are unfavourable for Pacific salmon then they will also be unfavourable for Atlantic salmon. Thus, the decline of particular Pacific salmon runs due to environmental or ecological reasons does not create a void or ecological niche for potential invasion by Atlantic salmon. That said, there is still a significant amount of high quality freshwater habitat suitable for salmon in British Columbia and certainly some of that habitat is not fully utilized. The potential for Atlantic salmon to successfully spawn in coastal streams exists but experience and evidence suggests that this is an exceptionally rare occurrence and it (successful spawning) does not constitute sustained colonization (Anonymous 1997; Volpe et al. 2000).

There are also behavioural and ecological issues that must be considered in evaluating the potential for sustained colonization by Atlantic salmon. In a study involving Atlantic salmon and steelhead trout (*O. mykiss*), Volpe et al. (2001) found that prior residence in a stream was the best predictor of performance (the ability to compete), regardless of species, with resident fish always outperforming challengers. While the study only considered steelhead trout and Atlantic salmon, the conclusions may extend to other species of Pacific salmon and the authors make that generalization in their conclusions. A study done in Ontario examined interactions between Atlantic salmon and Chinook salmon (*O. tshawytscha*) and found that Chinook salmon impeded the successful re-establishment of Atlantic salmon within their home range by modifying their behaviour and ultimately their (Atlantics) spawning success (Scott et al. 2003). The Ontario results could be a case of 'first residency' as noted by Volpe et al. (2001) or it may indicate that Chinook salmon are more aggressive than Atlantic salmon. Volpe et al. (2001) argue that Atlantic salmon may be capable of colonizing rivers that are underutilized by native species but the opposite argument is also likely true given their findings with respect to residency. Atlantic salmon are likely to experience great difficulty in competing with Pacific salmon where Pacific salmon are 'first residence' and relatively abundant. Also, if streams are underutilized by native (Pacific) species, then it is of course important to consider the habitat issues discussed above in evaluating the potential for colonization. If the habitat has become unsuitable for Pacific salmon (or trout), then it will also likely be unsuitable for opportunistic Atlantic salmon.

While there are obvious differences, the Great Lakes experience does offer some insight on the issue of potential colonization. Native Atlantic salmon were extirpated from the Great Lakes system through overfishing and habitat degradation just prior to the end of the 19th century (Scott et al. 2003) and numerous exotic species including Pacific salmon were intentionally introduced following a massive effort to restore fish habitat and the aquatic environment in the Great Lakes basin (Crawford 2001). As the new 'first residents', the evidence suggests that Pacific salmon impeded the reintroduction of Atlantic salmon into their native habitat (the Great Lakes system) for a variety of complex reasons. Although the reasons may be different on the Pacific coast, the Great Lakes experience and the failure of early attempts to establish Atlantic salmon in BC suggest that it is likely to be extremely difficult for Atlantic salmon to invade the Pacific. Some Pacific salmon stocks may be in low abundance at this point in time but the majority still remain relatively healthy and resilient (as witnessed by the remarkable returns of sockeye salmon to the Fraser in 2010) and Pacific salmon are not at risk of extinction (Noakes and Beamish 2011).

Of course, a prerequisite to the discussion above is that there are sufficient numbers of Atlantic salmon in coastal streams to pose a credible threat to Pacific salmon stocks in the same system. Atlantic salmon have been farmed in Puget Sound since 1972 and they have been used in the BC salmon farming industry since the late-1980s (Noakes et al. 2000). Fish have escaped from farms in both countries and the decision to allow Atlantic salmon to be farmed in BC was made, in part, because they were already being farmed and were escaping in Washington State. Between

1991 and 2009, 435,205 adult and juvenile Atlantic salmon were reported as escaping from fish farms in BC with the largest number of escapees, 88,514, in 1998 (Table 1). There have also been some very large escapes from salmon farms in Washington State most notably 107,000, 369,000, and 115,000 Atlantic salmon in 1996, 1997, and 1999, respectively, but much smaller escapes in recent years (Phillips 2005). It is likely that some of the fish that escaped from farms in Washington State were recovered in BC waters (Tables 2 and Appendix 2, Tables I and II). Juvenile Atlantic salmon have also escaped from freshwater facilities (hatcheries) in BC but only a single small escape of 247 fish in 2001 has been reported as escaping since 1999 (Table 1).

Table 1: Marine and freshwater escapes of Atlantic salmon in British Columbia, 1991 – 2009.

ATLANTIC SALMON - Marine and Freshwater Escapes

Year	Marine Adult Escapes	Marine Juvenile Escapes	Total Marine Escapes	Freshwater Escapes	Total Escapes
1991	6,651	0	6,651	0	6,651
1992	4,544	5,000	9,544	0	9,544
1993	10,000	0	10,000	0	10,000
1994	39,547	24,262	63,809	7,000	70,809
1995	51,883	0	51,883	941	52,824
1996	13,104	0	13,104	40,000	53,104
1997	7,650	0	7,650	10,464	18,114
1998	43,208	45,306	88,514	300	88,814
1999	35,248	482	35,730	0	35,730
2000	36,392	1,000	37,392	0	37,392
2001	57,643	0	57,643	247	57,890
2002	9,282	0	9,282	0	9,282
2003	34	0	34	0	34
2004	43,969	0	43,969	0	43,969
2005	6	0	6	0	6
2006	0	0	0	0	0
2007	17,000	0	17,000	0	17,000
2008	29,861	0	29,861	0	29,861
2009	48,857	0	48,857	0	48,857
TOTAL	**359,161**	**76,050**	**435,205**	**58,952**	**494,163**

It is likely that the true number of fish escaping is different than the number reported for each discrete event (escape) since best estimates of numbers are used at the time of the escape and a more accurate accounting can usually only be done when the fish are harvested. It is also possible and likely that some fish escape undetected (referred to as leakage) but the extent and magnitude of this problem is difficult to estimate. However, farm production is tightly regulated as a condition of licence and it is likely that large discrepancies in inventory as a result of leakage would be obvious and detected during harvest and mandatory reporting. The debate over this issue has been ongoing and Morton and Volpe (2002) provided a case study where they argue that the number of Atlantic salmon reported escaped for one incident in 2000 was significantly in error (underestimated). There are, however, serious flaws in their study as they used a voluntary census (with all of the associated biases and statistical inadequacies) with no obvious means of validating their (VHF radio) responses and combined these data with other non-random samples to make their case. It is entirely likely (almost certainly) that a number of fish in their study were double-counted (or counted multiple times) and consequently their results are statistically unreliable at best. These types of assessments are neither useful nor helpful from a public or scientific perspective (Hilborn 2006). The debate over the accuracy of escape numbers is likely to continue and efforts by industry and government should continue to improve the quality of these estimates and mandatory reporting.

A small percentage (less than 5% on average) of the escaped Atlantic salmon is observed or reported being caught in ocean fisheries or in freshwater (Table 2 and Appendix 2, Tables I and II). While some streams have been actively surveyed for Atlantic salmon, the majority of the sightings or captures were reported through the passive Atlantic Salmon Watch Program. Data on recoveries and sightings are relatively sparse since 2003 for a number of reasons. First, fewer Atlantic salmon have escaped from BC and Washington State farms over the last decade compared to the 1990s and decreases in catches and sightings would be expected as a result (Table 1; Phillips 2005). Effort devoted to surveying streams specifically for Atlantic salmon has also been scaled backed considerably in part because so few Atlantic salmon were being detected in streams during the surveys and most Atlantics were being found in close proximity active salmon farming areas where effort could be focussed. This was also the point in time (2002 – 2003) when monitoring and research efforts by government and other groups were being redirected away from escaped farmed fish to study sea lice. That said, in-river monitoring of Pacific salmon for escapement enumeration and stock assessment purposes continues so it would be incorrect to say that no one is looking for Atlantics in coastal streams.

Between 1987 and 2008, 19,850 adult salmon were reported caught in BC coastal waters with the majority (88%) of these fish (17,432) being caught in Statistical Areas 12 and 13 where a large number of salmon farms are located (Appendix 2, Table II). Most Atlantic salmon that escape are not caught since escapes rarely coincide with fishery openings and most escaped Atlantic salmon do not successfully feed and survive for any extended period of time (Appendix 2, Table V). Approximately 1,100 adult Atlantic salmon have also been found in 80 BC streams and rivers since 1987 with most again being found in areas close to active salmon farms (Statistical Areas 12, 13, 24 and 25; Appendix 2, Table I). With respect to the Fraser River, there have been a total of 31 adult Atlantic salmon reported in Statistical Area 29 (the Lower Strait of Georgia and Fraser River), consisting of 29 fish between 1991 and 1998 and 1 adult Atlantic salmon in each of 2001 and 2002 (Appendix 2, Table I). There was also a report of 1 Atlantic salmon in the Bonaparte River in 1999. There have been no reports of juvenile Atlantic salmon in the Fraser River system (Statistical Area 29) since records began (Table 2). The majority of the juvenile Atlantic salmon recovered from freshwater (478 of 668) was found in Georgie Lake with these juvenile fish escaping from a freshwater hatchery at that location. Atlantic salmon have also been observed and caught in Alaskan waters (Appendix 2, Tables III and IV). Only 5 Atlantic salmon have been recovered in Alaskan streams and rivers and about 600 Atlantic salmon have been caught in their ocean fisheries. There was a significant decrease in the number of Atlantic salmon reported in Alaskan waters since 2000. Stomach content analysis was also done on 1,584 Atlantic salmon with most (>80%) having nothing in their stomach suggesting that most are not actively feeding (Appendix 2, Table V).

While Pacific salmon do interbreed (Foerster 1935), attempts to cross Atlantic and Pacific salmon have repeatedly failed to produce viable offspring (Blanc and Chevassus 1979; Gray et al. 1993; Loginova and Krasnoperova 1982; Noakes et al. 2000). Also, with respect to disease, it is far more likely that farms would be a more viable source of pathogens than chance encounters between Pacific salmon and escaped Atlantic salmon. All of these issues have been considered in detail before and the main concerns regarding escaped Atlantic salmon appear to be potential ecological interactions and sustained colonization (Anon. 1997; Nash 2003; Waknitz et al. 2003). With respect to Fraser River sockeye, there is simply no evidence to suggest that escaped Atlantic salmon have contributed to the decline in recent years or that escaped Atlantic salmon pose any threat to these stocks. The same would also apply to other species of Pacific salmon in the Fraser River. No juvenile Atlantic salmon have been observed in the Fraser system and only 2 adult Atlantic have been observed in the Fraser (Statistical Area 29) in the last decade. It’s also important to note that the Fraser River is not a remote system and it is intensely monitored by many groups to assess the status of salmon stocks (and other fish) and to manage ocean and in-river fisheries. Given this level of effort and scrutiny, it is unlikely that the number of Atlantic salmon reported in the Fraser is substantially in error and that large numbers of Atlantic salmon reside in the Fraser. In general, the number of juvenile and adult Atlantic salmon found in freshwater rivers in BC has been sporadic and quite small. At these levels, it is difficult to imagine that escapees of farmed Atlantic salmon pose a significant threat in terms of ecological interaction or through colonization to Pacific salmon in the Fraser River or elsewhere in BC.

Table 2: Freshwater recoveries of juvenile Atlantic salmon in British Columbia, 1996 – 2008.

BC Freshwater Atlantic Salmon Recoveries - Juveniles

River	Area	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	Total
Adam	12				3										**3**
Amor de Cosmos	12				113	8									**121**
Cameleon Harbour Creek	13							1							**1**
Carnation	23		1	3		1		2							**7**
Georgie Lake	12	41	21	86	30									300	**478**
Keogh	12			1	2										**3**
Lake of the Mountains Creek	12		3					4							**7**
Lois Lake	16	13													**13**
Pye	13		1												**1**
Ritherdon Creek								1							**1**
Stamp	23						3								**3**
Tsitika	13			24	2	3			1						**30**
Total		**54**	**26**	**114**	**150**	**12**	**3**	**8**	**1**	**0**	**0**	**0**	**0**	**300**	**668**

Farm Wastes - Effect on Benthic and Pelagic Habitat Quality

Over a period of time, the Finfish Aquaculture Waste Control Regulation (FAWCR) Committee developed standards and guidelines (amended January 14, 2010) governing the discharge and monitoring of waste (as defined in the regulation) at finfish aquaculture sites (Anon. 2010). The standards are performance driven with mandatory reporting and audits by government personnel. The expectation is that these regulations in conjunction with independent government audits will be used within the Federal Government's Pacific Aquaculture Regulations to manage waste and waste discharge at finfish aquaculture operations (A. Thomson, pers. comm.).

Prior to stocking, baseline information (benthic sampling) must be conducted at the farm site. A reference site located between 500m and 2km from the farm that is not influenced by the farm's operation must also be established. At present, the trigger for stocking and restocking fish at a site is sulphide concentrations that are not statistically greater than 1,300 mml or not significantly (statistically) different than the mean reference baseline sulphide concentration from samples collected at locations near the farm as specified in the regulations (Anon. 2010). Monitoring (video and sampling) is done in both the direction of the dominant current and in the opposite direction at 0m and 30m from the net pen and at the edge of the tenure. Testing is done within a month of the peak biomass on the farm in an effort to monitor the highest level of impact (M. Parker, pers. comm.). When sediment samples are collected, the following physical and chemical parameters must be measured: free sulphides, redox potential, total volatile solids or total organic carbon, sediment grain size, total zinc, total copper, sediment colour, the presence or absence of fish feed or fish faeces or other materials, and other contaminants (such as therapeutants or pharmaceuticals) that may have been used at the farm and are of interest (Anon. 2010). For hard bottom sites, 6 video passes out to 125m from the edge of the net must be conducted to look for the absence or presence of biota. The results from 4 of the 6 video scans including the 2 scans furthest from the net pen must pass – not be significantly different than observed at the reference site located 500m to 2km from the farm. Although nets are pressure washed in-situ, chemicals are use only on land (M. Parker, pers. comm.). There are mandatory requirement for reporting as well as penalties for non-compliance (Anon. 2010).

While the transfer of jurisdiction for aquaculture from the Province of British Columbia to the Federal Government may see some changes to these requirements, it appears that a much higher level of mandated monitoring and reporting is require for this industry sector than is typically in other projects that result in habitat disruption (Quigley and Harper 2005). In a national review of projects, Quigley and Harper (2005) reported follow-up on less than half of the projects in their study with many reports from proponents being superficial and qualitative.

A number of studies and reviews have considered the effect of waste discharge from salmon farms and the primary impact (not surprisingly) is to the benthos with effects being negligible beyond 30m from the net pen (Anon. 1997; Brooks and Mahnken 2003a,b; Philips 2005; Waknitz et al. 2002). Similar results and conclusions were obtained and found from studies outside the Pacific Northwest (see for example Findlay et al. 1995). Although industry regularly monitors water quality at their farms for their own purposes, there is no ongoing monitoring by government. Waknitz et al. (2002) reported that dissolved nitrogen added to the water column from salmon farms was not measurable above background levels more than 10m from the farm and there was little or no effect on levels of dissolved oxygen. Similar effects have been observed for finfish farms in British Columbia (S. Cross, pers. comm.).

It is difficult to imagine a plausible link between the limited areal benthic disruption under a salmon farm and the survival of sockeye salmon (or any other species of salmon) and as far as I am aware no one (or no group) has raised this as a serious concern. The reviews of aquaculture to date have all focussed on the potential effect on the benthos itself as well as invertebrates and fish that live at or near the bottom of the water column (for example Anon. 1997). Any effect on the water column also appears to be limited in extent and it's logical to assume that any effect would be apparent and amplified for the farmed fish themselves. Migrating salmon are likely to experience very limited and transitory exposure to contaminants in the water column and I would expect little or no measureable effect in survival or other measures of health or performance.

Sea Lice

Two main species of sea lice, *Lepeophtheirus salmonis* (salmon louse) and *Caligus clemensi*, infect Atlantic and Pacific salmon although eight or more species of sea lice may and have been found on salmon and other marine fish (Harvey 2008; Johnson and Albright 1991; Margolis and Arthur 1979; Margolis and Kabata 1996; McDonald and Margolis 1995; Parker and Margolis 1964). While salmon are the primary host for *L. salmonis*, other species such as threespine stickleback (*Gasterosteus aculeatus*) may also act as hosts although it is unclear exactly how these other fish species contribute to the population dynamics or ecology of the salmon louse (Jones and Prosperi-Porta 2011; Jones et al. 2006; Losos et al. 2010). However, Jones and Prosperi-Porta (2011) found *L. salmonis* prevalence on sticklebacks ranged from 51% in 2005 to 11% in 2008 so at the very least stickleback may act as a significant reservoir for juvenile and sub-adult *L. salmonis* as well as other species of sea lice (Beamish et al. 2009, 2011b). Jones and Prosperi-Porta (2011) used genetic tests to confirm the lice species identification because it is extremely difficult to distinguish between some lice species using morphometric measurements alone. The smaller and less pathogenic *C. clemensi* has many hosts (Krkosek et al. 2007b; Margolis and Kabata 1996) and is generally more prevalent and in much higher numbers than the salmon louse (Boxshall and Defaye 1993; Jones et al. 2006; Kent 2011). *C. clemensi* appears to be by far the most prevalent species of sea lice on juvenile Pacific and Atlantic salmon including juvenile sockeye salmon (Beamish et al. 2009; Korman 2011; Price et al. 2011).

Sea lice have been a significant ongoing problem for farmed and wild Atlantic salmon in Norway, Scotland, and the east coast of North America (see for instance Boxshall and Defaye 1993; Costello 2006). There are, however, significant differences with respect to sea lice on the Pacific coast. First, the Pacific salmon louse is genetically different from Atlantic salmon louse (*L. salmonis*) having coevolved with Pacific salmon (independent from the Atlantic form of sea lice) for the last 2.5 – 11 million years (Yazawa et al. 2008). The genetic separation of the two forms of sea lice likely contributes to differences in pathogenicity (the Pacific salmon louse appears to be less pathogenic) and environmental sensitivities documented for the Atlantic and Pacific salmon louse (Yazawa et al. 2008). Also, whereas some weak geographic differences were found for the Atlantic form of the salmon louse using genetic analysis (Glover et al. 2011), no population structure was found for the Pacific salmon louse using samples of lice from both wild and farmed salmon from Alaska to southern British Columbia (Messmer et al. 2010). Based on an analysis of 27 microsatellites and 87 SNPs (single nucleotide polymorphisms), their results are very conclusive and support the hypothesis of a single well mixed *L. salmonis* population on the west coast of North America (Messmer et al. 2010). Boulding et al. (2009) using a more limited genetic analysis and fewer fish found a difference between farmed and wild fish but there is no apparent reason for the difference given that the farmed fish are infected and re-infected regularly by sea lice from returning wild salmon (Marty et al. 2011). The Messmer et al. (2010) study is much more complete and the evidence for a single well mixed population of salmon louse in the Pacific Northwest is scientifically convincing, reasonable, and plausible.

Another significant difference between the Atlantic and Pacific is that unlike Norway, Scotland, and eastern North America, there many more (by orders of magnitude) wild and hatchery salmon in the Pacific Ocean than salmon on farms. Whereas salmon farms are the primary source of the salmon louse *L. salmonis* in the Atlantic, that's not the case in the Pacific. A number of studies have documented natural infestations of *L. salmonis* at levels equal to or greater than those found on farmed salmon over a wide geographic range so there are several significant sources of *L. salmonis* infection apart from salmon farms (Beamish et al. 2009; Nagasawa et al. 1993; Price et al. 2011; Trudel et al. 2007). There is also good evidence from the sea lice data collected at the farms (Table 4 and Korman 2011) that farmed salmon are infected by sea lice (*L. salmonis*) from adult Pacific salmon that are returning to spawn in the late summer and fall (Marty et al. 2011). This is not surprising and makes perfect sense. Thus, the epidemiology of sea lice will be quite different between the Atlantic and Pacific as will be the measures required to control sea lice.

Several surveys and studies of sea lice and salmon in British Columbia have been completed and others are either on-going or planned. Interpretation of the data varies widely and there has been considerable debate both in the scientific literature and in the popular media. Two particular concerns that were raised early in this debate were inconsistencies in the collection and reporting of sea lice data by the many groups including problems with species identification for both juvenile salmon and sea lice as well as the reliability of estimates of absolute and relative abundance of both lice and salmon by species (Riddell 2003). These inconsistencies are not only between studies but also within individual studies where different gear and methodologies were used to collect information with no attempt to develop a common (standardized) framework for comparison and often a lack of recognition by the researchers that such a framework was even necessary. There are also many environmental factors that can influence the abundance and distribution of sea lice (Brooks 2005; Brooks and Stucchi 2006; Connors et al. 2008; Hahnenkamp and Fyhn 1985) and many studies have failed to measure or account for these factors in their survey design or analyses. Unfortunately, that means that the information from the different studies is not directly comparable and each must be assessed on their own merit.

Most of the sea lice studies have involved pink and chum (*O. keta*) salmon (Beamish et al. 2006, 2007, 2009; Jones and Hargreaves 2007, 2009; Jones and Nemec 2004; Krkosek et al. 2007a, 2009; Morton et al. 2004, 2005, 2011; Morton and Williams 2004, 2006; Price et al. 2010) although a few studies have also measured sea lice prevalence and abundance on other species of salmon including sockeye (Beamish et al. 2009; Price et al. 2011; Trudel et al. 2007). As noted previously, the differences in sampling methodologies and species identification (of both salmon and sea lice) means that direct comparisons of the data from the various studies are virtually impossible. Dip nets, trawls, and seines have been routinely used (sometimes in combination) but their relative efficiency (to catch fish) and whether samples are representative of the (salmon) population has not been assessed. Sea lice are sometimes counted on the fish in the field (sometimes through a plastic bag) and sometimes the fish are frozen and lice are counted in the lab at a later date. There is also a wide range of abilities of the field and laboratory staff involved in identifying the different species of juvenile salmon and sea lice and undoubtedly there are errors in many if not all of the data sets collected (R. Beamish, S. Johnson, and S. Jones, pers. comm.). Also, there is significant variability in the data which is often not recognized and generally not reported. By themselves, the data may be useful as a snapshot of salmon and sea lice prevalence and abundance at a point in time recognizing all of the problems in comparing the different samples. The differences and difficulties arise when the investigators try to link their ‘sample’ with sea lice on farms without any knowledge whatsoever about the sea lice levels on the farm. In these situations, the assumptions (which consciously or unconsciously incorporate some bias) often become the conclusions (given the statistical noise in the data) with a ‘model’ serving only to connect the two end points.

There are too many case studies to discuss in detail and it’s not a particularly useful exercise since they are in essence speculation about the impacts of sea lice from salmon farms on wild and hatchery Pacific salmon in the absence of sea lice data from the farms (data which were made available for this project). However, one study is worth mention as it and a number of related papers highlight some important issues and problems. Krkosek et al. (2007a) proposed a model that predicted the collapse of pink salmon in the Broughton Archipelago within a few generations due to sea lice from salmon farms. In doing so, they used some questionable assumptions such as farms being the predominant source of sea lice, they excluded important information such as pink salmon production from a key river in this area, and selectively viewed a portion of the data using one of the highest pink salmon returns on record for their reference point ignoring important information including historical patterns of returns (an important perspective). As a result, their assessment and conclusions were significantly skewed (biased) and were not credible. Krkosek et al. (2007a) were correctly criticized for these serious errors and omissions and an extensive exchange of views took place through a series of papers (Brooks and Jones 2008; Krkosek et al. 2008; Krkosek and Hilborn 2011; Riddell et al. 2008). The original predictions of a total collapse of pink salmon populations was subsequently tempered (Krkosek et al. 2009; Morton et al. 2011) and eventually (not surprisingly) Krkosek et al. (2007a) were proven to be wrong. There have been strong returns of pink salmon to the Broughton in recent years and a credible assessment using sea lice data from fish farms and other information showed no significant relationship between sea lice on fish farms and pink salmon survival (Marty et al. 2011). Speculation can be useful to stimulate discussion and an exchange of views but considerable caution should be used when it forms the basis of your 'model' or conclusions as it does in many of the cases studies to date. The data are often noisy (in a statistical sense), the relationships are often weak or not well defined, and the assumptions often consciously or unconsciously incorporate bias and all of these factors increase the likelihood that the conclusions will simply echo the assumptions. Riddell et al. (2008) all have extensive experience in analyzing complex fisheries data and they correctly identified serious omissions and errors in Krkosek's et al. (2007a) paper. The ensuing debate simply highlights the strong polarization around the salmon farming issue which I expect will continue for some time.

Although most of the studies dealt with pink or chum salmon, one study (Price et al. 2011) does speculate about the impact of sea lice from salmon farms on sockeye salmon again without the use of sea lice data from farms. Assumptions and lack of sea lice data from farms aside, there are enough serious problems with their data and analyses to significantly limit the utility of this study. First, the salinity for the 'North Coast' reference site is substantially less than (about 2/3) the salinity for sites in the south (16.97 vs. ~26.4). While sea lice can tolerate a range of salinity and temperature (Brooks 2005; Connors et al. 2008; Hahnenkamp and Fyhn 1985; Johnson and Albright 1991), growth and survival and ultimately prevalence and abundance are influenced by both salinity and temperature. It is not surprising that a large difference in sea lice numbers was found between the 'North Coast' site and the samples from the south given the difference in salinity alone. Perhaps the location of the 'North Coast' site was simply convenient to access but from a scientific perspective it was a careless choice at best.

The weight of the juvenile sockeye is also different for the 'Upstream' and 'Downstream' sites with fish at 'Downstream' sites being consistently larger in both 2007 and 2008. This issue is a particular problem in 2008 to the point where those data are likely useless for the stated purpose of the paper. If weight/size is a factor that influences sea lice infection and it appears to be from studies involving pink salmon, then the consistent difference in weight between the 'Upstream' and 'Downstream' samples alone could account for any perceived relationship. In addition to differences in size between the 'Upstream' and 'Downstream' sites in 2008 (~4 g difference in weight), there was more than a 5°C difference in temperature with the higher temperature being recorded for the 'Upstream' locations. The difference in temperatures suggests a considerable time lag between when the juvenile sockeye were sampled at the 'Upstream' and 'Downstream' sites. It's unlikely that the juvenile sockeye at the 'Upstream' and 'Downstream' sites in 2008 are from the 'same population' or at the very least there were enough significant changes that the data from the two groups are simply not comparable. While some changes to environmental variables (such as temperature) may be accounted for in a model, the observed discrepancies in these data are sufficiently large and numerous enough to seriously limit their utility.

The explanation associated with the 'outlier' observation is also questionable. It is difficult to believe that free floating sea lice would be carried 8 km against the prevailing current, infect only juvenile salmon at the 'outlier' site, and the same process (tidal transport) not have any significant effect on sea lice counts on juvenile sockeye at the other 'Upstream' sites. It's also not clear why juvenile sockeye would extend their stay downstream of a salmon farm when the prevailing current and presumably their instinct would make the juvenile fish want to continue their northward migration. Also, the juvenile fish are migrating so fish that were 'Upstream' at one point in time are 'Downstream' at a later point in time and vice versa. Thus, the same group of fish are being repeatedly sampled (except in 2008 where other problems with the data are significant enough to limit their usefulness) and this is not accounted for in the analysis. Given all of these deficiencies, the paper's conclusions are speculative and suspect.

L. salmonis are capable of causing mortality if present in large numbers and Johnson et al. (1996) documented a case involving adult sockeye salmon returning to Alberni Inlet. In that instance, unfavourable river conditions forced the returning sockeye to hold for an extended period of time and sea lice and associated secondary disease resulted in the death of some fish. In addition to killing juvenile salmon directly, sea lice (*L. salmonis*) could have sub-lethal or secondary impacts. For example, Mages and Dill (2010) found that swimming performance and endurance of juvenile pink salmon was reduced when the fish were infected with adult female *L. salmonis*. Nendick et al. (2011) found a similar result for small pink salmon but they found no significant impact on pink salmon that were greater than 1.1 g. Finally, Sutherland et al. (2011) also examined the response of pink salmon to *L. salmonis* infections and again they found a negative response for small fish but they also identified a possible parasite-induced growth augmentation (a positive response) for fish greater than 2.4 g. While all three studies dealt with small pink salmon, it is likely that fish size (along with the number of *L. salmonis* infecting the fish) is an important factor in other salmon species' response to *L. salmonis* infections. In particular, juvenile sockeye salmon (including those from the Fraser River) are considerably larger on average than the juvenile pink salmon examined in these three studies so it is certainly plausible (and quite likely) that they are able to mount an effective defence against *L. salmonis* infections (Kent 2011). Also, *L. salmonis* are typically not common on juvenile sockeye salmon with a prevalence of 4% and an abundance of less than 1 louse/fish for ocean surveys conducted in May and June 2010 (Kent 2011). At these levels of prevalence and abundance, it is unlikely that sea lice have a significant lethal or sub-lethal effect on sockeye salmon at the population level.

There is also the potential for sea lice to act as vectors for other pathogens (for instance, BKD or IHN) that may cause disease in sockeye salmon (Barker et al. 2009; Nese and Enger 1993). It is certainly possible to isolate a pathogen such as IHN from sea lice and to cause a disease through injection but disease agents have evolved more effective modes of transmission (K. Garver, pers. comm.). For instance, IHN can spread very effectively through water – much more effective and efficiently than using sea lice as a vector (K. Garver, pers. comm.). Thus, the transfer of disease through via a sea lice vector is unlikely to be of significance at a population (salmon) level.

The salmon farming industry uses a standardized sampling protocol at all farms to monitor sea lice levels on a monthly basis (Table VI, Appendix 2 and Korman 2011). The average number of motile *L. salmonis* sea lice per fish by fish health zone and by season is summarized in Tables 3 and 4, respectively. Farms in Zone 2 are on the West Coast of Vancouver Island, Zones 3-1 to 3-4 is the area between Vancouver Island and the BC mainland, and Zone 3-5 is the area north of Vancouver Island. The mean number of sea lice per fish has decreased significantly over time from an average of about 3 lice/fish in 2004 to about 1 lice/fish in 2010 (Table 3, Figure 4A, and Korman 2011). The decrease is more dramatic for the April – June period (denoted ‘Spring’ in Table 4) with an average number of lice per fish of ~ 0.5 lice/fish in 2009 and 2010 (Figure 4A). This is the timeframe when juvenile sockeye salmon from the Fraser River are migrating past the salmon farms. The highest number of lice per fish is in the fall and reflects the transfer of lice from returning adult Pacific salmon to farm fish (Table 4 and Marty et al. 2011).

The average number of *C. clemensi* sea lice per fish is higher than the number of *L. salmonis* per fish (Table 5, Figure 4B, and Korman 2011). There has been less of a decline in abundance over time for *C. clemensi* (compared to *L. salmonis*) with slightly higher numbers observed during the ‘Summer’ period (Table 5). The increased abundance of *C. clemensi* in the ‘Summer’ may be a consequence of herring (a known host) and other marine fish congregating to spawn in the spring or it may simply be related to the seasonal warming of the ocean. Whatever the case, abundance does not increase in the ‘Fall’ which suggests that Pacific salmon are only one of many sources and not the primary source of *C. clemensi* for farmed fish. Again, this is not surprising given the large number of hosts for *C. clemensi* and it is reasonable to assume that infestations of *C. clemensi* on wild and hatchery Pacific salmon come from a wide variety of sources as well.

Table 3: Number of motile *L. salmonis* sea lice per fish averaged over all months by fish health zone and by year. The sea lice count for Zone 3-5 in 2007 is from two farms, 'Jackson Pass' and 'Lochalsh Bay' located near Klemtu, BC in the North Coast.

	Fish Health Zone								
Year	**2-3**	**2-4**	**3-1**	**3-2**	**3-3**	**3-4**	**3-5**	**Mean All Areas**	**Mean 3-1 to 3-4**
2004	0.7	2.4	0.0	1.3	4.2	3.5	0.0	2.9	2.3
2005	1.3	1.7	0.1	1.4	3.0	1.6	0.0	1.9	1.5
2006	1.3	1.7	0.0	1.6	2.4	1.0	1.2	1.7	1.2
2007	1.7	1.7	0.0	1.1	0.8	1.8	7.2	1.6	0.9
2008	1.2	1.4	0.0	1.5	1.2	1.8	1.5	1.4	1.1
2009	0.5	4.0	0.0	1.3	1.0	2.2	0.1	1.5	1.1
2010	0.4	2.4	0.3	0.8	0.6	1.5	0.2	1.0	0.8
Average	**0.9**	**2.2**	**0.1**	**1.3**	**2.0**	**1.8**	**3.4**	**1.7**	**1.3**

Table 4: Number of motile *L. salmonis* sea lice per fish by season by fish health zone and by year. The 'Spring' season is from April to June inclusive.

	Season				
Year	**Spring**	**Summer**	**Fall**	**Winter**	**Avg.**
2004	3.0	3.0	2.4	3.1	2.9
2005	1.2	1.2	3.2	2.3	1.9
2006	1.2	1.3	2.3	2.1	1.7
2007	0.7	0.7	3.6	1.0	1.6
2008	1.2	0.8	1.6	1.9	1.4
2009	0.4	1.3	2.8	1.3	1.5
2010	0.5	0.6	0.0	1.8	1.0
Mean	**1.1**	**1.2**	**2.7**	**1.8**	**1.7**

With respect to the salmon louse, there was a noticeable drop between 2004 and 2005 and a steady decline from that time to about 1 – 1.5 lice/fish on average throughout the year and to about 0.5 lice/fish during the April – June period (Tables 3 and 4). Whether the annual average sea lice per fish (p-value ~ 0.79), the 'Spring' sea lice per fish (p-value ~ 0.72), or any of the four measures used by Connors (2011) are considered [Connors considered a) the number of motile *L.*

salmonis abundance (pre-adult I, II and adult), b) the number of gravid female *L. salmonis*, c) the number of motile *C. clemensi*, or d) the total abundance of motile lice for both species], there was no significant relationship between sea lice abundance on farms and Fraser River sockeye salmon productivity. It is also interesting to note that sea lice (*L. salmonis*) levels were relatively low in the 'Spring' of 2007 (~ 0.7 lice/fish) when the sockeye salmon that returned in 2009 were in the area. Conversely, *L. salmonis* levels were a bit higher (~ 1.2 lice/fish) although still relatively low in the 'Spring' of 2008 when the salmon from the record 2010 run entered the ocean. If sea lice from salmon farms were a major factor in the decline of Fraser sockeye, you would expect to see the opposite pattern of abundance for sea lice (*L. salmonis*) in 2007 and 2008 given the Fraser sockeye returns in 2009 and 2010. Infestation rates (lice/fish) for the smaller *C. clemensi* species of louse were higher and much more variable compared to the salmon louse but there was also no correlation between Fraser River sockeye productivity and 'Annual' (p-value ~ 0.86) or 'Spring' (p-value ~ 0.33) levels of *C. clemensi*.

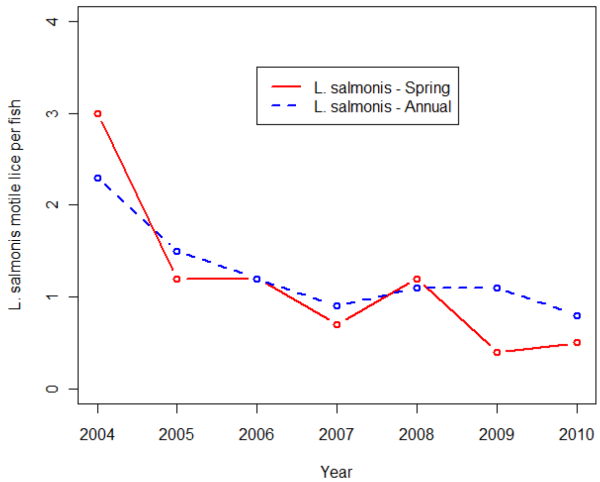
The time series of sea lice data is relatively short and this will affect the power to detect (or reject) trends and relationships (see for example Korman 2011). However, the decline in *L. salmonis* numbers is quite significant (a factor of 3) over the time period considered and the small p-values suggest that the declines are real and significant. Given the decline in sea lice abundance over time, it is conceivable that a positive or negative relationship could exist between sea lice numbers and Fraser River sockeye salmon productivity or no relationship at all. No significant relationship between sea lice numbers on farm salmon and Fraser River sockeye salmon productivity was found and the use of several different measures of sea lice abundance and different types of analyses strengthens the conclusion of no significant relationship.

Table 5: Number of motile herring lice *C. clemensi* per fish by fish health zone (all areas) , by season, and by year.

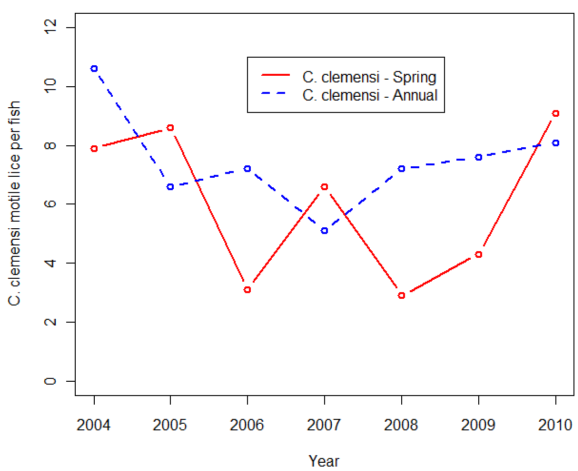
	Season				
Year	**Spring**	**Summer**	**Fall**	**Winter**	**Average**
2004	7.9	15.4	8.3	12.7	10.6
2005	8.6	1.8	5.0	9.8	6.6
2006	3.1	13.2	9.7	2.1	7.2
2007	6.6	5.7	3.1	5.3	5.1
2008	2.9	15.0	10.7	2.6	7.2
2009	4.3	8.9	5.1	12.5	7.6
2010	9.1	8.6	0.0	6.7	8.1
Mean	**6.1**	**9.6**	**6.7**	**7.2**	**7.3**

Figure 4. A) Average number of motile salmon sea lice (L. salmonis) per fish on farmed salmon throughout the year and for the three month period April – June. B) Average number of the sea lice (C. clemensi) per fish on farmed salmon throughout the year and for the three month period April – June. The data and figures are from Korman (2011).

A.



B.



Other Diseases

Kent (2011) provides a good summary of the diseases that may affect sockeye salmon and a qualitative assessment of the risk that each poses to sockeye. Atlantic salmon are susceptible to many if not all of the pathogens (virus, bacteria or parasite) that cause the diseases outlined by Kent (2011) but Atlantic salmon's susceptibility and response to these disease agents is likely to be different than Pacific salmon just as there are differences between the various species of Pacific salmon. For instance, Atlantic salmon appear to be far less susceptible to BKD than chinook and coho salmon and that is certainly reflected in the fish health data from the farms (Evelyn et al. 1998; P. McKenzie, S. Saksida, pers. comm.). All of the diseases found on salmon farms are common in BC and there is no evidence that any exotic pathogens or diseases have been introduced by the salmon farming industry. Infectious salmon anemia virus (ISA) has caused significant mortality to salmon in other parts of the world and this disease has been raised as a special concern by many in BC. The BC Ministry of Agriculture and Lands have conducted random audits for a number of years and ISA is one of the pathogens that they routinely screen for in their sampling program for farmed salmon. To date, these audits have not found ISA in any farmed salmon. There are certainly other avenues for the introduction of exotic diseases such as the live fish and shellfish imports for human consumption and ballast water and none of these sources are being monitored for diseases of concern to Pacific Salmon.

All salmon farms are required as a condition of licence to monitor the health of their fish and submit reports on a monthly basis (Appendix 2, Table VI). These standardized reports must contain information on the number of fish on each farm, the number of fish that died each month and the suspected causes of these mortalities, and monthly sea lice monitoring data. Farms are also required to randomly sample up to 60 fish from 3 net pens at each farm each month or more frequently to monitor the number of sea lice per fish and if necessary treat the fish once the sea lice levels reach a prescribed level. In addition, industry veterinarians or fish health technicians must report all fish health events (FHE). A FHE is defined as an active disease or suspected disease on the farm that triggers a) veterinary involvement and b) an action such as testing and diagnostics at a lab, a change in husbandry practices, prescription medication or further action aimed at reducing or mitigating the risk associated with the FHE. It should be noted that approximately 35% (45 out of 130 per year) of the reported FHE are associated with the use of anaesthetics and SLICE for the mandatory sea lice monitoring and control program (Table 6). The percentage of 'High Risk' FHE has remained relatively stable since 2005 (approximately 22 FHE or ~17% on average since 2005) with no outbreaks of IHN (Infectious Hematopoietic Necrosis virus) since 2003 and 8 cases of vibrio in total since 2002 (Table 4). The downward trend in the number of 'high risk' FHE reported (Korman 2011) is likely due in part to the routine vaccination of farmed fish for furunculosis, vibrio, and IHN as well as changes and improvements in fish husbandry practices (P. McKenzie, S. Saksida, pers. comm.).

In addition to the mandatory reporting by industry, the BC Ministry of Agriculture and Lands also conducted fish health audits at randomly selected farms (Table 7). On average, there are about 32 million fish on BC salmon farms and about 3 million of these fish die each year for a variety of reasons (Table 8). The reasons could be environmental (such as an algae bloom), predation by seals, poor performance, or other factors including disease. About 635,000 (or about 2%) of the mortalities are 'fresh silvers' that die for a variety of reasons including an unknown percentage due to disease. The BC fish health audits randomly select 'fresh silvers' and submit them to a standard suite of tests that includes the disease agents in Table 7 as well as ISA (Korman 2011). The presence of a particular disease agent does not necessarily mean that there is an active disease outbreak at a farm and very few of the 'fresh silvers' tested showed clinical signs of disease. Between 2002 and 2007, the BC Ministry of Agriculture and Lands tested 496 groups of 5 – 8 'fresh silvers' (between 2,500 and 4,000 fish) for 6 viral and bacterial pathogens and only found 2 cases of VHS (Viral Haemorrhagic Septicaemia) and 2 cases of IHN (Korman 2011). The vast majority of the audit cases tested negative with no sign of disease in the histopathological examinations. The mortality rate on farms is quite low especially for 'fresh silver' (~2%/year) particularly when compared to a mortality rate of ~3%/day for juvenile Pacific salmon entering the Strait of Georgia.

Table 6: Number of fish health events (FHE) reported by industry. The 'Risk' level is the qualitative risk to sockeye salmon suggested by Kent (2011). Approximately 35 – 40% of the FHE are associated with the mandatory sea lice monitoring program. The percentage of high risk FHE have remained relatively stable since 2005 (averaging between 15 – 20%) after a significant decline. Data for 2002 and 2010 are partial. Data from Korman (2011).

	Disease					**Year**				
Risk		**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**
High	Furunculosis	6	12	10	3	1	3	5	6	10
High	IHN	5	16	0	0	0	0	0	0	0
High	BKD	20	34	40	29	10	23	20	9	7
High	Vibrio	2	1	1	0	0	0	2	0	2
Moderate	Sea Lice	5	29	41	59	50	35	47	41	52
Low	Loma	0	0	0	2	0	0	0	0	0
Low	Myxcobacteriosis	4	27	46	64	52	57	46	36	53
Low	Piscirickettsia	8	1	10	4	2	3	4	0	0
Low	VHS	0	2	0	6	1	1	0	3	3
Low	Other	0	0	8	2	1	1	0	0	0
Low	No Diagnosis	0	0	1	3	0	1	2	3	2
	Total	**50**	**122**	**157**	**172**	**117**	**124**	**126**	**98**	**129**
	Percent Lice	10%	24%	26%	34%	43%	28%	37%	42%	40%
	% high risk	66%	52%	32%	19%	9%	21%	21%	15%	15%
	No. High Risk	33	63	51	32	11	26	27	15	19

Table 7: Number of disease agents detected in randomly selected 'fresh silver' salmon sampled from the randomly selected farms used in the BC Ministry of Agriculture and Lands fish health audits. The first 4 diseases (furunculosis, IHN, BKD and Vibrio) were qualitative identified as 'high risk' diseases to sockeye salmon (Kent 2011). Data from Korman (2011).

Disease	Year							
	2002	2003	2004	2005	2006	2007	2008	2009
Furunculosis	0	6	0	0	0	0	0	1
IHN	5	2	0	0	0	0	0	0
BKD	6	7	16	9	11	16	11	5
Vibrio	0	0	0	0	0	0	0	0
Sea Lice	0	1	0	0	0	0	0	0
Loma	2	1	3	5	3	4	0	0
Myxcobacteriosis	0	2	6	6	7	9	0	0
Piscirickettsia	2	0	2	5	6	3	0	0
VHS	0	0	3	7	1	2	0	2
Other	1	9	22	18	12	4	17	34
No Diagnosis	13	77	59	61	65	73	69	59
Total	29	105	111	111	105	111	97	101
Total 'high risk'	11	15	16	9	11	16	11	6
% 'high risk'	38%	14%	14%	8%	10%	14%	11%	6%

A significant problem in assessing the impact of disease on the survival of sockeye salmon is that there is no ongoing monitoring of the diseases identified by Kent (2011) for any species of wild or hatchery Pacific salmon in BC. With very few exceptions (such as studying in-river mortality of sockeye), monitoring of disease in hatchery and wild Pacific salmon is only done in responses to emergencies or crises and the fish health records do not accurately reflect the level of disease in wild or hatchery salmon. All of these diseases are endemic to the west coast and at any point in time most if not all will be present to some degree at sub-clinical (no obvious signs of disease) or clinical (obvious symptoms) levels in wild and hatchery Pacific salmon (Kent et al. 1998). Also, even if a particular disease is an issue on salmon farms, there is no way of knowing whether the same disease is causing problems for Fraser River sockeye salmon and if so whether the source of the infection is from other wild or hatchery fish or from salmon farms. The disease data from salmon farms provides some insight on the impact (from a disease perspective) from salmon farms but unfortunately no information about why Fraser River sockeye salmon died. The lack of disease data for wild and hatchery Pacific salmon is an issue that must be addressed.

Table 8: The number of farmed salmon dying each year and the associated cause. The data between 2000 and 2002 are incomplete so averages are calculated for the period 2003 – 2010. The 'Fresh Silvers' die for a variety of reason including an unknown number by disease. Between 2002 and 2007 the BC Minister of Agriculture and Lands tested 496 groups of 5-8 'Fresh Silvers' randomly selected from farms for six types of viruses and bacteria and found only 2 cases of IHN and 2 cases of VHS. Data from Korman (2011).

Year	Fresh Silvers	Environmental	Predators	Other	Total	% Mortality	% Fresh Silvers	% Mort Fresh Silver
2000	30,354	0	4,570	25,606	60,530	10.7%	50.1%	5.4%
2001	31,695	0	5,669	27,462	64,826	11.1%	48.9%	5.4%
2002	710,054	398,745	26,165	394,249	1,529,213	8.5%	46.4%	4.0%
2003	3,561,782	2,584,714	115,794	2,088,295	8,350,585	29.8%	42.7%	12.7%
2004	811,008	733,744	131,281	1,716,913	3,392,946	12.2%	23.9%	2.9%
2005	1,131,805	613,031	86,079	1,357,220	3,188,135	10.8%	35.5%	3.8%
2006	887,449	664,101	169,642	1,435,822	3,157,014	9.3%	28.1%	2.6%
2007	591,004	510,487	227,849	1,968,809	3,298,149	10.0%	17.9%	1.8%
2008	624,015	1,436,449	216,884	1,862,301	4,139,649	13.2%	15.1%	2.0%
2009	696,832	517,388	208,141	1,289,685	2,712,046	8.9%	25.7%	2.3%
2010	376,181	169,469	134,617	841,302	1,521,569	4.9%	24.7%	1.2%
Average 2003-10	**635,096**	**903,673**	**161,286**	**1,570,043**	**2,965,685**	**11.8%**	**22.3%**	**2.0%**

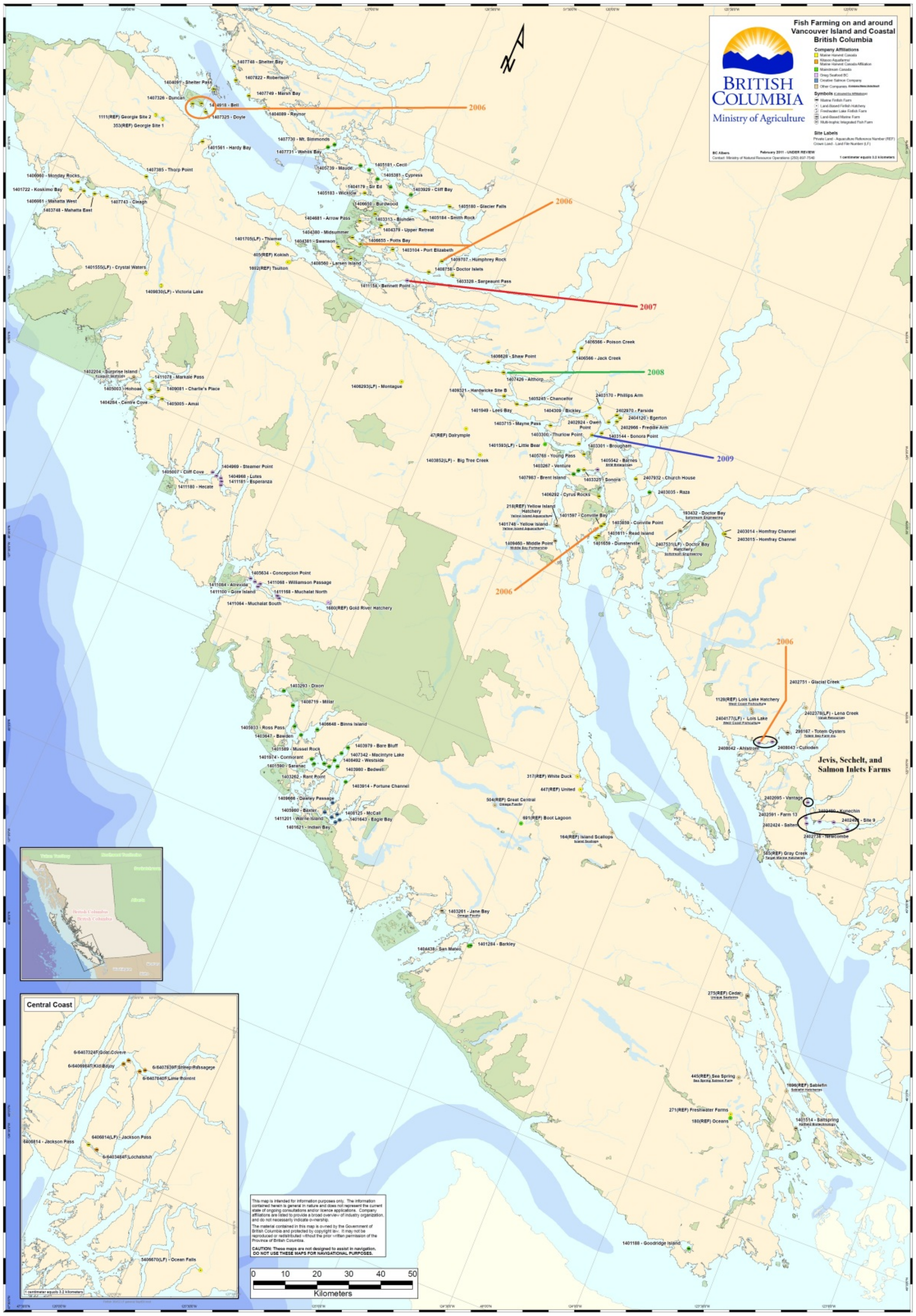
Connors (2011) found no significant relationship between the 'high risk' diseases and Fraser River sockeye salmon production and the reasons are clearly evident from the FHE reports and fish health audits (Tables 6 and 7). There have been no cases of IHN reported or observed in the fish health audits since 2003 so if Fraser River sockeye salmon are dying of IHN (which we don't know to be true) salmon farms are not the source of the infection (Tables 6 and 7). Tests for IHN are very good (accuracy between 75% - 90%) so it is extremely unlikely that repeated tests (hundreds each year) would fail to detect any cases of IHN if it was indeed present (McClure et al. 2008). It is also highly unlikely that any carrier or latent form of IHN is present without any active outbreak of disease and not surprising given the efficacy of the IHN vaccine (http://ocs.vre.upei.ca/index.php/FHS/FHS2008/paper/view/282). Likewise, there have been very few cases of vibrio (no more than 2 cases in any given year) reported on farms since 2002 and no reports from the fish health audits. Again, if vibrio is a problem for Fraser River sockeye salmon farms are not a significant source of infection (Tables 6 and 7). A few more cases of furunculosis have been reported on farms but since 2003 most of the furunculosis cases have been from farms located on the west coast of Vancouver Island (9/10 in 2010, 6/6 in 2009, 4/5 in 2008, 2/3 in 2007, 8/10 in 2004, and 5/12 in 2003) and not from farms located in the main migration route followed by Fraser River sockeye salmon. Again, if furunculosis is a problem for Fraser River sockeye salmon then salmon farms do not appear to be a significant source of infection. It is therefore not surprising that Connors (2011) found no significant relationship between these factors and Fraser River sockeye salmon productivity.

Table 9 shows the BKD FHE reported for the BC Ministry of Agriculture and Lands Fish Health Area 3, the waters between Vancouver Island and the BC Mainland and the area just north of Vancouver Island (Korman 2011). The numbers in brackets indicate the number of BKD FHE reported by the specific farm and provides some indication of how persistent the problem has been over time. For instance, 5, 6, 2, and 1 BKD FHE were reported for farm site 'Newcombe' (or Newcomb, located in Salmon Inlet in the Sechelt area) between 2007 and 2010 indicating an ongoing issue with BKD at that location over that time period. While this is useful information, knowing the number of farms experiencing BKD outbreaks and their location is more important for assessing potential impacts on Fraser River sockeye salmon. For instance, two reports for 10 farms is likely more significant from a population perspective than 20 reports from 1 farm. In that respect, there was a sharp drop in the number of farms reporting BKD FHEs in 2006 from a number in the teens to an average of 6 farms reporting BKD FHE over the last 5 years (Table 9). Either coho or chinook salmon (both very susceptible to BKD) were raised at each of the farms in Table 9 for the years indicated and typically for several sequential years (Korman 2011). Although a vaccine for BKD is available, its efficacy is modest and chinook and coho are not routinely vaccinated against BKD (P. McKenzie, S. Saksida, pers. comm.).

Table 9: Bacterial kidney disease (BKD) fish health events (FHE) by farm site in BC Ministry of Agriculture and Lands Fish Health Area 3 (Sub-zones 3-1 to 3-5 inclusive) and the number of farm sites with BKD fish health events by year. Multiple FHE at the same farm site (number in brackets) may represent follow-ups to an initial case but they are reported and listed as separate FHEs. Data for 2002 and 2010 are partial (data from Korman 2011).

Year	No. of Farms in Area 3	Farm Site
2002	6	Conville Point (2); Cyrus Rocks (2); Orchard Bay (1); Read Island (3); Sonora Point (3); Young Pass (4); + 5 FHE from Area 2
2003	11	Arthur Island (2); Church House Calm Channel (3); Conville Bay (3); Conville Point (9); Cyrus Rocks (1); Dunsterville Bay (2); Glacial Creek (1); Jackson Pass (2); Lochalsh Bay (1); Power (1); Young Pass (3); + 6 FHE from Area 2
2004	18	Brougham Point (1); Cecil (1); Church House Calm Channel (2); Conville Bay (2); Conville Point (1); Cyrus Rocks (2); Dunsterville Bay (2); Jackson Pass (2); Lochalsh Bay (3); Maude (1); Newcombe (1); Potts (1); Read Island (1); Sargeaunt Pass (1); Sonora Point (3); Thurlow South (1); Vantage (1); Young Pass (4) + 10 FHE from Area 2
2005	14	Althorp (2); Cecil (1); Chancellor Channel (1); Cliffe Bay (1); Conville Point (3); Doctor Islets (1); Lees Bay (1); Maude (1); Phillips Arm (1); Port Elizabeth (1); Read Island (3); Sir Edmund Bay (1); Shaw Point (1); Sonora Point (11)
2006	6	Ahlstrom (1); Conville Bay (2); Humphrey Rocks (1); Potts (2); Bell Island (1); Doyle (1); Duncan (1) + 1 FHE from Area 2
2007	6	Ahlstrom (3); Bennett Point (1); Culloden (3); Kunechin (4); Newcombe (5); Vantage (3) + 4 FHE from Area 2
2008	9	Ahlstrom (4); Althorp (2); Culloden (3); Farm 13 (1); Kunechin (1); Newcombe (6); Potts (1); Sargeaunt Pass (1); Vantage (1)
2009	5	Ahlstrom (1); Kunechin (2); Newcombe (2); Thurlow South (1); Vantage (3)
2010	3	Frederick Arm (1); Humphrey Rocks (1); Newcombe (1); + 4 FHE from Area 2

Figure 5: Salmon farms that reported BKD FHE in 2006 (orange), 2007 (red), 2008 (green) and 2009 (blue). One or more of the farms in Jervis, Sechelt, and Salmon inlets experienced BKD FHEs during this 4-year period. Map used with permission of the BC Provincial Government.



Some geographic clustering of outbreaks is apparent with some nearby farms reporting BKD FHE during the same time period (Figure 5). For instance, in 2006 three (3) farms from the northern part of Queen Charlotte Strait (Bell Island, Doyle, and Duncan) all reported BKD FHE (http://www.salmonfarmers.org./sites/default/files/All%20Companies%20Out%20Migration%20Sites%20P4.pdf). Two farms sites in the Broughton Archipelago (Humphreys Rock and Potts) slightly more distance apart also reported BKD FHE in 2006 (Table 9). In 2007, 5 of the 6 farms (Ahlstrom, Culloden, Kunechin, Newcombe, and Vantage) reporting BKD FHE were from the Jervis Inlet/Sechelt Inlet area with Bennett Point (Broughton area) being the only farm site in the main migration route for Fraser River sockeye reporting a BKD FHE (Table 9). Similarly, in 2008 six (6) of the 7 farms reporting BKD FHE were from the Jervis Inlet/Sechelt Inlet area (the same five farms as in 2007 plus Farm 13) with the only farm in the Fraser River sockeye salmon migration path being 'Althorp' (or Althorpe) in Johnstone Strait (Table 9). The fish health audits identified some additional cases of BKD (not associated with a FHE) in Queen Charlotte Strait in both 2007 and 2008 (Korman 2011). The 2007 and 2008 information is of particular interest given the huge difference in returns of Fraser River sockeye in 2009 and 2010. With only one farm (Bennett Point) along the main migration path of Fraser River sockeye reporting a BKD FHE, it would be unreasonable (in the extreme) to suggest that BKD from salmon farms contributed to the significant decline in sockeye returns in observed 2009. Again, it is important to note that we don't know if BKD (or any specific disease) was a problem with Fraser River sockeye salmon in any particular year. Not much changed (with respect to the incidence of BKD on salmon farms) in 2008 with a record number sockeye salmon returned to the Fraser River in 2010 (as well as near record returns of pink salmon [~20,000,000 pinks] to the Fraser River in 2009). There is no evidence of any significant link or relationship between BKD in farmed salmon and Fraser River sockeye salmon returns when the data are examined in finer detail.

While this last issue is worthy of mention, it may or may not be of any relevance to the subject of this report. In a recent paper, Miller et al. (2011) identified a genomic signature that appears to be correlated with increases in pre-spawning mortality of Fraser River sockeye salmon. These authors found that ocean-tagged sockeye salmon with this genomic signature had a 13.5 fold greater chance of dying without spawning compared to sockeye salmon that did not exhibit this genomic signature. The genomic signature may be a response to an environmental factor or factors (including disease) but at this point the factor or cause is unknown. Their data suggest a potential linkage to viral infections but a review of the histological slides of tissue from affected fish (those exhibiting the genomic signature) by two fish health experts (Dr. Michael Kent, Oregon State University and Dr. Gary Marty, BC Ministry of Agriculture and Lands) revealed no significant pathological changes or evidence of a viral infection (Kent 2011). Viral screening also did not reveal any evidence of a virus so the genetic signature does not appear to be the result of any known virus (Kent 2011). However, sockeye and other species of wild salmon are exposed to many viruses and it is possible that the genomic signature is associated with one or more viruses that are present at a subclinical level. The genetic signature (actually, the first principle component presented by the authors) also had some confusing attributes with a negative associations for several stress factors which is counterintuitive if the fish are diseased. The genetic signature may or may not be associated with a novel (previously undocumented) virus and that is certainly a key next step in this interesting research. Another important issue is to determine if the genomic signature (if it is a virus) is the cause of mortality or coincidental.

Although the sample sizes used in Miller et al. (2011) are small and the percentage of variance explained by the model is modest (12%), a larger number of sockeye from other years has been analyzed (K. Miller-Saunders, pers. comm.). The genomic signature has been found in juvenile sockeye salmon (before they smolt) in their natal streams as well as in returning adults caught as far away from the Fraser River as Haida Gwaii (Queen Charlotte Islands) and at points in between (K. Miller-Saunders, pers. comm.). The genomic signature has also been found in coho and chinook salmon and there were difference between the three species tested as well as between years. Testing of pink, chum, and Atlantic salmon has not yet been done to date (K. Miller-Saunders, pers. comm.). If the genomic signature is not related to a virus or other type of disease (pathogen) then it may have little or no link with the subject of this report. It may, however, still be of use in forecasting pre-spawning mortality either pre-season or in-season.

Concluding Remarks

The salmon farming industry in British Columbia has changed substantially from its beginnings in the early 1980s and there is no question that the intense exchange of views and opinions by all involved has resulted in positive changes. Debates over potential impacts have been antagonistic to say the least and largely speculative given the lack of data and to some degree 'belief-oriented science' where research was focussed more by the strongly held views of researchers and was generally much less objective than would normally be expected. The provision of fish health and production data by industry and government was crucial in understanding potential impacts.

Based on the information available, there appears to be no evidence of a significant impact from fish farms on Fraser River sockeye. The risk from escaped Atlantic salmon and waste discharge from farms are both miniscule approaching zero. Data from the fish health records provided by industry and the fish health audits conducted by government staff indicate that farmed fish are generally very healthy with very low rates of mortality that could potentially be due to disease (~ 2% mortality for 'fresh silver' fish). Kent (2011) identified four 'high risk' diseases for sockeye and the fish heath records and fish health audits documented very few incidences of these diseases at salmon farms along the main migration path for Fraser River sockeye salmon since 2003. In any given year, a very small number of farms (typically less than 5 farms) along the main migration route for Fraser River sockeye salmon reported any of these four 'high risk' disease. Given these disease are endemic and wide spread, I believe the additional risk posed by salmon farms for these four diseases is minimal and likely undetectable. There has been a significant decrease in the number of sea lice (*L. salmonis*) at salmon farms since 2003 and no significant relationship was found between sea lice on salmon farms and Fraser River sockeye salmon productivity (this study and Connors 2011). While adult female *L. salmonis* have experimentally been shown to negatively affect small (< 0.7 g) juvenile pink salmon, larger pink salmon were able to mount an effective defence against sea lice. Juvenile sockeye salmon are much larger, are primarily infested with the smaller and less pathogenic *C. clemensi* sea lice, and do not appear to be affected by sea lice from salmon farms. Also, it does not appear that sea lice from salmon farms have affected juvenile pink salmon from the Fraser River as pink salmon returns to the Fraser have been generally quite good for the past 20 or more years with near record returns in recent years such as 2009 when 20 million or more pink salmon returned.

I expect that there are many reasons for the decline of Fraser River sockeye salmon but based on the information available the impact from salmon farms appears to be minimal at best.

State of the Science

Controversy and advocacy have generally hindered cooperation and progress in many areas. A good example is work on the impact of sea lice on wild and hatchery Pacific salmon where there is a general lack of trust and respect between the various groups. Differences in methodology including the collection of juvenile salmon and sea lice as well as species identification for both salmon and sea lice make it very difficult to compare samples and data from the various studies. This was an issue that was raised when sea lice first became an issue and despite attempts at coordination some differences still persist. Many of the sea lice studies published to date are speculative and the hypotheses and assumptions used to model the data strongly determine the outcome and conclusions. As such, the studies add little in terms of scientific value beyond perhaps the data used in the study. Only one published study used sea lice data from fish farms to assess the impact on juvenile pink salmon and the results are quite different from studies that speculated on impacts in the absence of any sea lice data from salmon farms. There is generally little or no agreement on the results of the scientific analyses, interpretation or conclusions and it would be fair to say the views of the various groups remain quite polarized.

Some progress has been made and a consistent approach is now used at all salmon farms to collect and report sea lice data. The detail and quality of the farm sea lice data (both mandatory monitoring and audit programs) appear to be excellent. Also, some of the sea lice publications (those not dealing with the impact on Pacific salmon) simply present survey results and these studies have provided general information on the prevalence and abundance of sea lice on Pacific salmon and other marine fish. These surveys in combination with laboratory experiments have also provided us with a better understanding of sea lice biology and ecology including linkages and relationships with various environmental factors, preferred host response and interaction, potential intermediate hosts, and theories on life history strategies that sea lice may adopt to enhance their ability to survive. These studies have generally been less controversial and have enjoyed a greater level of cooperation. While sea lice are both abundant and common, there are still many questions about their biology and ecology that need to be answered not only for their scientific merit but also to potentially develop strategies to manage and control these pests.

There is also a high level of consistency in the testing and reporting of other (non-sea lice) diseases on salmon farms and the data are of high quality and detail. Unfortunately, there is very little disease data for wild and hatchery fish and the data are not generally available. The lack of fish health information for wild and hatchery fish is a serious deficiency. Regular and routine sampling of wild and hatchery fish for disease and publicly reporting this information to the same level of detail and quality as for farmed salmon is required for proper assessment.

Recommendations

There is an ongoing need to develop new diagnostic tests for pathogens and the use of functional genomics to better understand how these pathogens interact with their host(s) and environment and to develop management strategies including the development of vaccines and treatments.

Specific recommendations to address information and data gaps include:

1. Maintain the scope and level of fish health and sea lice monitoring and reporting currently in place for the salmon aquaculture industry.

2. Develop long-term disease monitoring programs for wild fish to provide data to the same level of quality and detail as available from the aquaculture industry. Monitoring should include the abundance and prevalence of sea lice and pathogens of concern for salmon.

3. Develop fish health management plans for all federal and provincial hatcheries including all CEDP (Community Economic Development Program) facilities comparable to and consistent with those required for the salmon farming industry.

4. Mandatory fish health monitoring and reporting programs for all federal, provincial and CEDP hatcheries consistent with the standards applied to the salmon farming industry.

5. Establishment of a research fund to foster collaboration between hatchery programs and the aquaculture industry to ensure best practices within each sector.

6. Regular and routine monitoring and reporting of water quality and oceanographic data and the establishment of a system for ensuring public access to these data.

7. Maintain the 3 lice/fish trigger for treating sea lice but only for the period March – June when the juvenile Fraser River sockeye salmon are migration past salmon farms. Adult salmon returning to spawn carry high levels of lice and treating sea lice on farms during the late summer and fall will not substantially reduce the risk of sea lice (*L. salmonis*) infection but increases the risk of the sea lice developing a resistance to SLICE.

8. Examine the lethal and sub-lethal effects of sea lice (both *L. salmonis* and *C. clemensi*) on juvenile sockeye salmon.

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Appendix 1

The following individuals were interviewed or provided information relevant to this project. Their time and contributions are sincerely appreciated and acknowledged.

Mr. Clare Backman – Marine Harvest
Dr. Richard Beamish CM OBC FRSC – Fisheries and Oceans Canada
Dr. Elizabeth Boulding – University of Guelph
Dr. Ken Brooks – Pacific Rim Mariculture
Dr. Stephen Cross – University of Victoria
Ms. Sharon DiDominicis – Marine Harvest
Dr. Kyle Garver – Fisheries and Oceans Canada
Dr. Brad Hicks – Taplow Feeds
Dr. Stewart Johnson – Fisheries and Oceans Canada
Dr. Simon Jones – Fisheries and Oceans Canada
Dr. Michael Kent – Oregon State University
Dr. Ben Koop – University of Victoria
Dr. Martin Krkosek – University of Otago, New Zealand
Dr. Peter McKenzie – Mainstream Canada
Dr. Kristina Miller – Fisheries and Oceans Canada
Ms. Chrys-Ellen Neville – Fisheries and Oceans Canada
Ms. Mia Parker – Grieg Seafood
Dr. Terrance Quinn – University of Alaska Fairbanks
Dr. Sonja Saksida – BC Centre for Aquatic Health Sciences
Dr. Mark Shepherd – Fisheries and Oceans Canada
Mr. Andrew Thomson – Fisheries and Oceans Canada
Dr. Marc Trudel – Fisheries and Oceans Canada
Ms. Mary Ellen Walling – BC Salmon Farmers Association
Dr. Tom Watson – Triton Environmental Consultants Limited

Appendix 2 – Supplemental Technical Information

Cross-correlation Analysis

Removing the trend and autocorrelation in a time series is a necessary first step if plausible causal links (sometimes referred to as Granger causality) with other time series are to be explored (Box and Jenkins 1976; Granger 1969; Haugh 1976; Hipel and McLeod 2005). The process is referred to as pre-whitening and is common practice in time series analysis. Two key plots, the autocorrelation function (ACF) and the partial autocorrelation function (PACF), are useful for determining the degree of autocorrelation present in the time series and the appropriate type of model to remove the trend and autocorrelation. The ACF and PACF for farmed salmon production are shown in Figure I-B and Figure I-C, respectively. The lag-1 autocorrelation is fairly large (~ 0.85) and the slow decay in the ACF suggests that the series be differenced or that a first order autoregressive model be fit to the data (Box and Jenkins 1976). Differencing is often (and usually done) when the lag-1 autocorrelation is close to 1. The single significant (large) partial autocorrelation at lag 1 (Figure I-C) confirms such an approach. In this case, first order differencing the time series provided an adequate fit to the data as confirmed by a plot of the residual ACF (Figure 1-D). Differencing the time series has resulted in no significant correlations at any time lag. The differenced time series is calculated by subtracting farmed salmon production at time ‘t’ from farmed salmon production at time ‘t-1’ (the previous year). Thus, the differenced time series is simply looking at the change in production year-over-year.

A similar approach was used for log(R/S) data for Fraser River sockeye salmon. The lag-1 autocorrelation for this time series (~ 0.55) was less than the lag-1 autocorrelation for farmed salmon but the pattern of decay and the single significant PACF (at lag-1) suggested that an autoregressive model of order 1 (designated as AR(1)) would be appropriate (Figure II). The ACF estimated using the residuals from the AR(1) model showed now significant autocorrelation at any lag. The residuals from this model and the residuals from the differenced farmed salmon production time series were used to estimate the cross-correlation between these two series. No significant correlation was found between the two time series at any lag (see Figure 1).

Figure I. A. Production from salmon farms located within the main migration path of Fraser River sockeye salmon. B. The autocorrelation function (ACF) for farmed salmon production. The dashed 'blue' lines represent the upper and lower 95% confidence interval. C. The partial ACF for farmed salmon production and approximate 95% confidence interval. D. The residual ACF (RACF) for the differenced farmed salmon production time series.

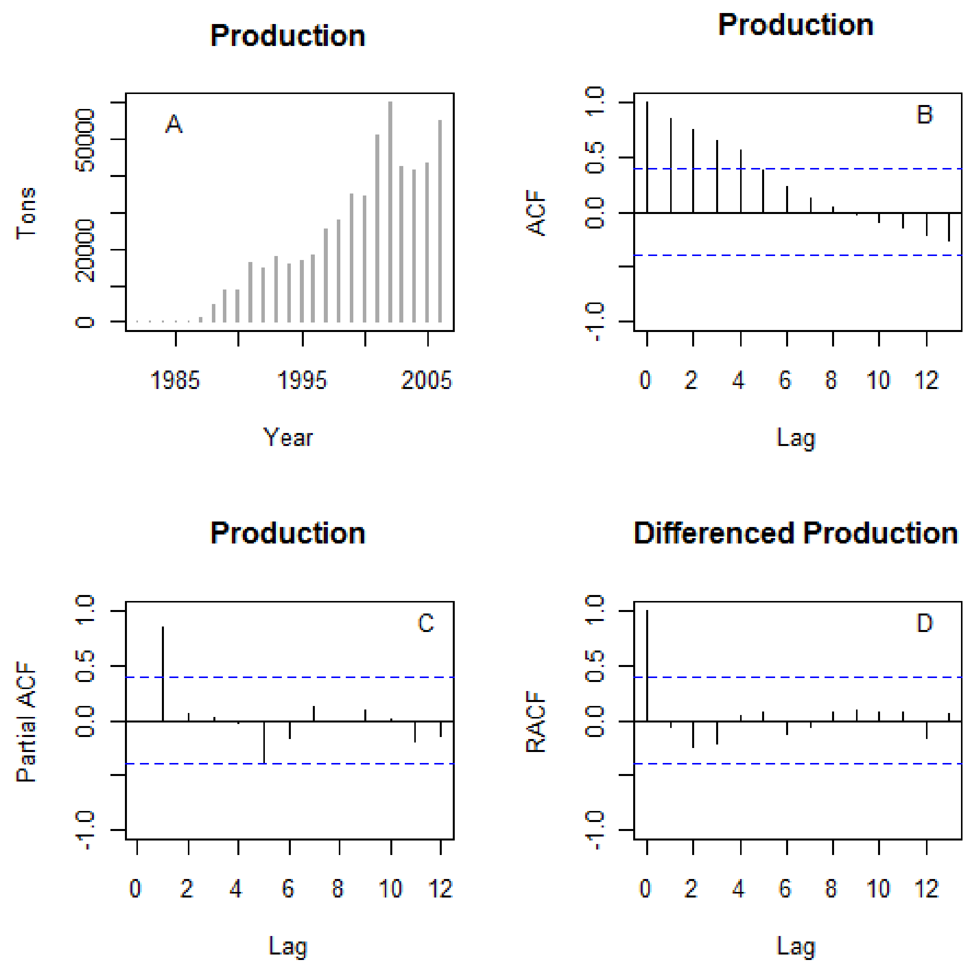
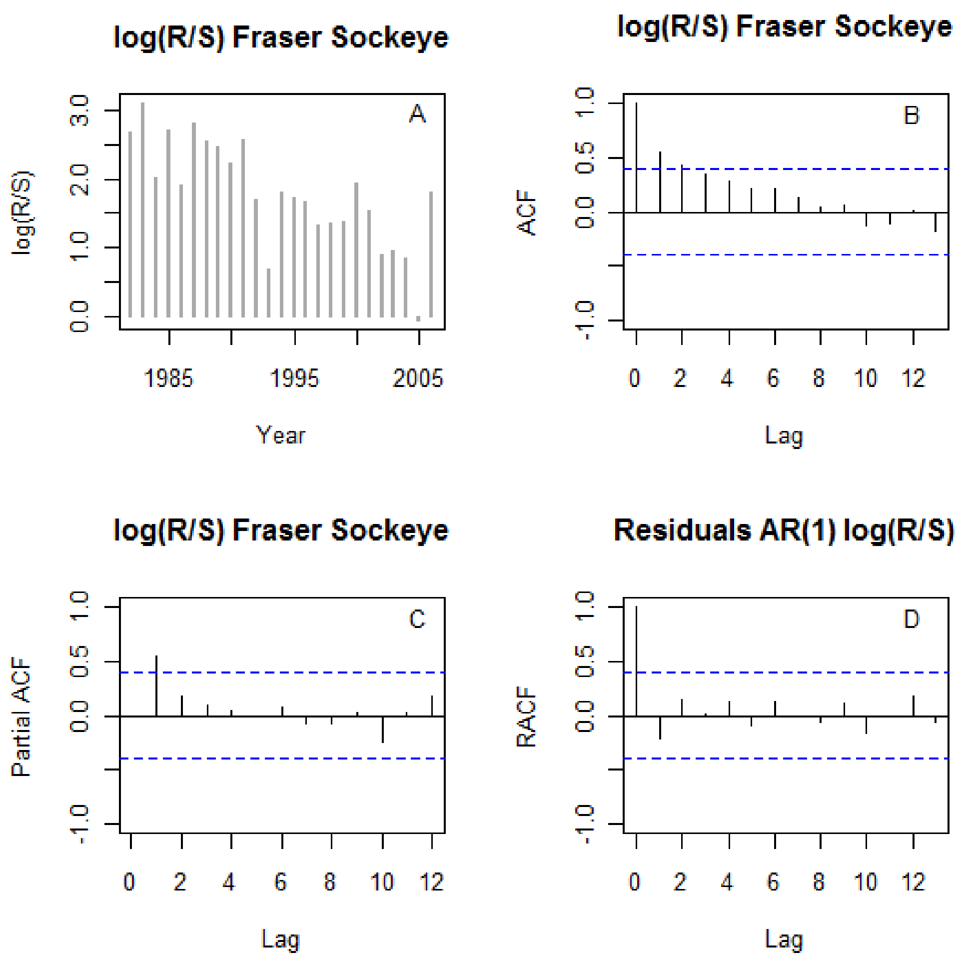


Figure II. A. log(R/S) for Fraser River sockeye salmon. B. The autocorrelation function (ACF) for Fraser River sockeye salmon log(R/S). The dashed 'blue' lines represent the upper and lower 95% confidence interval. C. The partial ACF for log(R/S) data and approximate 95% confidence interval. D. The RACF for the residuals from the AR(1) model fitted to Fraser River sockeye salmon log(R/S) data along with upper and lower 95% confidence intervals.



Atlantic Salmon Recoveries

Table I lists by river and statistical area sightings and recoveries of adult Atlantic salmon in BC rivers and streams from 1987 to 2007. Approximately 1,100 adult Atlantic salmon have been found in 80 different streams over this 21-year record. Over the same time period, 19,850 adult Atlantic salmon were capture in ocean fisheries in BC. As expected, far fewer Atlantic salmon have been observed or caught in Alaskan water (Tables III and IV). Most Atlantic salmon that were recovered did not have anything in their stomachs (Table V).

Table I: Freshwater sightings and recoveries of adult Atlantic salmon in British Columbia, 1987 – 2007.

BC Freshwater Adult Atlantic Salmon Sightings and Captures

RIVER	AREA	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Adam / Eve	12											17	4	4
Ahta	12													
Amor de Cosmos	12												2	1
Arnette	24						24	1						
Atleo	24							2	1					
Bedwell	24							1	2	10	27	6	14	12
Bella Coola	8											1		
Bonaparte	INT													1
Brunette	29												1	
Burman	25											3	1	
Campbell	13									1	15	2	1	4
Canton Crk	25										2	2	1	
Capilano	28											2		
Cluxewe	12							1				3	6	
Colonial / Cayhegle	27				3	1	2		1		3	1		
Conuma	25										3	1	5	
Cowichan	18										1		2	
Cypre	24													
Dean	12												1	
Englishman	14											1		
Fraser	29					1	8	9		1	6			
Glenlyon	12								1			4		
Gold	25							1		1		1	1	
Goodspeed	27						1		1					1
Gordon	20							2						
Great Central Lake	23									1				

RIVER	AREA	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Harrison	29						1							
Herbert Arm (Unnamed)	24							2						
Kakweikan	12										1			
Kaouk	26									1	1			
Kitimat	6												1	
Kokish	12					4		1	3	14	5	3		10
Kwalate	12													
Leiner Crk	25										14	5	2	
Little Campbell	29										1			
Marble	27								10					
Maurice	INT												1	
May Lake	23													2
Megin	24							1	1		4	1		
Moyeha	24								5	2	17	1	9	4
Nahmint	23												1	
Nahwitti	12									1		1		
Nanaimo	17											1		
Nimpkish	12						9		6	3		2		
Nitnat	22												1	
Nitnat Lake Nrws	22							1						
Oyster	14						1				2	2		
Phillips	13									1		3	2	
Puntledge	13													
Quaal R.	6											1		
Quatse	12					1		1		3	1	3		
Quinsam	13									3	3			
Roberts	16	1				1								
Robertson R.	lake											1		
Salmon	13									1	39	5	3	133
Scott Cove Cr.	12									2		3	1	6

RIVER	AREA	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Somass	23											1	2	
Sombrio	21													1
Songhees	12											1		
Sooke	20										1			
Sproat	23												1	
Squamish	28						1				1			
Stamp	23								1		1	2	3	
Stave	28										3			
Stikine	3													
Sucwoa	25										1	1		
Tahsis	25										4	12	2	
Tlupana	25										3	1		
Tranquil	24													
Treat	16						1							
Tsitika	13											1	3	
Tsolum	13													
Tsowwin R.	25										3			
Ursus	24									1	7	3	2	3
Vedder	29										1			
Viner	12									1		1		
Wakeman	12													1
Waukwaas	27													
Wannock	9									1				
Washlawlis	12										1			
Zeballos	25								18	9	40	30	17	1
TOTAL		**1**	**0**	**0**	**3**	**8**	**48**	**23**	**50**	**57**	**211**	**129**	**90**	**184**
Number of rivers		**1**	**0**	**0**	**1**	**5**	**9**	**12**	**11**	**19**	**30**	**30**	**28**	**14**

Table I (cont'd) BC Freshwater Adult Atlantic Salmon Sightings/Captures

RIVER	AREA	2000	2001	2002	2003	2004	2005	2006	2007	TOTAL
Adam / Eve	12	16	3	10						**54**
Ahta	12	4								**4**
Amor de Cosmos	12									**3**
Arnette	24									**25**
Atleo	24									**3**
Bedwell	24	4	34	2					4	**116**
Bella Coola	8									**1**
Bonaparte	INT									**1**
Brunette	29									**1**
Burman	25									**4**
Campbell	13	3								**26**
Canton Crk	25									**5**
Capilano	28									**2**
Cluxewe	12									**10**
Colonial / Cayhegle	27	2		2						**15**
Conuma	25									**9**
Cowichan	18	1						1		**5**
Cypre	24		3							**3**
Dean	12									**1**
Englishman	14									**1**
Fraser	29		1	1						**27**
Glenlyon	12									**5**
Gold	25		1	1						**6**
Goodspeed	27									**3**
Gordon	20									**2**
Great Central Lake	23									**1**

RIVER	AREA	2000	2001	2002	2003	2004	2005	2006	2007	TOTAL
Harrison	29									**1**
Herbert Arm (Unnamed)	24									**2**
Kakweikan	12	5								**6**
Kaouk	26									**2**
Kitimat	6									**1**
Kokish	12	1								**41**
Kwalate	12	1								**1**
Leiner Crk	25			1						**22**
Little Campbell	29									**1**
Marble	27									**10**
Maurice	INT									**1**
May Lake	23									**2**
Megin	24		1	4						**12**
Moyeha	24	1	28							**67**
Nahmint	23									**1**
Nahwitti	12			1						**3**
Nanaimo	17			1						**2**
Nimpkish	12	1		1						**22**
Nitnat	22									**1**
Nitnat Lake Nrws	22									**1**
Oyster	14	2								**7**
Phillips	13									**6**
Puntledge	13			1						**1**
Quaal R.	6									**1**
Quatse	12	1		2						**12**
Quinsam	13									**6**
Roberts	16									**2**
Robertson R.	lake									**1**
Salmon	13	53	1				2			**237**
Scott Cove Cr.	12									**12**

RIVER	AREA	2000	2001	2002	2003	2004	2005	2006	2007	TOTAL
Somass	23									**3**
Sombrio	21									**1**
Songhees	12									**1**
Sooke	20									**1**
Sproat	23			1						**2**
Squamish	28									**2**
Stamp	23									**7**
Stave	28									**3**
Stikine	3	5								**5**
Sucwoa	25		1							**3**
Tahsis	25									**18**
Tlupana	25									**4**
Tranquil	24		1							**1**
Treat	16									**1**
Tsitika	13	29								**33**
Tsolum	13		3							**3**
Tsowwin R.	25									**3**
Ursus	24	1	31	12					1	**61**
Vedder	29									**1**
Viner	12									**2**
Wakeman	12		8							**9**
Waukwaas	27	1								**1**
Wannock	9									**1**
Washlawlis	12									**1**
Zeballos	25									**115**
TOTAL		**131**	**116**	**40**	**36**	**0**	**2**	**1**	**5**	**1,099**
Number of rivers		**18**	**13**	**5**			**1**			**80**

Table II: Marine recoveries of adult Atlantic salmon in British Columbia, 1987 – 2008.

BC Marine Adult Atlantic Salmon Captures

AREA	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
1											2
2								7			
3		82					1	1	1	13	2
4							1	4	1		11
5											1
6										3	2
7									1		1
8						4		3	10	19	10
9						3	37	3	13		
10					2	15		1	17		
11					2	1	48	57	5	14	117
12			7	2	25	267	4,141	939	399	99	2,283
13						3	256	13	224	10	177
14									2	3	1
15											
16					1	2	24	2		2	
17										1	1
18			1			1		1			
19								1		1	10
20						5	16		3	327	41
21		2			1	5	1			18	0
22							1			1	
23							11		1	108	2
24							4	1	1	10	1
25						5	1			1	
26										14	
27								1		8	
28							1			1	2
29		22				1		3		2	
101											
102											
123											
124											
125											
126											
126-2										1	
127											
142											
Other											
Unkn	**1**					37				17	
Total	**1**	**106**	**8**	**2**	**31**	**349**	**4,543**	**1,037**	**678**	**673**	**2,664**

Note: The class `Other` includes the Nitnat Net (20, 21, & 121), Fisher-Fritz Hugh Net Area, Mathieson Channel, Finlayson Channel, and Tlupana areas.

Table II (cont`d): Recoveries of adult Atlantic salmon in BC coastal waters, 1987 – 2008.

BC Marine Adult Atlantic Salmon Captures (cont`d)

AREA	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	Total
1	1		1									**4**
2		1		4	7		1					**20**
3	1			12	5	1	2	2		5		**128**
4				14	13	4	1		2	2		**53**
5	2			2				3				**8**
6	5			41	2	2		7	7	3		**72**
7	1											**3**
8	4		5	13	37							**105**
9			1									**57**
10												**35**
11		3	4	2	46				1			**300**
12	8	52	7,688	67	53	6	4		51			**16,091**
13	1	109	116	2	6	11	5	9	9		390	**1,341**
14		1		1	1	1						**10**
15												**0**
16												**31**
17												**2**
18			1									**4**
19												**12**
20	7	18		1								**418**
21												**27**
22												**2**
23	106		8	1	8	5			1			**251**
24		5	2	5	6							**35**
25			1	2								**10**
26												**14**
27												**9**
28		1										**5**
29			7	1	6		110					**152**
101				2	76	3	17		104			**202**
102						1		1				**2**
123				9	28			1		1		**39**
124					59				17			**76**
125					18				1	1		**20**
126					135	3						**138**
126-2												**1**
127					23	8				8		**39**
142					33		5					**38**
Other						1	3	4	32	1		**41**
Unkn												**55**
Total	**136**	**190**	**7,834**	**179**	**562**	**46**	**148**	**27**	**225**	**21**	**390**	**19,850**

Note: The class `Other` includes the Nitnat Net (20, 21, & 121), Fisher-Fritz Hugh Net Area, Mathieson Channel, Finlayson Channel, and Tlupana areas.

Table III: Freshwater recoveries of Atlantic salmon in Alaska, 1998 – 2002.

Alaska Freshwater River	**1998**	**1999**	**2000**	**2001**	**2002**	**Total**
Doame			1			1
Ward L.	1					1
Martin				1		1
Copper					1	1
Situk				1		1
TOTAL	1	0	1	2	1	5
Number of rivers						**5**

Table IV: Marine recoveries of adult Atlantic salmon in Alaskan waters, 1990 – 2003.

Area	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**unk**	**Total**
101		1		3	6	8	2	25	35	12	25					117
102		1		2	5	4	8	18	14	1	22					75
103	1	1			2	1					3					8
104				1	6	3	3	3	14							30
105																
106		1		5	5	4	22	14	36	2	20				1	110
107								1		1						
108							1									1
109							1	4	9							14
111						1										1
113								1			6	1				8
114										1						1
152										1						1
182											1					1
SSE		3	2	16		2	94	10	26		2					155
282					1											1
Bering Sea								1					1			2
UNK					2		4		21	1	2	34	5	3		72

Total	**1**	**7**	**2**	**27**	**27**	**23**	**135**	**77**	**155**	**19**	**81**	**35**	**6**	**3**	**1**	**599**

Table V: Stomach contents of a sub-sample of recovered Atlantic salmon. Data provided by the BC Provincial Government.

Unspecified (blank)	20
2 insect cocoons	1
BLOOD	12
CRAB Larvae.	2
Empty	**1281**
Euphausids	2
Euphausids and fish remains	1
fish food pellets	18
Fish Remains	18
Fish scale	5
Grey Muck	83
Herring	31
Herring and Fish Remains	2
Insect	2
Insect Coccoon	1
Insects - Aquatic	1
Invertibrate	1
Iteropods	5
KELP	6
Leaf	1
MISC	9
N/A	42
Piece of Wood	1
SANDLANCE	3
STONE FLY N	6
Unidentified Digested Material	23
WOOD	7
Grand Total	**1584**

Table VI. Links to BC Ministry of Agriculture and Lands fish health and sea lice monitoring and management programs as well as the annual reports.

http://www.agf.gov.bc.ca/ahc/fish_health/FHMP_manual_template.htm

http://www.agf.gov.bc.ca/ahc/fish_health/fish_health_management_plan.htm

http://www.agf.gov.bc.ca/ahc/fish_health/fhmp_Required_Elements_June-03.pdf

http://www.agf.gov.bc.ca/ahc/fish_health/fhasp.htm

http://www.agf.gov.bc.ca/ahc/fish_health/bcsfa_database.htm

http://www.agf.gov.bc.ca/ahc/fish_health/

http://www.agf.gov.bc.ca/ahc/fish_health/sealice_MS.htm

http://www.thefishsite.com/articles/847/sea-lice-management-in-british-columbia

http://www.pacificsalmonforum.ca/pdfs-all-docs/Regreviewprogress.pdf

Appendix 3 – Scope of Work

Cohen Commission of Inquiry into the Decline of Sockeye Salmon in the Fraser River (the "Commission")

"Impacts of Salmon Farms on Fraser River Sockeye Salmon: Assessment by Donald Noakes, Ph.D. (the "Contractor")"

SW1 Background

1.1 The Commission of Inquiry into the Decline of Sockeye Salmon in the Fraser River (www.cohencommission.ca) was established to investigate and report on the reasons for the decline and the long term prospects for Fraser River sockeye salmon stocks and to determine whether changes need to be made to fisheries management policies, practices and procedures.

1.2 An assessment of the impacts of salmon farms on Fraser sockeye is required to evaluate their importance to the ecology and survival of Fraser sockeye and to determine their role, if any, in the reductions in Fraser sockeye abundance.

SW2 Objective

2.1 To prepare a technical report containing a review and evaluation of the effects of salmon farms on Fraser River sockeye salmon.

SW3 Scope of Work

3.1 The Contractor will evaluate the linkage between salmon farm operations and Fraser sockeye spawning returns, if any. This research will consider any impacts on Fraser sockeye from sea lice exposure, farm wastes that affect benthic and pelagic habitat quality, Atlantic salmon escapees and disease.

3.2 Although the focus will be on Fraser sockeye, the Contractor may consider research related to other salmon species insofar as it informs the analysis with respect to Fraser sockeye.

3.3 The Contractor will consider the practicality and outcome of salmon farm management methods for mitigating risks to Fraser sockeye, if any. This should include consideration of using closed containment systems, scheduling of net pen harvesting to reduce contact with sea lice and disease, re-locating farms, compressing maturation schedules, optimizing densities and using SLICE and other chemotherapeutics to control sea lice.

3.4 The Contractor will evaluate whether the current state of scientific research on Fraser sockeye is sufficient to estimate the extent to which reductions in Fraser sockeye abundance are associated with salmon farms.

3.5 The Contractor will review and analyze data that will be organized and provided by Dr. Josh Korman of Ecometrics Ltd, as described in the Statement of Work "Impacts of Salmon Farms on Fraser River Sockeye Salmon: Assessment by Josh Korman, Ph.D." attached here as Annex A.

SW4 Research methods and sources of information

4.1 While the primary source of information will be peer-reviewed journal articles and technical data, the Contractor may also draw on non-peer reviewed reports and articles ("grey" literature), as well as interviews with individual scientists, representatives of the salmon farming industry, commercial, sport and First Nations fishers and NGOs. All sources of information must be cited in the report. The Contractor will consider all available sources of information, including international sources where relevant.

SW5 Deliverables

5.1 The Contractor will participate in a Project Inception Meeting to be held within 2 weeks of the contract date in the Commission office. The meeting will involve Commission scientific staff and 2 researchers, Dr. Larry Dill and Dr. Josh Korman, who are also being engaged by the Commission to evaluate and report on salmon farm impacts.

5.2 The Contractor will participate in a second Project Development Meeting to be held on, or around March 15, 2011 involving Commission scientific staff and Dr. Larry Dill and Dr. Josh Korman. The objective of this meeting is to ensure the integration of the statistical analysis into the Contractor's work product.

5.3 The main deliverables of the contract are two reports evaluating the effects of salmon farms on Fraser River sockeye: 1) a progress report, and 2) a final report.

5.4 The Contractor will provide a Progress Report (maximum 20 pages) to the Commission in pdf and Word formats by May 1, 2011.

5.5 The Contractor will provide a draft Final Report to the Commission in pdf and Word formats by June 1, 2011. The draft Final Report should contain an expanded Executive Summary of 1-2 pages in length as well as a 1-page summary of the "State of the Science". The Commission may obtain and forward comments on the draft Final Report to the Contractor by June 15, 2011. The Contractor will provide any revisions to the Commission by June 30, 2011.

5.6 The Contractor will make himself available to Commission Counsel during hearing preparation and may be called as a witness.

ANNEX A

"Impacts of Salmon Farms on Fraser River Sockeye Salmon: Assessment by Josh Korman, Ph.D. (the "Contractor")"

SW1 Background

1.1 The Commission of Inquiry into the Decline of Sockeye Salmon in the Fraser River (www.cohencommission.ca) was established to investigate and report on the reasons for the decline and the long term prospects for Fraser River sockeye salmon stocks and to determine whether changes need to be made to fisheries management policies, practices and procedures.

1.2 An evaluation of the impacts of salmon farms on Fraser sockeye is required to determine their importance on the ecology and survival of Fraser sockeye and to determine their role in the reductions in Fraser sockeye abundance.

SW2 Objective

2.1 To undertake quantitative analysis of fish farm and environmental data related to fish disease frequency and sea lice densities at, or adjacent to, salmon farms. The investigation will evaluate salmon disease frequency and occurrence, sea lice densities and mortalities of farmed fish.

SW3 Scope of Work

3.1 The Contractor will review data, reports and other information provided by the Commission. This will include information that the Commission receives from the B.C. Salmon Farmers Association, the Province of BC and Canada, as follows:

3.1.1 Data to be furnished by the BC Salmon Farmers Association is expected to include: (1) documents and data relating to fish health, mortality, and pathogens, including sea lice and disease for 120 fish farm sites identified below; and (2) documents and data relating to the stocking of salmon farms identified below including number of fish, species, location, dates of entry into the facility, harvesting, mortality and age-class.

3.1.2 Data to be furnished from BC is expected to include documents and data related to fish health, mortality and pathogens, including sea lice and disease for the sites identified below. This includes the data from the Province's Fish Health Database.

3.1.3 Data and documents to be furnished by Canada is expected to include: (1) case reports pertaining to wild sockeye salmon health; (2) documents from CFIA related to the National Aquatic Animal Health Program; (3) Canada's submissions to the World Organization for Animal Health related to salmon diseases; and, (4) the summary created by CFIA officials of test results related to therapeutant use in finfish aquaculture facilities.

3.2 The time period of reference for the data and the quantitative analysis contemplated by this Statement of Work is January 1, 2000 – September 1, 2010.

3.3 The salmon farms subject to investigation are the 21 sites referenced in the Commissioner's October 20, 2010 Interim Ruling plus an additional 99 sites identified in the Commissioner's December 8, 2010 Final Ruling. The rulings are attached to this Statement of Work as Annex 1 and 2.

The salmon farms identified in the Interim Ruling are as follows:

- <u>Discovery Islands:</u> Conville Bay; Conville Point; Read Island; Dunsterville; Owen Point; Bickley; Chancellor; Lees Bay; Hardwick Site B; Homfray; Raza; Brent Island; Yellow Island Aquaculture.

- <u>Queen Charlotte Strait:</u> Shelter Pass; Duncan; Bell; Doyle; Shelter Bay; Robertson; Marsh Bay; Raynor.

The additional 99 sites described in the December 8 Final Ruling include the following:

- <u>In Johnstone Strait and eastern Queen Charlotte Strait:</u> Wehlis Bay; Mt. Simmonds; Maude; Cecil; Cypress; Sir Ed; Simoom Sound; Cliff Bay; Smith Rock; Burdwood; Deep Harbour; Wicklow; Blunden; Upper Retreat; Arrow Pass; Midsummer; Potts Bay; Port Elizabeth; Larsen Island; Swanson; Bennett Point; Bocket & Lily; and Mistake Island.

- <u>Along the Central Coast:</u> Jackson Pass and Lochalsh.

- <u>In the Discovery Islands and Johnstone Strait:</u> Poison Creek; Jack Creek; Althorp; Shaw Point; Phillips Arm; Freddie Arm; Egerton; Farside; Sonara Point; Thurlow; Brougham; Young Pass; Mayne Pass; Venture; Sonora; Cyrus Rocks; Barnes; Doctor Bay; and Church House.

- Along the northern portion of the West Coast of Vancouver Island: Markale Pass; Charlie's Place; Amai; Centre Cove; Hohoae; Monday Rocks; Koskimo Bay; Mahatta West; Mahatta East; and Cleagh.

- In Georgia Strait: Ahlstron; Culloden; and St. Vincent Bay.

- Along the southern portion of Vancouver Island: Sooke Basin; Goodridge Island; and Saltspring.

- In Queen Charlotte Strait: Hardy Bay.

- Along the central portion of the West Coast of Vancouver Island: Cliff Cove; Esperanza; Lutes; Hecate; Steamer Point; Conception Point; Williamson Passage; Muchalat North; Muchalat South; Gore Island; Atrevida; Shelter Inlet; Dixon; Millar; South Shelter; Ross Pass; Binns Island; Bare Island; Bawden; Westide; Cormorant; Saranc; Bare Bluff; MacIntyre Lake; Bedwell; Rant Point; Mussel Rock; Fortune Channel; Tranquill; McCall; Eagle Bay; Indian Bay; Warne Island; Baxter; Dawley Passage; Jane Bay; Barkley; and San Mateo.

3.4 The Contractor will integrate his work with that of Dr. Don Noakes and Dr. Larry Dill who are evaluating and analyzing the impacts of salmon farms on Fraser River sockeye.

SW5 Deliverables

5.1 The Contractor will participate in a Project Inception Meeting to be held within 2 weeks of the contract date in the Commission office. The meeting will involve Commission scientific and legal staff and 2 researchers, Dr. Don Noakes and Dr. Larry Dill, who are also being engaged by the Commission to evaluate and report on salmon farm impacts on Fraser sockeye. The work of the latter researchers will be based, in part, on the results of the present statistical analysis contract.

5.2 The Contractor will participate in a second Project Development Meeting to be held on, or around March 15, 2011 involving Commission scientific and legal staff and Dr. Don Noakes and Dr. Larry Dill. This objective of this meeting is to ensure the integration of the statistical analysis results with the work of the latter two researchers.

5.3 The main deliverable of this contract is a report describing disease and parasite frequency data on salmon, in and adjacent to salmon farms, and their potential relationship to Fraser River sockeye survival.

5.4 The contractor will provide a draft Final Report to the Commission in pdf and Word formats by March 15, 2011. The draft Final Report should contain an expanded Executive Summary of 1-2 pages in length as well as a 1-page summary of the "State of the Science". The Commission will obtain and forward comments on the draft Final Report to the contractor by March 22, 2011. The contractor will provide any revisions to the Commission by March 31, 2011.

5.5 The Contractor will make himself available to Commission Counsel during hearing preparation and may be called as a witness.

ANNEX 1 - INTERIM RULING RE: R. 19 APPLICATION FOR PRODUCTION OF AQUACULTURE HEALTH RECORDS, OCTOBER 20, 2010

1. Pursuant to Rule 18 of the commission's rules of procedure and practice, two participant groups, the Conservation Coalition and the Aquaculture Coalition (the "applicants"), sought to have commission counsel request copies of the following documents from the Province of British Columbia, the Government of Canada, and the British Columbia Salmon Farmers' Association ("BCSFA") (the "respondents"):

i. Documents in the possession or control of the Department of Fisheries and Oceans, the Canadian Food Inspection Agency, Environment Canada and/or any other federal department relating to the occurrence of, monitoring of, and response to pathogens, including sea lice and disease (in particular, infectious hematopoietic necrosis virus, bacterial kidney disease, infectious salmon anemia and furunculosis) in wild salmon stocks. Included in the document request are any documents submitted to the World Organization for Animal Health relating to disease in salmon in British Columbia waters in compliance with reporting obligations to that organization;

ii. Documents in the possession or control of the federal government (particularly DFO), and the provincial government (particularly the Ministry of Agriculture and Lands and the Ministry of Environment and their respective predecessors), relating to fish health, mortality and the occurrence of, monitoring of and response (including treatment, enforcement, and authorizations) to pathogens, including sea lice and disease (in particular infectious hematopoietic necrosis virus, bacterial kidney disease, infectious salmon anemia and furunculosis) in finfish aquaculture facilities;

iii. Documents in the possession or control of the BCSFA relating to fish health, mortality, and the occurrence of, monitoring of and response (including treatment, enforcement, and authorizations) to pathogens, including sea lice and disease (in particular infectious hematopoietic necrosis virus, bacterial kidney disease, and furunculosis) in finfish aquaculture facilities; and

iv. Documents in the possession or control of the BCSFA relating to the stocking of finfish aquaculture facilities including: number of fish, species, location, dates of entry into facility and harvesting or mortality, as well as age-class.

2. On August 19, 2010 commission counsel wrote to the respondents requesting the documents proposed by the applicants, but limited to the period 2004–2009, and to 21 identified fish farms. This limitation was based on commission counsel's assessment of the material available to them at that time, and of the relevance and necessity of the requested documents. In limiting the requests, commission counsel advised that they were attempting to balance the following competing considerations:

- This is a public inquiry which should permit a full public examination of the issues arising in the terms of reference.
- The Commissioner is to investigate and make findings of fact regarding the causes for the decline of Fraser River sockeye.
- There is a lively public debate surrounding aquaculture and its impact, if any on the Fraser River sockeye.
- The terms of reference explicitly list aquaculture as a potential cause for decline that the Commissioner shall investigate (cl. A(i)(C)(i))
- The Commissioner has granted participant status to organizations that focus exclusively on aquaculture issues (such as the Aquaculture Coalition and the BCSFA). There will be hearings addressing this topic in order to permit the Commissioner to investigate and make findings of fact and if warranted to make recommendations for improving the future sustainability of the sockeye salmon fishery.

- Counsel's assessment of what documents are relevant and necessary must strike a balance between (1) ensuring a full and informed investigation of the issue, and (2) avoiding a prolonged and tangential review of the documents with little or no connection to the commission's work.
- Documents produced to the commission do not enter the public domain, but are provided to participants on the basis of undertakings of confidentiality which ensure they cannot be used for purposes beyond the commission (see Rule 17).

3. The respondents support the request made by commission counsel (21 identified fish farms for a five year period), with one qualification: the respondent BCSFA asks that I consider ordering that its documents be produced on an aggregate basis. Moreover, this respondent resists the application on the basis that the order sought for a broader time frame and additional fish farms would have the effect of making the work of the commission on this issue unmanageable and greatly delay disclosure, thus prejudicing the inquiry process and the public interest.

4. The respondent Canada supports the document request made by commission counsel. It takes no position on the geographic scope of production but asserts that the five year time period is consistent with the initial approach this respondent and commission counsel settled upon for its document production.

5. The respondent Province supports commission counsel's request, and raises concerns regarding the practicality of extending the request further back in time.

6. The participants, Area D Gillnetters Association/Area B Seine Society and the Heiltsuk Tribal Council, both filed written submissions supporting the applicants' position

7. At the hearing, counsel for the respondent Province said that this respondent would be in a position to produce the documents sought by commission counsel within two weeks. Thus I order that this respondent's documents be produced forthwith.

8. Counsel for the respondent BCSFA said at the hearing that this respondent, if ordered, could produce the documents sought by commission counsel forthwith. Thus I order that the documents sought from this respondent be produced forthwith. I also order that this respondent produce the documents in the form requested by commission counsel as I am not persuaded that providing the documents only in the aggregate as proposed by this respondent will be sufficient.

9. With respect to the respondent Canada, it is engaged with the commission in an extensive document production process. As such I will not make a similar order with respect to the timing of the production of the documents. I would, however, ask that this respondent provide the documents to the commission counsel at the earliest possible date, but without causing undue disruption to the broader process of document production. Thus I order that this respondent advise commission counsel within one week of the date of this ruling of its estimate of time for delivering the documents sought by commission counsel. The other respondents, the applicants and commission counsel have liberty to seek directions from me if the respondent Canada's estimate of time for delivery of the documents is considered by any of them to prove problematic.

10. I should add that it has been brought to my attention since the date of the hearing that some of the fish farms identified by commission counsel may not have been stocked during the relevant time period. In this respect, my order only requires production of documents to the extent that they exist.

11. Finally, while I am satisfied that the material filed by the applicants and respondents necessitates my consideration of the limitation placed by commission counsel on the documents sought by the applicants, I have concluded that I need some further evidence before issuing my ruling.

12. In my consideration of the temporal and geographic limits to be applied to the requested documents, I intend to apply the principles adopted by commission counsel reproduced at paragraph 2, in particular, that I must strike a balance between ensuring a full and informed investigation of the issues while avoiding a prolonged and tangential review of the documents with little or no connection to the commission's work.

13. While I heard submissions of counsel regarding the impact the order sought might have on the respondents and the conduct of this inquiry, some of these submissions were not supported by evidence.

14. In this regard, I invite counsel for the respondents to provide me with additional evidence addressing any hardship that would be occasioned by the collection and production of a broader set of documents than that now sought by commission counsel.

15. Further, I invite counsel for the applicants, the respondents and the commission to provide me with evidence addressing any consequences in terms of timeliness and cost associated with the analysis and presentation of the evidence on this topic which may flow from me ordering a broader production of documents than that now sought by commission counsel.

16. Such additional evidence may be delivered to the commission by 4:00 p.m. Monday November 1, 2010. The commission shall promptly distribute the evidence to all participants. Supplemental written submissions from the applicants, respondents, participants or commission counsel may be delivered to the commission by 4:00 p.m. Monday November 8, 2010.

17. It should be noted that all documents disclosed to participants are subject to an undertaking of confidentiality and all counsel shall abide by this undertaking and ensure that their clients understand the limited use to which the disclosed documents may be put.

Signed 20 October 2010

The Honourable Bruce I. Cohen
Commissioner

ANNEX 2 - RULING RE: RULE 19 APPLICATION FOR

PRODUCTION OF AQUACULTURE HEALTH RECORDS, DECEMBER 8, 2010

Background to the application:

18. On July 5, 2010, pursuant to Rule 18 of the commission's rules of practice and procedure, the Aquaculture Coalition and the Conservation Coalition (the "applicants") asked commission counsel to request of the Province of British Columbia (the "Province"), the Government of Canada ("Canada") and the British Columbia Salmon Farmers' Association ("BCSFA") (together, the "respondents") certain documents (the "Initial Request").

19. The Initial Request sought documents relating to fish health, pathogens and disease, as well as stocking data in farmed salmon. The applicants also requested fish health data for wild salmon. The geographic and temporal scope of the Initial Request was for fish farms and "wild salmon on the Fraser River migration route (including both sides of Vancouver Island and north of Vancouver Island through Klemtu) dating from 1980 to the present."

20. The BCSFA wrote to commission counsel on July 30, 2010, advising that it found the Initial Request "overreaching in its scope, both in terms of the kinds of documents requested and the period of time which the request covers." The BCSFA expressed concern about the temporal scope of the Initial Request:

> We are concerned that expanding the timeframe of the evidence placed before the Commission will detract from the Commission's process and will place additional financial pressures on all participants. As a practical

> consideration, the Commission should seek to limit the scope of the investigation to material times, which based upon our understanding of the Terms of Reference, would be within the last five to ten years.

21. In its letter, the BCSFA proposed providing the commission with "aggregated data for the years 2007 to 2009 from the Fish Health Documents with a report summarizing and explaining the raw data …"

22. On August 11, 2010, Canada responded to the Initial Request, noting that it had relevant documents (i.e. fish health records for Fraser sockeye covering 2004-2009) which it was in the process of producing to the commission, but it expressed concern about a request reaching further back in time from 2004, as it would delay the production of other relevant documents.

23. On August 18, 2010, the applicants wrote in response to the positions of the respondents. They reiterated their request for information from individual salmon farms (as opposed to aggregated data proposed by BCSFA); however, they revised their request, seeking documents going back 22 years (to 1988). The applicants also accepted a suggestion of the Province that the scope be limited to "documentation, and hence farm data, in the Fraser River and along the migration routes of the Fraser River sockeye."

24. Although commission counsel supported the Initial Request, on August 19, 2010, commission counsel wrote to the respondents requesting the documents sought by the applicants, but limiting the request to documents from the period 2004-2009 and from 21 identified fish farms explaining as follows:

> At a broad level, the Applicants' request touches on a topic that is expected to be the subject of hearings which may be controversial. There is likely to be disagreement and debate on whether, for instance, the presence of salmon farms – in the migration routes of Fraser River sockeye – has a deleterious impact on migrating salmon. To attempt to answer this question, it becomes relevant and necessary to have an understanding of the type of information sought in this application.

> Given this, commission counsel have agreed in many respects with the Applicants' request for documents. There are, however, several parameters that may properly be placed on the request that commission counsel are making through this letter. …
>
> First, in obtaining general documentary production from Canada, the commission has commenced with a five-year time frame (2004-2009), though the production to date from Canada contains many relevant documents that pre-date this period. The five-year time frame permits a good understanding of the recent documentary record, and strikes a balance by not going back decades. Unless otherwise noted, our requests below employ this five-year period.
>
> Second, insofar as the documents at issue deal with wild salmon, relevant materials will be those dealing with Fraser River sockeye, as opposed to other species of Pacific salmon.
>
> Third, geographically, relevant materials relate to the migration routes of Fraser River sockeye, rather than Fraser River salmon generally.
>
> …
>
> For both the Province and the BCSFA, commission counsel have, with the assistance of the commission's science staff, identified aquaculture facilities which are proximate to the migration routes of Fraser River sockeye. The enclosed maps detail these areas and facilities. …

25. The specific requests of the respondents for documents for the time period from 2004 to 2009 made by commission counsel were:

> <u>the Province</u>:
>
> …
>
> - Documents relating to fish health, mortality and pathogens including sea lice and disease, for the farms in the area identified above and in the maps appended to this letter. This includes the data from the Province's Fish Health Database.
>
> <u>the BCSFA</u>:
>
> …
>
> - Documents relating to fish health, mortality, and pathogens including sea lice and disease, for the sites in the area identified above and in the maps appended to this letter; and

- Documents relating to the stocking of salmon farms identified above, including the number of fish, species, location, dates of entry into the facility, harvesting, mortality, and age-class.

The BCSFA is requested to supply the above information at a farm-specific level, rather than as aggregated information. …

<u>Canada</u>:

… Commission counsel confirm that we seek the following documents ….

- Case reports pertaining to wild sockeye salmon health;
- Documents from CFIA [Canada Food Inspection Agency] related to the National Aquatic Animal Health Program;
- Canada's submissions to the World Organization for Animal Health related to salmon diseases; and
- The summary created by CFIA officials of test results related to therapeutant use in finfish aquaculture facilities.

The Rule 19 application:

26. In response to commission counsel's request, the applicants brought this application under Rule 19 to compel production of the documents they initially sought (as revised in the letter of August 18, 2010). A hearing date of September 22, 2010 was set and the applicants and respondents, as well as any other participants and commission counsel were invited to provide written submissions.

27. In addition to their written submissions, the applicants tendered the affidavits of Stan Proboszcz, fisheries biologist with Watershed Watch Salmon Society, and of Alexandra Bryant Morton, fisheries biologist, both affirmed September 9, 2010. The applicants objected to the five year and 21 farms approach of commission counsel, maintaining that "a longer time span of production is necessary for the Commission to assess the impact and causation between health of fish in aquaculture facilities and health of wild sockeye stocks [and] there are additional fish farms that are of sufficient proximity to Fraser sockeye migration routes to potentially impact Fraser sockeye which ought to be included in the production request."

28. The applicants objected to the geographic limits of commission counsel's request, which covered only 21 fish farms:

> 25. In the Applicants' submission, a proximate fish farm is one that can potentially impact Fraser sockeye stocks. In this regard, a 2005 study entitled *Transmission dynamics of parasitic sea lice from farm to wild salmon* Krkosek et al found that infection pressure from salmon farms caused sea lice levels to exceed ambient levels for an average of thirty kilometres. Therefore, a reasonable and scientifically sound way to determine which farms are potentially relevant to declining stocks is to identify which farms are within thirty kilometres of Fraser River sockeye salmon migration routes.
>
> 26. In the Applicants' submission, all farms within thirty kilometres of Fraser sockeye migration routes could potentially impact Fraser sockeye and are therefore sufficiently proximate to warrant ordering the production of all fish health and stocking documents.

29. The applicants relied on the affidavit of Mr. Proboszcz, seeking information from an additional 99 fish farms which he identified as within 30 kilometres of Fraser River sockeye migration routes.

30. The applicants criticized commission counsel's request for documents from the five-year period of 2004-2009:

> 30. There is no biological or scientific basis to limit the examination of fish health data to a five-year time frame. It is only with an examination of multiple life-cycles of specific salmon stocks that any comprehensive and reliable scientific determinations can be made regarding long-term impacts of disease and parasite exposure. Absent multiple comparator years of specific Fraser sockeye runs, any determination of the relationship between the health and stocking of fish farms and declining salmon stocks will be of limited value. ...

31. The participant groups, Area D Salmon Gillnet Association and Area B Seine Society, and the Heiltsuk Tribal Council filed brief written submissions supporting the application.

32. The Province did not provide written submissions in response to the application, though orally supported the parameters set by commission counsel.

33. Canada provided written submissions on September 14, 2010, reinforcing its position that an extension of the time period beyond November 1, 2004 would "entail a significant restructuring of the document production work, both by having to add resources to assemble further documents and by diverting existing resources away from current document processing work". Canada supported its submissions with affidavits sworn on September 14, 2010, from Rachelle Haider and Christina Gallo, support staff at the Department of Justice.

34. The BCSFA provided written submissions objecting to the application, but offering to provide "the requested documents on the terms in the Commission's Request of August 19, 2010, subject [to] the Commissioner's consideration of the BCSFA's affidavit materials … explaining the scientific basis for aggregating the requested fish farm data." In support of its submissions, the BCSFA tendered the affidavits of Kenneth M. Brooks, a fisheries biologist and environmental scientist, affirmed September 16, 2010, and of Tom Watson, a biologist, affirmed September 13, 2010.

35. The affidavit material filed by the BCSFA took issue with the 30 kilometre limit identified in the affidavit of Mr. Proboszcz, asserting that there is no evidence disease or lice from fish farms can travel this distance and subsequently infect wild sockeye salmon.

36. Commission counsel provided written submissions on September 17, 2010, in which they expanded their reasons for limiting the Initial Request to 21 identified fish farms and for a period from 2004-2009, as follows:

> **The Fish Farms Selected for Specific Document Disclosure**
>
> 6. Commission counsel limited the Request for documents from fish farms to 21 aquaculture facilities proximate to the sockeye migration route along the east side of Vancouver Island. With reference to scientific articles (cited in the Request at footnote 1, page 5), and in particular to the map on p. 58 of the article by Groot and Cooke (reproduced at Exhibit "E" of Affidavit #1 of

Stan Proboszcz), commission counsel identified aquaculture facilities located along the assumed migratory routes of Fraser River sockeye smolts. The 21 fish farms identified in the Request are comprised of (1) those that are closest to the sockeye routes identified on the Groot and Cooke map through the Discovery Islands; and (2) those that border the waters of the Queen Charlotte Strait, through which the smolts migrate.

…

9. The Applicants have pointed out, correctly, in their submissions, that Fraser River sockeye sometimes use an alternative migratory route along the west side of Vancouver Island. Therefore, they say, fish farm data from the west side of Vancouver Island must also be disclosed to the commission. Commission counsel did not include farms from the west side of Vancouver Island in the Request for the following reasons. We understand the "inside" route to be the preferred and primary route for migrating Fraser River sockeye. Also, unlike the Discovery Islands where the migrating salmon are forced by geography to swim through narrow channels which bring them into proximity with fish farms, we had no scientific information available to us concerning how close the sockeye smolts come to fish farms along the west coast of Vancouver Island. Furthermore, we determined that the objective of testing for relationships between fish farms and the health of Fraser River sockeye could be accomplished with a data set collected from fish farms along the main sockeye migration route.

10. The Applicants have also suggested that the commission should be seeking fish health data from all fish farms within a 30 km radius of sockeye migration routes. In our view, the question that should be asked on this application is whether the 21 sites identified will adequately inform the understanding of salmon-farm disease and sea lice frequency adjacent to sockeye smolt migration routes. We have deliberately selected 21 "worst-case scenario sites" in terms of pathogen exposure. If a trend cannot be demonstrated at these sites, there is little value in studying other locations that are situated at greater distances from these routes.

…

The Time Frame for the Document Requests

12. Commission counsel limited the Request to documents produced in the five years leading up to the announcement of the Inquiry (November 2004-2009). Commission counsel chose to employ the five-year period reflected in the commission's current approach to initial disclosure from Canada.

…

> 14. Commission counsel acknowledge the possibility that the temporal limits placed around the document request may prevent some effects from being determined through the planned analyses (which we describe below). But given the number and complexity of the issues under investigation by this Inquiry, we felt it acceptable to proceed in the face of this risk. A five-year data set will provide an opportunity to understand relationships between fish farms and the 2009/2010 returns. A sufficient picture of aquaculture effects, proportionate to the topic's place in the Inquiry, can be provided through data for the last five years.

37. In the reply submissions filed by the applicant Conservation Coalition on September 17, 2010, it noted that the only issue before me at this stage "is whether the scope of the production of documents as requested by Commission Counsel ought to be expanded along geographic and temporal planes." In support of expanding the scope of the request it wrote:

> 6. It is worth pointing out that the same scientific studies and publications relied upon by the Commission Counsel in his letter of August 19 are in fact relied upon by the Applicant in its evidence.
>
> 7. A close examination of those publications shows that the out migration path of the juvenile sockeye salmon from the Fraser River predominantly occurs through the Strait of Georgia in a northerly direction. However the publications also support a finding that juvenile sockeye from the Fraser River are to be found along the West coast of Vancouver Island and the central coast of British Columbia. The in migration of adult sockeye to the Fraser occurs either along the West Coast of Vancouver Island or through the Strait of Georgia.
>
> …
>
> 10. Thus there is ample authority to expand the production of records from salmon farms located along all of the migration paths of Fraser River sockeye and not just the ones as delimited in Commission Counsel's letter of August 19.

38. The co-applicant, the Aquaculture Coalition, also filed its reply submissions on September 17, 2010 stressing that the temporal scope of the documents requested must be extended back to 1988:

> 21. The appropriate time-line must take into account that, although individual year returns have varied, it is clear that productivity has been declining steadily since 1992. It is in 1992 that salmon farms first reported disease events. Nothing less than a full examination, starting from 1988 (the generation preceding to the 1992 returns) will provide a fair examination of the possibility that disease and pathogens have played an important part in the as yet unexplained variability and declines.

39. On September 22, 2010, I heard argument on the application and on October 20, 2010, I issued my Interim Ruling.

The Interim Ruling:

40. In my Interim Ruling, I noted at paragraph two the rationale of commission counsel for limiting the applicants' initial request temporally and geographically, in particular, that counsel's assessment of what documents are relevant and necessary "must strike a balance between (1) ensuring a full and informed investigation of the issue, and (2) avoiding a prolonged and tangential review of the documents with little or no connection to the commission's work."

41. At the hearing, the respondents acknowledged that they could produce the documents as requested by commission counsel. Thus, I ordered that the Province produce the documents requested by commission counsel forthwith, and that the BCSFA produce forthwith the documents requested by commission counsel and in the form requested by commission counsel.

42. Given the extensive document production process engaged in by the respondent Canada, I ordered Canada to advise commission counsel within one week from the date of my Interim Ruling of its estimate of time for delivering the documents sought by commission counsel.

43. With respect to the applicants' assertion that the requested documents should be expanded geographically and temporally to conform to their initial request, I concluded that I needed further evidence before issuing my final ruling. Accordingly, I invited counsel for the respondents to provide me with additional evidence by November 1, 2010, addressing any hardship that would be occasioned by the collection and production of a broader set of documents than that sought by commission counsel.

44. I further invited counsel for the applicants, the respondents and the commission to provide me with evidence addressing any consequences in terms of timeliness and cost associated with the analysis and presentation of the evidence on this topic which may flow from me ordering a broader production of documents than that sought by commission counsel.

Additional Evidence following Interim Ruling

45. In her affidavit sworn October 29, 2010, filed on behalf of Canada, Annie Champagne, Director of the Aquatic Animal Health Division of the Canadian Food Inspection Agency ("CFIA"), deposed that with respect to the temporal limits, the Fish, Seafood and Production Division of the CFIA holds documents relating to therapeutant and toxin level test results dating from 1990 and could produce these documents in a few days to a week. In the affidavit of Alan Cass, a DFO biologist, sworn November 2, 2010, he deposed that Canada holds records for wild sockeye case reports from 1962-2009 (and they have started scanning the case reports from 1998-2004), parvicapsula-related documents from 2000-2004, and infectious hematopoietic necrosis virus documents from 1987-2009. The estimate of time to collect and produce these documents to the Department of Justice for uploading to Ringtail varies, but it is generally under a month.

46. However, in her affidavit sworn November 1, 2010, Ms Haider deposed that expanding the request beyond five years would result in further delay of the ongoing

production of documents by Canada relevant to the hearings and would result in upwards of “several hundred thousand documents for each additional five year period” requested. I note that Ms Haider does not distinguish in her affidavit between documents related to aquaculture and general documents related to the work of the commission. This application, of course, only deals with the limited set of aquaculture documents being sought.

47. In his affidavit sworn November 2, 2010, Mark Sheppard, Aquatic Animal Health Veterinarian, Ministry of Agriculture and Lands, deposed that the Province’s Fish Health Program was initiated in 2001 and that the Province can produce relevant records from 2002 forward in approximately 24 days. Raveen Sidhu, staff with the Legal Services Branch of the Ministry of Attorney General, deposed that relevant records from 2000 forward are stored electronically in an archived database; however, relevant records prior to 2000 have been destroyed.

48. The BCSFA also asserted that prior to the implementation of provincial regulation, the aquaculture industry’s record keeping is difficult to ascertain and in the affidavit of Stephen Budgeon, IT Manager of Marine Harvest Canada Ltd., sworn November, 1, 2010, he said that it would take “many months” to determine whether data exists and to put it into useable form.

49. The BCSFA estimates between $12,000 - $19,000 per month in “lost productivity” if the request for documents were to reach back before the early 2000s (affidavit of Budgeon, paragraphs 6 & 7; affidavit of Mia Parker, Manager, Regulatory Affairs, Grieg Seafood B.C. Ltd., sworn November 2, 2010, paragraphs 5 & 6; and affidavit of Frank Bohlken, environmental scientist for Triton Environmental Consultants Ltd., sworn November 2, 2010, paragraph 7). I note that this affidavit material does not define “lost productivity” and does not provide sufficient details for me to assess the likely magnitude of any hardship which would be occasioned. It does, however, provide some evidence of potential hardship to the BCSFA should I order the production of documents from the 1990s or earlier.

50. In his affidavit provided at the request of commission counsel, Josh Korman, a fish biologist at Ecometric Research Inc., sworn November 1, 2010, noted the difficulty in limiting the requested information to a five-year data set and commented upon the timeliness and cost of expanding the information:

> 10. Hypothetically, it would be helpful to consider a longer time series of data. It is reasonable to expect that the expanded dataset would substantially strengthen inferences regarding the effects of salmon farms on Fraser sockeye returns. A key part of such an analysis would likely entail relating temporal variation in disease and lice frequency with marine survival rates (as indexed by variation in recruits/spawners). Such an analysis could be undertaken using an expanded 20-year dataset, if those data were available in a consistent format, but is not possible with the current five-year dataset because of insufficient replication.
>
> …
>
> 13. Currently, given my other commitments and the later-than-expected start to this project, I expect the assessment of the data from 21 farms for five years to be completed by March 31, 2011. If the additional data were available with sufficient consistency, I would expect a 50 per cent increase in the amount of time required to do my analytical work. Despite this, I anticipate that I could still complete the work by March 31, 2011. The cost of the analysis would also increase by approximately 50 per cent.

Analysis

51. I am satisfied, on the whole of evidence that the geographic and temporal limits imposed by commission counsel ought to be broadened for the reasons that follow.

52. First, with respect to the geographic scope of the request, while I understand the approach of commission counsel to limit the request to 21 identified fish farms along the out-bound northern migration route, I have concluded that information from fish farms in proximity to other potential migration routes (such as the western or southern portion of Vancouver Island) would be relevant and contribute to a full and informed investigation of this issue.

53. The applicants urged me to adopt the approach set out by Mr. Proboszcz in paragraph 15 of his affidavit:

> According to my research and understanding of the transmission of disease and parasites, in order to assess the impact of aquaculture on declining Fraser River sockeye, including the impact of diseases and sea lice from salmon aquaculture facilities, fish health and stocking records of all those facilities that are sufficiently proximate to the various Fraser sockeye migration routes as to potentially transmit pathogens, including disease or sea lice must be reviewed. In this regard, a reasonable and scientifically sound way to determine which farms are potentially relevant to declining stocks is to identify which farms are within thirty kilometres of Fraser River sockeye salmon migration routes.

54. The respondent BCSFA takes strong issue with Mr. Proboszcz's opinions and with the literature upon which Mr. Proboszcz relied to reach his opinions, particularly the conclusion that a reasonable and scientifically sound way to determine which farms are potentially relevant to declining stocks is to identify which farms are within thirty kilometres of the Fraser River sockeye salmon migration routes.

55. In my view, this ruling is not the time or place for me to decide the serious conflict in the parties' positions regarding the evidence on this point. However, I think that data from the additional fish farms identified in the affidavit of Mr. Proboszcz may assist me in assessing such issues as the impact of fish farms on Fraser River sockeye salmon (if any) and in determining the degree of proximity required for a risk of infection to exist.

56. Moreover, neither the Province nor the BCSFA identified any hardship to them or delay of the commission's proceedings which would be occasioned by broadening the geographic reach of the documents ordered to be produced by the respondents. On this point, the respondent Canada stated:

> 5. … Canada has not taken a position on the geographic reach of any Order made. Further, the breadth of the geographic reach, whether it be 21 farms as set by Commission counsel in his letter or a larger number requested in the motion, will not have a significant impact on the work entailed or timing to produce documents.

57. Second, in considering the temporal scope of the request and whether it should be expanded past the five years, I am of the opinion that there is substantial utility in obtaining documents from a broader period, especially to the extent that they can be obtained in a timely way and useful format.

58. In assessing the need for further documents, I note the evidence of Dr. Korman, who opined that it is reasonable to expect that an expanded data set would substantially strengthen inferences regarding the impact of salmon farms on Fraser sockeye.

59. The benefits of a larger data set going back further in time were also identified in the affidavit of Gordon Fredric Hartman, fisheries scientist, sworn November 1, 2010, filed on behalf of the applicants:

> 4. It is also my opinion that there is a greater chance that a subset of data (instead of all spatially and temporally relevant information) may produce inconclusive results, thereby producing a need for additional data to substantiate scientific findings. In addition, the statistical analysis of a subset of data will often produce results with larger associated error relative to the same analysis of a larger data set. Thus, there will likely be greater confidence in scientific findings derived from a larger data set. Moreover, solely analyzing a subset of data increases the likelihood of coming to erroneous conclusions. It is therefore most efficient to obtain a more robust data set at the outset and avoid inconclusive or erroneous scientific findings.
>
> 5. Furthermore, five-years of data cover only one and one quarter life cycles of the common run component among Fraser River sockeye salmon. As such, in my opinion, analyzing five-years of data respecting the environmental conditions faced by out-migrating Fraser sockeye salmon is unlikely to provide a reasonable basis for the meaningful evaluation of sockeye salmon population fluctuations. …

60. I note the opinion of Dr. Brooks that “examining arbitrary time periods in temporally cycling data can lead to misleading results that depend on the period examined”, however, none of the affidavit material filed by the respondents persuades me that an expanded data set (if available) would not strengthen the analysis.

61. On the issue of the quality and availability of data, I note the evidence from the Province that it did not regulate the aquaculture industry until 2001, and that documents from prior to 2000 have been destroyed. In her affidavit, Ms. Sidhu deposed that she had been advised by Gary D. Marty, D.V.M., Ph.D., Diplomate, A.C.V.P. Fish Pathologist that:

> 1. ....:
> (a) The Cases from 2000-2002 - … These records are stored electronically in an archived database. … We would be able to provide individual case reports, but these case reports would not be summarized on a spreadsheet …
> (b) Note that many of these case reports will have no information about the farm of origin. …
> (c) Cases before 2000 – we have no records from cases before 2000 (they have all been destroyed).

62. In his affidavit, Dr. Sheppard deposed:

> 12. The BCMAL [British Columbia Ministry of Agriculture and Lands] maintains a Fish Health Audit and Surveillance Database dating 2004-2009. …
> …
> 19. To my knowledge the randomized overseeing audit information was not collected by BCMAL prior to 2002.
>
> 20. In the pre 2002 period, the Province may have some scattered project and case by case diagnostic confidential medical records from fish samples submitted by owners of aquaculture facilities on an as needed basis for diagnostic analysis. This material is submitted when an individual owner or private veterinarian would like to investigate or confirm fish lesions. If the private veterinarian was not in need of confirming the diagnosis the samples would not be submitted to the BCMAL.

> 21. These non random submissions are sometimes submitted without specific site of origin information and would not be considered representative of the farm or general area, or region, or of population dynamics.
>
> …
>
> 23. If the Commission decides to order additional disclosure from the 21 specific farms along the Fraser River migration route subject to this commission from 1988 onwards, I do not know what information may be located if any, or how long it would take to find and collate these materials if they exist.
>
> 24. If the Commission decides to order additional disclosure from all farms subject to this Commission from 1988 onwards, I do not know what information may be located if any, or how long it would take to find and collate these materials if they exist.

63. The BCSFA also provided evidence regarding the likely state of documents prior to 2000 and the time and hardship associated with collecting these documents. In his affidavit, Mr. Budgeon stated:

> 6. I am informed by Clare Backman, Environmental and Sustainability Director for Marine Harvest, that the present Marine Harvest is composed of at least twenty-four now-defunct companies, and that in the course of numerous purchases and amalgamations the fish health and fish stocking records of those former companies, which would have been kept in paper form, were likely lost, or were not transferred as part of any asset purchase agreements. I am also informed by Mr. Backman that it would require considerable time and expense just to determine whether any of these former companies' records dating back to the 1990s or earlier even exist and could be obtained for the Commission.
>
> 7. I am informed by Clare Backman that there are 5 of Marine Harvest employees who would be somewhat qualified to engage in such a search for the documents the Aquaculture and Conservation Coalitions have requested. Were they to devote half of their work week to searching for these documents, I roughly estimate that it could take many months to determine whether the data exists and, assuming it is decipherable and coherent, to put it into a useable form. At those employees' hourly rates, such an undertaking could cost Marine Harvest as much as an estimated $12,000 dollars per month in lost productivity.

64. In his affidavit, Mr. Bohlken deposed:

> 7. On November 1 2010 I spoke with Dr. Dianne Morrison, a veterinarian employed by Marine Harvest Canada Ltd., concerning data collection by the B.C. aquaculture industry. Dr. Morrison stated, and I verily believe it to be true, that an initiative by the B.C. aquaculture industry in the early 2000s resulted in standardized reporting of aquaculture data including inventory, mortality (number and cause), and fish health events. Dr. Morrison stated, and I verily believe [it] to be true, that prior to this standardization, fish farms may have used a variety of methods for compiling data, including paper files and spreadsheet files. Dr. Morrison further stated, and I verily believe [it] to be true, that prior to the aquaculture industry initiative of the early 2000s there was no regulatory requirement to maintain data on fish health or mortality rates.

65. In the affidavit of Ms. Parker, she stated:

> 5. Records from before Grieg began using the fish health database, if they even exist, are likely in paper format or held within legacy data systems that are incompatible with current operating systems and software. These records may also hold different types of information than that submitted to the current fish health database, as there was no prior comprehensive reporting scheme in place and no regulation saying what data had to be collected.
>
> 6. It would require considerable time and effort to determine whether or not these records even exist. There are 3 employees at Grieg who may be able to identify such records in various forms and formats. At those employees' hourly rates, such an undertaking could cost Grieg as much as an estimated $19,000 dollars per month in lost productivity.
>
> 7. Due to the likely gaps or non-existence of older data, interpretation of the data would be very difficult and time consuming and may not result in an accurate and reliable analysis. Furthermore, there is a real risk that older data collected using different methods, missing data, and data lacking context could inadvertently cause confusion or be misused. ….

66. Canada provided the evidence of Mr. Cass that it had assigned resources to scan the wild sockeye salmon case reports from 1998 through 2004, but that documents prior to 1998 are in hard copy and additional resources and time would be

required to scan the hard copy reports, because "the paper size varies among reports and each page must be scanned manually."

67. In their submissions on this point, the applicants assert, *inter alia*, that "the evidence shows that the increase in cost or time is difficult to assess, but is not such that it outweighs the increased scientific value and public benefit" in having an expanded set of data dating back to 1988.

68. Commission counsel submitted that I weigh the likely quality, availability and format of data from a period prior to 2004, against the value of that additional evidence in determining the temporal scope of an order for production of documents from a period prior to 2004:

a) <u>The likely quality of data prior to 2004</u>. Is the data prior to 2004 comprehensive, or is it haphazard and uneven? Was it collected and recorded in ways that would allow for a continuous data set? One of the themes running through various affidavits, particularly with respect to the fish-health data under control of the Province or the BCSFA, is that the quality (and availability) of the data decreases when one reaches back in time beyond 2002 – even more so in the years before 2000. Working backward in time, this apparent reduction in quality and availability appears to correspond to the period prior to the Province's implementation of mandatory reporting requirements for finfish aquaculture facilities.

b) <u>The likely availability of data prior to 2004</u>. Do records exist prior to 2004? How far back in time? Are the data sets consistent? If pre-2004 data are inaccessible from participants, and inconsistent in nature, the older records are of less assistance. In contrast, if the earlier data are consistent and available, they may permit a more detailed examination.

…

d) <u>The likely format of additional information</u>. Are the documents and data prior to 2004 likely to be in a paper format, such that they would require extensive data input to be presented in an electronic form? Are the documents in a compatible electronic format? How much work would it take to make the data compatible? As some of the affiants point out, if data are available and can be provided in the same format as the current request, they can be accommodated into the analysis of post-2004 data (see Affidavit of Josh Korman #1, at para. 13; Affidavit of Gordon Fredric Hartman #1, at para. 3). But variable formats could greatly increase the scope of work required to get the data in shape for analysis and if the earlier data are not available in a comparable or consistent format, "the utility of reaching back to 1992 is greatly diminished" (see Affidavit of Josh Korman #1 at para. 11; see also paras. 9, 12 and 14).

…

f) The delay to the commission's work that may be occasioned by seeking further documents. Dr. Korman does not suggest any difficulty associated with adding data from the 2002-2004 period into his analysis, but does note potential difficulties and delays if data from the pre-2002 are included, given his understanding of the nature of the earlier data. He cannot comment on the extent of that delay without seeing the data, but notes that it could result in a "substantial increase in the amount of work required to complete the analysis" (Affidavit of Josh Korman #1 at para.12). The documents at issue are to be considered not only by participants, but also (1) by Dr. Korman in his statistical analysis, and (2) by contracted scientific researchers who will engage in a further assessment of the effects of fish farms on wild sockeye salmon. For these contracted researchers, who have yet to be retained, it is expected that their work will rely on Dr. Korman's analysis, and that it is realistic to expect their conclusions to be provided some time *after* Dr. Korman's report is complete. If the additional data would delay Dr. Korman's analysis, this could have a cascading effect on the timing of the contracted researcher's work.

69. The evidence provided by Ms. Sidhu, Dr. Sheppard, Mr. Cass, Mr. Budgeon, Mr. Bohlken and Ms. Parker persuades me that there is a likelihood that the respondents

possess documents in a useable format from 2000 to the present which will assist me in making findings regarding the impact, if any, of salmon farms on Fraser River sockeye salmon, and which can be obtained without impacting disproportionately on the participants or the conduct of the commission. However, I am not persuaded that I should order the production of documents sought by the applicants prior to 2000.

70. In my view, there is much uncertainty regarding the quality, availability and format of data from the years prior to 2000 as established by the evidence of Ms. Sidhu, Dr. Sheppard, Mr. Budgeon, Mr. Bohlken, Ms. Parker and Dr. Korman. Their evidence suggests that even if available, such data is likely to be in a format which is not helpful. Further, according to the evidence of Drs. Korman and Sheppard, Mr. Budgeon, Ms. Parker, Ms. Haider and Mr. Cass, the search for, production and analysis of documents from this earlier period is likely to occasion significant delay in the commission's process and some hardship to the respondents. I do not think such delay and hardship is warranted given that the outcome of this expenditure of time and effort is unlikely to advance my understanding of this complex issue.

71. In the result, I find that the respondents should produce those documents sought in this application, which are in their possession and control, for the period of January 1, 2000 to September 1, 2010, for

i. the 21 fish farms originally identified by commission counsel; and

ii. the additional 99 farms, identified in Mr. Proboszcz's affidavit, specifically:

- In Johnstone Strait and eastern Queen Charlotte Strait: Wehlis Bay; Mt. Simmonds; Maude; Cecil; Cypress; Sir Ed; Simoom Sound; Cliff Bay; Smith Rock; Burdwood; Deep Harbour; Wicklow; Blunden; Upper Retreat; Arrow Pass; Midsummer; Potts Bay; Port Elizabeth; Larsen Island; Swanson; Bennett Point; Bocket & Lily; and Mistake Island.
- Along the Central Coast: Jackson Pass and Lochalsh.
- In the Discovery Islands and Johnstone Strait: Poison Creek; Jack Creek; Althorp; Shaw Point; Phillips Arm; Freddie Arm; Egerton;

Farside; Sonara Point; Thurlow; Brougham; Young Pass; Mayne Pass; Venture; Sonora; Cyrus Rocks; Barnes; Doctor Bay; and Church House.

- Along the northern portion of the West Coast of Vancouver Island: Markale Pass; Charlie's Place; Amai; Centre Cove; Hohoae; Monday Rocks; Koskimo Bay; Mahatta West; Mahatta East; and Cleagh.
- In Georgia Strait: Ahlstron; Culloden; and St. Vincent Bay.
- Along the southern portion of Vancouver Island: Sooke Basin; Goodridge Island; and Saltspring.
- In Queen Charlotte Strait: Hardy Bay.
- Along the central portion of the West Coast of Vancouver Island: Cliff Cove; Esperanza; Lutes; Hecate; Steamer Point; Conception Point; Williamson Passage; Muchalat North; Muchalat South; Gore Island; Atrevida; Shelter Inlet; Dixon; Millar; South Shelter; Ross Pass; Binns Island; Bare Island; Bawden; Westide; Cormorant; Saranc; Bare Bluff; MacIntyre Lake; Bedwell; Rant Point; Mussel Rock; Fortune Channel; Tranquill; McCall; Eagle Bay; Indian Bay; Warne Island; Baxter; Dawley Passage; Jane Bay; Barkley; and San Mateo.

72. Further, said documents shall be produced by the respondents by January 21, 2011.

73. I wish to make it clear that this ruling is not to be construed in any manner as a finding on whether aquaculture is a cause for the decline of Fraser River sockeye salmon.

Dated December 8th, 2010

The Honourable Bruce I. Cohen
Commissioner

Appendix 4 - Reviews and Response to Reviewers

Report Title: Technical report 5C: Impacts of Salmon Farms on Fraser River Sockeye Salmon: Results of the Noakes Investigation

Reviewer Name: Professor A.P. Farrell, Canadian Research Chair (Tier I) in Fish Physiology, Culture and Conservation

Date: 20th June 2011

Abbreviations used:

NR= Noakes Technical Report; 5C KTR = Korman Technical Report 5A; CTR = Connors Technical Report 5B; SS = sockeye salmon; FR = Fraser River

1. Identify the strengths and weaknesses of this report.

1. The NR makes five clearly stated conclusions. These conclusions are arrived at either by direct analysis, or by refuting analysis that suggests otherwise in the CTR. The approach of the NR represents a normal scientific method.

2. By including literature, data and analyses beyond those found in the KTR and the CTR, the NR tries to remedy deficiencies in these technical reports. In fact, I suggest that the NR does a better job than either the KTR or the CTR in some respects. The NR builds logical arguments from a balanced and objective treatment of available information. A few important literature gaps are highlighted below.

3. Overall, the NR is an extremely comprehensive scientific review and makes excellent reading for a scientist. However, its scientific density makes it less accessible to the generalist reader. Nevertheless, the author does attempt to simplify the scientific language, complexities and nuances for the reader. But as always, the devil lies in details, and so these scientific details ultimately must be available to the reader.

4. The NR makes excellent use of simple empirical data to show that there is not a MAJOR impact of salmon farming on FR. However, the major weakness of the NR is that is does not clearly and explicitly state the difficulty of resolving a minor negative impact of salmon farming on FR SS productivity, especially when using multivariate analysis. Indeed, the general reader might be left to wonder if the scientists know what they are doing. The two technical reports, the three external reviews of the CTR and the NR are peppered with many different types of statistical analyses, several cautions over spurious interpretations of these analyses, numerous warnings that the analyses do not establish any cause-and-effect and a concern that the analysis is premature given the limited data set. Thus, with the suggestion of a need for more complex multivariate than that presented in the CTR and the NR, one also has to wonder if there is any hope of success in the stated objectives. As a consequence, a major weakness is that the NR does not attempt to step outside of the current analytic "box" to provide fresh insight to the problem. I believe that other approaches are possible both with the present data and with different forms of experimentation.

Some further analysis may be possible but not within the timeframe of this project. Also, the data records are quite short (particularly the fish health data) Some further analyses may be possible but not within the timeframe of this project. Also the data records are quite short (particularly the fish health data) and based upon my own experience trying to fit various multivariate and complex univariate models to several (13 or 14) years of coho salmon data from the Strait of Georgia and several environmental covariate time series I think that it is unlikely that a more complex model would yield any significant results (Beamish et al. 2011a). As well from a population perspective, data from the individual farms or from individual salmon stocks are not independent so the degrees of freedom in any analysis are much fewer than the number of farms and stocks and that will reduce the likelihood of finding any significant relationships.

5. The speculation and personal interpretations are kept to a minimum.

2. Evaluate the interpretation of the available data, and the validity of any derived conclusions. Overall, does the report represent the best scientific interpretation of the available data?

Overall, the NR does not identify a smoking gun left by salmon farmers that can explain the catastrophic collapse of FR SS in 2009. It presents five clearly stated conclusions, arrived at either by direct analysis, or by refuting analysis that suggests otherwise in the CTR. A clear attempt was made to bring all information available to the author to bear on the question in a balanced and scientifically robust manner. I show my support for and critique of each of the five statements below.

1) "There is no correlation between farmed salmon production within the main migration path of Fraser River sockeye salmon, the waters between Vancouver Island and the mainland of British Columbia, and the returns of Fraser River sockeye salmon."

This conclusion is reached through a long and sometimes complex scientific analysis, including the suggestion that some of the conclusions of the CTR report are spurious. Ultimately, which of the many possible statistical approaches is correct (or perhaps best) will depend on the opinions of those who are true experts in statistic analysis in the trends in productivity fish stocks, which I am not.

I have extensive (more than 30 year) experience in time series analysis and based on the analysis presented in this paper I can with a high degree of confidence conclude that there is no significant correlation between the farmed salmon production time series and the survival of Fraser River sockeye salmon. I am also confident that some of the results presented in Connors (2011) draft report (and his Appendix Table A4.6) are spurious. I note that the only statistically significant relationship found in Connors final report was with sea surface temperature (Connors 2011, Table 6). Except for the intercept parameter for the models, the confidence intervals for all of the other factors and combinations are not statistically significant (the confidence interval includes zero [0]).

However, three points are very clear to me from the reports.

Foremost, there is not a MAJOR negative impact of salmon farming on FR SS productivity. If this were the case, and even withstanding concerns of statistical power associated with short-term data sets, the CTR would not conclude that: "My analyses found no statistical support for a relationship between these aquaculture variables and sockeye survival anomalies.". Similarly, the KTR concludes that: "Negative effects of salmon farms on returns of Fraser River sockeye between 2002 and 2010 were not apparent based on a qualitative comparison with salmon farming data provided in this report.". In this regard, the NR report correctly highlights that, during the period from 2004 when FR SS productivity has fallen below historic levels, the salmon farming production in tonnage remained almost stable with disease outbreaks at a low and perhaps declining level. Even multiple levels of statistical analysis revealed only weak correlations, such that the CTR concludes: "the large uncertainty around these estimated effects makes drawing definitive conclusions from these findings tenuous.".

Second, the potential for WEAK negative impacts has not been convincingly eliminated by any of the analysis that I have seen. Perhaps it may be impossible to convincingly demonstrate weak impacts, except to all but experts. To convince others, I think the problem lies in the failure of the KTR, and hence the reports that followed, to simply frame the difficulty of the analytical challenge in a manner that it can be generally appreciated. My simple analogy is the challenge of finding a needle in a haystack.

As the NR states more scientifically, the observed population stability for FR SS between 1970 and 1990 required that, for every pair of SS spawning 4 years earlier, another pair returns to the river to spawn. With each female SS carrying ~3,000 eggs and fertilization success ~100% in SS, only 2 in 3,000 offspring are required to return. Thus, natural selection allows for an average mortality of 99.933% for a stable SS population (conversely 2,998 of the 3,000 offspring 'naturally' die at some time). An extreme example of doubling survivorship (4 return spawners per pair) to grow a population versus halving survivorship (1 return spawner per pair) to shrink a population represents only a 1.110% difference SS mortality (99.997% versus 98.867%). The challenge set by the Cohen Commission (to identify a needle in a haystack) is to reliably detect a signal of ~ 1% additional mortality (the needle) against a background noise of 99% natural mortality (the haystack).

I worry that such fine resolution is beyond any type of multivariate correlational analysis. With many factors naturally affecting SS survival and that correlation does not establish cause-and-effect, even data sets that span a longer time period (the future analysis as suggested by the CTR) and analysis that includes more, better and more regional specific variables (as suggested by the NR and the CTR) may be no more informative. Perhaps a different experimental approach, ones used in other regions where salmon farming is more intensively practiced, is needed to address question of impacts of salmon farming on FR SS productivity.

Third, no one has yet considered the possibility of positive impacts of salmon farming on FR SS productivity. This would mean that benefits are potentially offsetting an even worse scenario than we see today. I am not saying that these exist, but rather that when considering "impacts" a balanced scientific approach should consider both positive and negative impacts. *A priori* these reports start with the tenet that only negative impacts are possible. This tenet has yet to be scientifically defended.

2) "There is no evidence to suggest that escaped Atlantic salmon have contributed to the

decline in Fraser River sockeye salmon stocks over the past two or three decades (since salmon farming began in British Columbia) or that escaped Atlantic salmon pose any threat to sockeye or any other salmon stocks in the Fraser River."

The scientific arguments presented for this conclusion are balanced and comprehensive. It is perhaps the best summary that I have read and provides information and analysis well beyond the KTR, which concludes that "Only 33 Atlantic salmon escapes have been caught or sighted in the Fraser River drainage, and there is no documented evidence of reproduction in this system.". Dr. Lauren Donaldson (now deceased) once told me that he had released many Atlantic salmon from his research laboratory at the Washington University Fisheries Centre (likely well before 1970's when he retired) with the hope of establishing a spawning population – no Atlantic salmon ever returned although he had great success in Pacific species returning to "The Pond" (http://www.fish.washington.edu/hatchery/history.html). Even with the NR identifying and presenting evidence for the potential of 'first residence' being advantageous when native Pacific species are under utilizing the habitat, the many thousands of Atlantic salmon accidentally released from farms over the years have not successfully invaded the FR system or depressed FR SS productivity. The NR uses the Great Lakes as an excellent example of where Pacific salmon outcompete Atlantic salmon when they coexist in a common garden. As the NR report identifies, the advantage of Pacific salmon in BC relates in part to vastly outnumbering Atlantic salmon, which points to the need for an even greater effort to conserve the numbers and diversity of Pacific salmon we currently enjoy and wish to restore.

3) There is no obvious plausible link or evidence to support a link between the deposit of waste on the sea bed or into the water column and sockeye salmon survival.

I agree with the conclusion that there is "no obvious plausible link or evidence to support a link between the deposit of waste on the sea bed or into the water column and sockeye salmon survival." Here I have the benefit of additional knowledge through my involvement in reviewing the Provincial Government's new regulations. Here the primary argument is that there is a large spatial separation between SS swimming by the salmon farms and the benthos.

However, I disagree with the suggestion that there no obvious plausible link between the deposit of waste into the water column and sockeye salmon survival. Here I would argue that release of nitrogenous wastes from fish into the water column could cause local eutrophication and increase primary and secondary productivity. This could plausibly act as a new and additional food source for out-migrating FR SS should they enter these hypothetical areas and be able to consume the available prey. Given that the NR makes a point of the high natural mortality of FR SS while in the Strait of Georgia, an *a priori* consideration should be the potential for the positive impacts of an additional food source.

The addition of nitrogen to the water column could increase primary and secondary productivity but I expect the affect would be minimal given the increase in nutrients from upwelling and the influence of the Fraser River plume.

Juvenile salmon normally grow rapidly and continuously seek food as they out-migrate, moving between patches of food in the sea (to paraphrase the well-published conclusions of Dr. Michael Healey, a salmon ecologist). Juvenile salmon can quickly starve to death (see results in Krkosek et al. 2009) and starvation (= inability to find the next patch of food soon enough) may account much of the natural background mortality suggested for out-migrating juvenile salmon, which the NR suggests is 3% per day, which translates to roughly half of the juvenile salmon dying within the first 25 days of entering the Strait of Georgia, or an astounding 5 million juvenile sockeye salmon dying on average every day after they enter the Strait of Georgia.

4) “There is no correlation between the number of sea lice on farmed salmon and the return of Fraser River sockeye salmon.”

This conclusion is valid even with a cursory look at the available data, which clearly indicate that the number of sea lice on salmon farms has decreased appreciable during the same time period that FR SS productivity has decreased. The NR recognizes that the average number of lice (*Lepeophtheirus salmonis*) on farmed salmon has decreased at least 3-fold between 2004 and 2010 (and perhaps 6-fold for the specific time period that juvenile sockeye salmon would migrating past the salmon farms). The CTR “found no statistical support for a relationship between these aquaculture variables” (*vis-a-vis* sea louse abundance on farmed salmon in the spring/summer of the year of sockeye marine entry) and (FR) sockeye survival anomalies. Thus, the likelihood of a MAJOR impact of sea lice of out-migrating FR SS (suggested as high as 80% mortality of pink salmon by Krkosek et al. 2007) is remote.

Given the high level of public debate about sea lice impacts, the NR is justified in comprehensively describing the published literature for the lethal and sublethal effects of sea lice on juvenile pink salmon in the Broughton Archipelago and in presenting additional analyses that challenge some of the analyses in the CTR. The NR concludes that: “There have been strong returns of pink salmon to the Broughton in recent years and a credible assessment using sea lice data from fish farms and other information showed no significant relationship between sea lice on fish farms and pink salmon survival (Marty et al. 2011).”. Krkosek et al. (2007) had earlier predicted a total collapse of pink salmon populations by 2010, which we now know to be incorrect.

The NR suggests that “Krkosek et al. (2007) were correctly criticized for serious errors and omissions”, noting that Krkosek et al. (2009) have subsequently tempered the original predictions of a total collapse of pink salmon populations. Among the noted concerns was the failure of Krkosek et al. (2007) to consider the ability of juvenile pink salmon to readily shed sea lice.

The NR, however, does not fully explore the results of Krkosek et al. (2009), who exposed juvenile chum and pink salmon for at least 30 days to *Lepeophtheirus salmonis*. The result was that: “In all cases, the louse populations showed a decline to almost zero abundance after 30 days.” Inspection of the data shows a near zero louse abundance can occur even before 30 days. This result led to the conclusion that “louse populations rapidly decline following brief exposure of juvenile salmon, similar to laboratory study designs and data.” Unfortunately, information on shedding of sea lice by juvenile salmon was available in the literature (Morton and Routledge 2005; Jones et al. 2006) but ignored for the predictions contained in Krkosek et al. (2007), despite the information being generated one of the coauthors.

The results in Krkosek et al. (2009) also clearly state that “there were few fish mortality events”, and that “the mortality observed later in the trials - particularly after 25 days was associated with emaciated fish… a near zero lice presence … and few louse-associated scars indicating that some fish had starved". Clearly, an 80% sea-lice induced mortality, as proposed by Krkosek et al. (2007), was not supported.

Krkosek et al. (2009) also correctly suggest that time of exposure to sea lice is a critical consideration, which is potentially a "two to three month migration of juvenile salmon past multiple salmon farms' in the case of Broughton pink salmon and leads to the likelihood of reinfections offsetting the ability of pink salmon to shed sea lice. Given that juvenile FR SS out-migrate past salmon farms on the east of Vancouver Island much faster (about 25 days in the NR), the likelihood of reinfection is reduced proportionately.

In terms of the potential for a weak effect of sea lice on FR SS productivity, the NR report challenges the analysis of the CTR. Again, this is in the realms of statisticians and beyond my expertise.

However, I agree that as a result of the sensitivity analysis performed in the CTR, a curious and non-intuitive report emerges. The CTR long-term analysis used 18 FR SS populations along with out-group populations from Alaska (5) and Washington State and BC (8), which when removed (and by limiting the analysis to just 17 FR SS populations) increased the predicted direct effect of farmed salmon production on mortality and decreased the uncertainty around the effect. Curiously, why the interaction of the pink salmon abundance on FR SS abundance should reverse depending on the inclusion or exclusion of out-groups is non-intuitive and unexplained. As pointed out by the NR, more worrisome is why the Harrison River SS population was considered an out-group. This was the only example in the CTR where a FR SS population was singled out for special treatment. Yet, there is no explanation why, or what might occur had the Harrison River population remained in the analysis.

A priori a multitude of factors, and not just the migration past a salmon farm, differ for the out-group populations and so I concur with the concern expressed more scientifically in the NR that the rather coarse analytical approach in the CTR is in need of sharper focus.

5) "There is no evidence that disease originating from salmon farms has contributed to the decline of Fraser River sockeye salmon."

The NR deals with specific diseases of concern (including high risk pathogens) and makes a strong case for his final conclusion, going well beyond the data reported and analyses reported in the KTR and the CTR. As reported in the KTR: "There was a statistically significant declining trend in the number of high risk diseases reported by salmon farms between 2003 and 2010". A decrease in ~6 high-risk disease events per year over this period runs counter to a contribution to the decrease in FR SS productivity during the same period. Correspondingly, the CTR analyses "found no statistical support for a relationship" between either "the occurrence of high-risk pathogens on farmed salmon in the year sockeye migrate to sea" or "the proportion of farmed fish that died of disease or unknown causes ("fresh silvers" in industry jargon) in the spring/summer in the year sockeye migrate to sea" and the FR SS anomalies.

There have been strong, near record returns of FR pink salmon. This is non-intuitive given their alleged sensitivity to sea lice and other diseases. A causative mechanism unique to SS but not pink salmon is unknown.

If a sea louse is an important vector for disease in out-migrating FR SS, then preventing sea lice infestation with a prophylactic feeding of SLICE, as performed by Jackson et al. (2010) with Atlantic salmon, would prevent such transfers. This means that Jackson et al. (2010) demonstrated that the COMBINED direct and indirect (including being a vector) impacts of sea lice were similarly small on juvenile Atlantic salmon. This result, of course, does not preclude the possibility that data obtained for juvenile Atlantic salmon and in different regions of the world cannot be directly transferred to the specific case FR SS.

3. Are there additional quantitative or qualitative ways to evaluate the subject area not considered in this report? How could the analysis be improved?

As noted above, the NR report presents literature and analytical evaluations that go well beyond the CTR and the KTR. As such, it is extremely comprehensive in both its coverage and evaluation.

However, an important shortcoming is an acknowledgment or evaluation of the relevance of Hvidsten et al. (2007), which considers that the impact of sea lice on out-migrating, ranched Atlantic salmon at a much higher abundance and intensity (>10 lice per fish), and in a far more intensive Atlantic salmon farming area (Norway). To summarize this work, a 3-year (1996-1998) tagging and recapture technique was used to study the effect prophylactic feeding of approximated 3,000 Atlantic salmon smolts each year with an undisclosed substance “EX”, which decreases sea lice for up to 16 weeks. Comparisons were made with 3000 control fish similarly tagged and released year. Linear regression analysis on the results capture of 1 sea winter post-smolt capture revealed a no significant effect for all 3 years combined. When each year was analyzed individually, statistical significance was reached (P=0.05) only for the 1998 data. Possibly because of low % recapture (0.51 to 2.2%) and the lack of a treatment effect in 2 out of the 3 years, the authors wisely suggest to “… interpret the data with caution”.

A similar, but more comprehensive experiment was presented by Jackson et al. at the 2010 Sea Lice Conference held in Victoria, BC and is now in press after being peer-reviewed for the journal *Aquaculture*. This study, based on the west coast of Ireland where there is intensive Atlantic salmon farming, also examined the consequence of prophylatic feeding SLICE to ranched Atlantic salmon smolts for 7 days, which protected them from sea lice for 9 weeks while they swam well beyond the salmon farms. The study lasted 9 years (2001-2008), using 10 releases of over 100,000 tagged salmon: 3,000-10,000 control salmon per year (total >58,000) and 3,000-6,000 treated salmon per year (total >54,000). An alarming result was the dramatic collapse in the number of returning salmon - a progressive collapse from a ~10% adult returns to a ~1% adult returns between 2001 and 2008. However, the temporal trends were parallel for the treated and control salmon, and there was a small effect of the prophylactic SLICE treatment on the return. One type of statistical test (Chi-squared) showed SLICE improved returns significantly in 4/10 experiments, while another statistical test (sign test) showed SLICE improved returns significantly in 9/10 experiments. Overall, there was a small (0.8%) numeric difference in the intercepts of the linear regressions of the control and treated fish for returning adults over time. While these results clearly show that Atlantic salmon returns collapsed almost 10-fold despite the potential for direct and indirect sea lice effects, an argument still can be made for a weak improvement on the number of returning adult Atlantic salmon as a result of a prophylatic SLICE treatment.

4. Are the recommendations provided in this report supportable? Do you have any further recommendations to add?

The NR makes one general and five specific recommendations. I do not disagree with any of these, but I would generalize them as being precautionary measures that are focused primarily on the issues regarding the potential for disease and disease-related impacts on wild salmon. Given the potential for unexpected disease outbreaks (as well illustrated in all agricultural practices, especially at high density), disease monitoring should be maintained at a rigorous level and preventative treatments should employ the best available technologies.

Missing among the recommendations, however, are experiments that directly examine for impacts. There is a need to step outside of the present analytical box and provide more direct insights into causes and mechanisms of impacts. Two interventional experiments (rather than more correlative analyses that leave us with cause-and-effects and no mechanisms) are suggested in the next section. There could be others.

Given that the potential for direct interactions between farmed fish and out-migrating FR SS is only several weeks each year, a useful precautionary practice might be to allow the industry sufficiently flexibility in the temporary siting of sea pens so that they can relocate farmed fish away from migratory channels during the critical migration periods.

5. What information, if any, should be collected in the future to improve our understanding of this subject area?

If there is a desire to prove cause-and-effect negative impacts by fish farms on FRSS productivity, intervention experiments must be performed locally. As it stands, we are still very much in the observational phase of the scientific method, with few attempts and apparently little willingness (= funding) to test hypotheses with respect to impacts of salmon farming on FRSS.

Lacking are comprehensive, controlled studies of lethal and sublethal effects of sea lice on juvenile sockeye salmon, similar to those performed with juvenile pink salmon. This makes any attempt to assign a mechanism for a cause-and-effect of sea lice on FR SS productivity entirely premature and speculative. The experimental knowledge base recently generated for juvenile pink salmon in the Broughton Archipelago has greatly shifted our thinking relative to earlier speculative and theoretical writings.

Research on lethal and sub-lethal effects of sea lice on sockeye salmon would be useful and this recommendation has been specifically added. If louse retention is an issue, the SLICE experiment involving sockeye could be considered.

A key interventional experiment that should be performed in BC is one already used in Norway and Ireland. Wild out-migrating SS could be captured prior to reaching fish farms and fed prophylatically with SLICE for a couple of days to protect them from sea lice as they swam past the farms. Then it is a 2-year wait to count surviving adults relative to control fish. This experiment would directly test the impact of sea lice.

Given the perceived importance by the public as well as the highly polarized positions that have been adopted on the issue of the potential aquaculture impacts on wild salmon, I recommend that a working group – not a single individual – assemble existing information in a manner useful for ongoing analyses. The greatest challenge will be the selection of the members of the working group, which must include individuals with a good working knowledge of multivariate statistical analysis, fish stocks, an ability to faithfully represent all existing data, support conclusions with data, have few preconceived ideas other those supported by data, and bring with them a good measure of common sense and willingness to have an open mind to new data and its analysis.

Touched on by the CTR and the NR, but not fully explored, is the fact that all FR SS populations are not created as equals. Weaver Creek sockeye are more susceptible to high temperature river mortality than interior populations (Farrell et al. 2008) and the Chilko sockeye presently stand out a 'superfish' in this regard (Eliason et al. 2011). Therefore, there is good reason (well beyond the concerns of negative impacts of salmon farming) that the multifactorial factors affecting the rises and falls in FR SS production are population-specific. For example, the Harrison population have continued to do well (the NR) despite an overall decline. Hence, the selective omission of this population in the CTR long-term analysis is rather peculiar.

Rates of louse shedding by juvenile SS represent a major knowledge gap in our efforts to assess interactions between farmed and wild salmon populations. For example, if the chances for reinfection are reduced because FR SS pass the farm sites rapidly and if FR SS can shed sea lice as effectively as pink salmon, then juvenile FR SS potentially could have fewer attached sea lice when sampled in the ocean. This possibility could be tested.

6. Please provide any specific comments for the authors.

Any attempts by the author to further simplify the language and presentation, thereby improving the access of this complex scientific matter to the general reader, would be appreciated. It is a solid, balanced and powerful report, therefore, general readers need appreciate it messages as best as possible.

Works specifically cited above.

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Report Title: Scientific Research Project #5C – Impacts of salmon farms on the Fraser River sockeye salmon – by **Dr. Donald J. Noakes**
Reviewer Name: John R. Post
Date: June 20, 2011

1. Identify the strengths and weaknesses of this report.

This review is very well argued, backed up by extensive data presentations and reasonable statistical analyses and logic.

Although there is substantial discussion of inappropriate bias in the public debate, and use of belief amongst various stakeholders in the salmon farm impacts controversy, it appears as if this review demonstrates some of this himself. A number of the conclusions are too strongly expressed given the uncertainty in information. Rather than saying that it is "unlikely" that there is impact, a more appropriate conclusion is that there is no evidence of a particular impact. Clearly the author recognizes that there are two explanations for such an outcome, one that there is no effect and one that there is an effect but it is not strong enough to exceed our threshold of proof due to data quantity and variability.

A number of the conclusions have been reworded.

2. Evaluate the interpretation of the available data, and the validity of any derived conclusions. Overall, does the report represent the best scientific interpretation of the available data?

The author very carefully explains the inappropriateness of a causation interpretation from the simple negative correlation between the growth in the number and production of salmon farms and the decline in sockeye survival at sea. The time series analysis from this short series, and the unidirectional trend in both variables, render the analysis uninformative- the reviewer is absolutely right. A longer time series with increases and decreases in both variates would be much more informative in terms of developing rigorous statistical models. But that is not the case here. There are 3 logical alternate biological hypotheses to be considered here. First- no impact of farms on survival, second- a positive impact of farms on survival, and third- a negative impact. So given the data, what is the most informative prior? I would suggest that the logical starting point is the observation of a negative relationship, which should lead to a search for mechanisms that could lead to this or alternate observations. Without more information I don't think we can go further than this. I think that this is the most objective conclusion from the information we have at this point.

Based on my expertise in time series analysis, I conclude with a high degree of confidence that the two time series (farmed salmon production and Fraser River sockeye salmon production) are not significantly correlated.

3. Are there additional quantitative or qualitative ways to evaluate the subject

area not considered in this report? How could the analysis be improved?

The analysis should include discussion of the power available to reject the null model of no effect. If power is low it is inappropriate to conclude that there is no effect.

I have included a very brief discussion of power analysis and a reference to Korman (2011) who conducted some simulation analyses. The discussion is primarily relevant to sea lice since all farms have this common problem. As the other diseases are specific to only a few farms, I do a more thorough analysis of each disease at the farm level rather than performing correlation tests.

4. Are the recommendations provided in this report supportable? Do you have any further recommendations to add?

Recommendation 1 is good but should be expanded to include spatial and temporal patterns in pathogens in young sockeye from before, to well after, encountering farms.

I agree but leave the detailed design to government, industry and stakeholders.

Recommendation 4 I don't understand.

Based on my past experience, there are significant on-going disease problems at many community salmon enhancement facilities and little or no staff expertise at these facilities to deal with these issues. The salmon farming industry has the expertise to help and are willing to do so if funding was made available to foster partnerships. It is in both groups interest to properly manage disease problems.

Recommendation 6- why a 3 lice/fish trigger? As in Recommendation 1, this monitoring should follow spatial and temporal patterns in lice in young sockeye from before, to well after, encountering farms. How many lice/fish before encountering farms, while encountering farms, and later in their migrations.

The 3/lice/fish trigger was an arbitrary limit imposed by government a number of years ago. Other jurisdictions use a higher limit (6/lice/fish). The trigger applies to the farm fish not the juvenile sockeye (or other species) salmon.

There is no recommendation for research aimed at determining pathogen and lice impacts, and their interactions, on condition and survival of juvenile sockeye during migration as above.

A general recommendation has been added.

There is no recommendation related to assessments of juvenile sockeye survival, which is really the crux of the whole issue. It should also be monitored spatially and temporally throughout the migration process as above.

This is a difficult problem and beyond the scope of this study.

There is no recommendation related to maintenance of the time series to improve our ability to measure effects, if they exist.

Recommendation added.

In general, the list of 6 recommendations offered by the reviewer are not directed at effectively answering the question of "is there an impact" and "what can we do about it if there is". I think that these should be the key recommendations for further assessment because we still do not know the magnitude of the impact.

5. What information, if any, should be collected in the future to improve our understanding of this subject area?

Covered in point 4.

This is not the responsibility of the reviewers, but in many ways this type of analysis is bound to be ineffective in providing the "best" weight of evidence for the cause of decline in sockeye survival. Partitioning the problem into single factors, with responsibility only within that factor. Is likely to result in accepting a long list of single factor null hypotheses when experience suggests that systems like this are likely much more complex. It would be useful if the reviewers made this point strongly and recommend an alternate approach to problem solving.

Agreed. The list of recommendations from the various projects will likely be long and fragmented.

6. Please provide any specific comments for the authors.

The logical hypothesis of cumulative and interactive effects should be raised. Complex biological systems like this are unlikely to be controlled by single drivers.

The issue of cumulative impact is being dealt with in another project.

Report Title: Impacts of Salmon Farms on Fraser River Sockeye Salmon: Results of the Noakes Investigation

Reviewer Name: Rick Routledge
Date: June 14, 2011

1. Identify the strengths and weaknesses of this report.

Unfortunately, I found this report to contain many weaknesses. Although some solid points were made regarding many of the issues discussed, key contradictory evidence was often either not mentioned or dismissed with what I found to be flawed reasoning. I therefore found the overall conclusions and recommendations to be inadequately supported.

I recognize the reviewer has strongly held beliefs and views of the salmon farming industry and that he has expressed his opinions in several articles. My assessment of the data and available information differs from those views and I expect that we will continue to disagree on many issues.

2. Evaluate the interpretation of the available data, and the validity of any derived conclusions. Overall, does the report represent the best scientific interpretation of the available data?

For reasons summarized above, and described in considerable detail in my response to Item 6, I find that this report falls short of representing the best scientific interpretation of the available data.

3. Are there additional quantitative or qualitative ways to evaluate the subject area not considered in this report? How could the analysis be improved?

Please see more detailed comments in item 6.

4. Are the recommendations provided in this report supportable? Do you have any further recommendations to add?

I do not find the recommendations to be adequately supported. The recommendations also focus primarily on reforms in areas other than aquaculture, and therefore seem tangential to the primary issue at hand.

Fish health information for wild and hatchery salmon is necessary to answer questions about what diseases may be influencing the survival of Fraser River sockeye salmon and what if any role salmon farms are playing.

The “Concluding Remarks” section ends with the statement, “I expect that there are many reasons for the decline of Fraser River sockeye salmon but based on the information available the impact from salmon farms appears to be minimal at best.” I find this to be a substantial underestimate of the potential impact of salmon farms. There remains, in my assessment, considerable uncertainty over the impact of the salmon farms on Fraser River sockeye salmon – and other wild Pacific salmon. Also, with one of the potential impacts being the spread of a pathogen with potentially devastating, long-term impacts on wild salmon, the Precautionary Principle needs to be invoked, which in turn calls for a far more substantial suite of responses than those presented in this report.

Again, the reviewer has strongly held views which differ from my assessment of the data and information presented in this report.

5. What information, if any, should be collected in the future to improve our understanding of this subject area?

I believe that the Dill report summarizes future information needs reasonably thoroughly, and I refer the reader to those. Also, please see my additional comment regarding a more overarching, related recommendation in my review of that report.

6. Please provide any specific comments for the authors.

In keeping with the instructions to the reviewers, most of my comments below refer specifically to this report. Nonetheless, since there is considerable overlap – and disagreement – between the two reports on aquaculture impacts, I have found it useful to make limited cross-references to the Dill report in this review. I begin with one such instance.

One issue on which the two reports differ substantially is on the statistical analysis of a potential association between (i) aquaculture production along what is thought to be the major juvenile migration route for Fraser sockeye salmon between Vancouver Island and the mainland and (ii) the so-called productivity of Fraser sockeye salmon. Although the competing analyses are relatively complex and are based on markedly different approaches, some general conclusions seem to emerge.

First, there were not enough years of data available to the analysts on potentially important risk factors on the farms to be able to detect a statistically significant influence. This is not surprising. Many influential and uncontrollable factors can impact Fraser River sockeye from when the eggs are laid until the survivors return to the approaches to the Fraser River. The notorious inaccuracy of forecasts of returning abundance provides plenty of evidence of the unpredictable year-to-year variation in adult returns. With all that uncertainty, it is not reasonable to expect definitive evidence of aquaculture impacts from so few years of observations.

Second, I believe that the somewhat divergent conclusions in the two reports regarding potential correlation between the longer-term time series on farm fish production and Fraser sockeye productivity can likely be reconciled in the following way:

One analysis found a correlation. The other, which pre-screened the data to remove trends (and other potential complicating factors) did not. The divergent results of the two analyses suggest to me that the reason for the correlation is likely mostly associated with the similar longer-term trends in the two series, and not with short-term, year-to-year fluctuations. In my assessment, this dilutes the strength of the case for aquaculture impacts, but does not eliminate it. There could well be long-term aquaculture impacts that are building up over time that could be substantial but that would not produce short-term, transient fluctuations in Fraser sockeye productivity in direct response to year-to-year fluctuations in farmed salmon production.

In light of this, I am inclined to conclude the following: (i) There is some correlation between the time series most likely attributable to the similar overall trends, (ii) this evidence warrants attention, but (iii) it does not constitute definitive proof that the low Fraser sockeye productivity in many recent years is attributable to aquaculture impacts.

Based on my expertise in time series analysis, I conclude with a high degree of confidence that the two time series are not significantly correlated.

The Noakes report makes considerable reference to the fact that farm fish production will likely not be driven by the same factors as wild fish production. It then goes on to conclude**, "**Thus, there is no apparent common underlying driving force (environmental factor) that would tend to make the two time series (farmed salmon production and Fraser River sockeye salmon productivity) behave in a similar or opposite fashion (direction). Considerable care should be taken in such cases to avoid spurious or nonsensical correlations." While I agree with the premise, I disagree with the conclusion. If a correlation cannot be attributed to a common environmental factor, then this surely weakens the case for a spurious or nonsensical correlation.

This comment doesn't make any sense.

Nonetheless, such correlations in time series can only provide circumstantial evidence. Considerable reliance needs to be placed on more direct assessments of potential linkages, to which this report correctly pays considerable attention.

Most of the evidence of impacts of salmon aquaculture on wild salmon is on other species: Atlantic salmon on both sides of the North Atlantic, and pink and chum salmon on the Pacific coast of Canada. In my assessment, and that of many other independent scientists, there is clear evidence that salmon aquaculture, as currently practiced in open net pens along migration routes for wild salmon, can have, and indeed has had, substantial impacts on these species. I strongly disagree with the arguments stated in the Noakes report that purport to discredit the bulk of the research on impacts on pink and chum salmon. I cite the following two reasons in particular.

First, the report discredits much of the research by citing inconsistent use of types of gear used to sample juvenile pink and chum salmon. Although the very first studies relied on questionable use of dip nets and unmodified trawl nets, the majority of the studies have relied on seine nets. Dip nets have a potential to bias the samples in favour of weaker fish who are less able to evade the dip net. To my knowledge dip-netting has been used in only two studies: the first one reporting on elevated lice levels on juvenile pink and chum salmon in the Broughton Archipelago, and a later study[1] where it was deliberately used to sample lethargic fish whose behaviour was similar to fish observed in a holding study shortly before they died. Sampling strategies that focus deliberately on afflicted individuals are commonly used in case-control studies on human health research, and the results were analyzed using the same sort of established statistical methodology as has been developed for case-control studies.

In addition, trawl nets, if not modified appropriately, can dislodge a potentially large fraction of lice from the fish. Small surface trawls have been specially designed with modified retention boxes to minimize the risk of lice dislodgement. Some studies have included data from samples obtained with such sampling gear. I have used such gear myself in sampling juvenile salmon for other purposes. Although I have not conducted any formal tests, my sense is that, if anything, the gear might well cause less dislodgement of lice than the more common seining method. In addition, with so few studies relying on this gear type, the issue is of only marginal importance.

Hence, I do not agree that sampling gear is a central issue in assessing the validity of the conclusions of much of this research.

There are problems with all types of gear and as I noted comparative studies have not been done. There are also problems concerning how lice are counted and identified. These are problems that should be dealt with but they are not the most significant problem with many of the studies that I examined.

Nor is it valid to argue that, because most of the researchers did not have access to estimates of lice abundance on the farms, their results should have no credibility. If lice abundances are substantially higher on fish that have been caught after they have passed by a fish farm vs. before, and if the differences cannot be attributable to changes in other potentially important factors such as sea surface salinity and temperature, then the most obvious explanation is that the farms provided the source of the infection. Estimates of lice abundance in the farms could likely have strengthened the inferences, but the absence of such estimates does not invalidate the conclusions.

Information on sea lice numbers and species on farmed fish is required if a goal is to determine what if any impact salmon farms have on wild salmon. Krkosek et

[1] Morton, A., and Routledge, R. (2006) Fulton's Condition Factor: Is It a Valid Measure of Sea Lice Impact on Juvenile Salmon? North American Journal of Fisheries Management 26:56–62.

al. (2007a) is a good example of what can go wrong and Marty et al. (2011) is an example of what can and should be done.

The evidence regarding potential impacts on Fraser sockeye is, by contrast, sketchy and incomplete. Again, though, I disagree on a key conclusion in the Noakes report in its assessment of the Price et al. (2011) paper. The Noakes report correctly points to a weakness in attributing the higher abundance of lice on sockeye salmon in the Discovery Islands area vs. the Skeena estuary to the salmon farms in the former area. Other factors, including salinity as mentioned in the report, could readily explain the difference.

As a co-author, I recognize the reviewer is sensitive to criticisms of the paper. There are, however, significant problems with the data, assumptions, and analyses which I note in this report.

Nonetheless, the paper also reports the results of comparisons within the Discovery Islands are itself. Sampling sites were divided into two categories: “upstream (a position on the juvenile sockeye migration route where fish likely had not passed a salmon farm), and downstream (a position where fish must have passed at least one salmon farm), given the net movement of juvenile sockeye through the region.” The paper reports that the total abundance of the more abundant louse species (*Caligus clemensi*) was significantly larger in downstream sites vs. upstream ones.

Hence, there is evidence, within the Discovery Islands area itself, that lice abundance on juvenile Fraser sockeye salmon can be increased by exposure to fish farms. (The paper also reports an anomalously large abundance of lice on fish sampled in the vicinity of a farm fish processing plant.) The abundances for the larger species, *Lepeophtheirus salmonis*, though, were not as large as were found in some years on pink and chum salmon in the Broughton Archipelago, and direct impacts on sockeye marine survival are as yet undetermined.

How substantial might these impacts be? Until appropriate assessments are conducted on Fraser River sockeye salmon, the best that can be done is to make educated guesses based on other species and populations. I agree with the conclusion in the Noakes report that sea lice can impact small (0.7 g) pink salmon, but note that Morton and Routledge[2] also report evidence that even small numbers of lice can increase the short-term mortality rate of pink salmon that weighed considerably more. In addition, as cited in the Dill report, there are publications reporting adverse impacts of low lice abundances on considerably larger Atlantic salmon. The evidence from these other species indicates that the potential direct impacts of sea lice infestations on juvenile

[2] Morton, A., and Routledge, R. (2006) Mortality rates for juvenile pink and chum salmon (*Oncorhynchus gorbuscha* and *keta*) infested with sea lice (*Lepeophtheirus salmonis*) in the Broughton Archipelago. Alaska Fisheries Research Bulletin. 11:2, 146-152

Fraser sockeye salmon cannot be dismissed. Nor can their role as potential disease vectors be lightly dismissed.

I have provided references to studies which found that larger salmon can mount an effective defence against sea lice and Dr. Farrell's review also provides a number of additional references on this issue. While sea lice, sea lamprey (Eissa et al. 2006), and other species may be able to act as potential disease vectors (at least in laboratory experiments using high doses of pathogens), it is unlikely (based on conversations that I've had with many fish health experts) that this mode of transmission is likely to be important at the population level. Most diseases are easily transmitted through water without the need of a 'vector'.

Eissa, A.E., E.E. Elsayed, R. McDonald and M. Faisal. 2006. First record of Renibacterium salmoninarum in the sea lamprey (Petromyzon marinus). Journal of Wildlife Diseases 42(3): 556-560

I agree with the conclusion in the Dill report: that, of the potential mechanisms for fish farming impacts on Fraser sockeye productivity, "the most likely candidate is disease transfer." The potential for disease evolution, magnification and transfer is, in my assessment, serious and worthy of considerable further attention. In addition, although as suggested in the Noakes report, such a transfer may well take place without the need for a transmission vector, the role of sea lice, especially *Caligus clemensi*, with its more diverse base of host species, may well be important. (In that context, I also note that Morton *et al.* (2008)[3] found this species on larval Pacific herring as well as sockeye salmon. The potential for fish farm impacts on Pacific herring warrants consideration as well.)

I note that both reports discuss knowledge gaps regarding the possible retro-virus associated with early up-river migration timing and high pre-spawning mortality in late-run Fraser sockeye salmon. The Noakes report does not, however, highlight the potential impact of such a novel virus. Nor does it address the potential role of fish farms in the evolution of more virulent strains of pathogens as described in the Dill report. In my assessment, this is a serious omission given the potential impact of a virulent pathogen on a population which has not been previously exposed to it.

As noted in my report, the genomic signature identified by Miller et al. 2011 may or may not be a novel virus and this is an area of research that should be pursued by researchers with expertise in genetics and fish health. It is also important to determine if the genomic signature is related to the cause of mortality in sockeye

[3] Morton, A., Routledge, R., and Krkošek, M. 2008. Sea lice infestation of wild juvenile salmon and herring associated with fish farms off the east central coast of Vancouver Island, BC. North American Journal of Fisheries Management. 28: 5323-532.

salmon or is simply an indicator (genomic) signature of those fish that are more likely to die from a disease (or combination of diseases).

The reports also differ markedly in their presentation of the evidence surrounding the infectious salmon anemia (ISA) virus. The Noakes report states, “To date, these [BC Ministry of Agriculture and Lands] audits have not found ISA in any farmed salmon.” By contrast, the Dill report, after reporting the same result, adds, “However, in his diagnostic reports on dead fish collected from salmon farms Gary Marty (fish pathologist with BCMAL) reports ‘classic symptoms of ISA’ (see BCP002975, BCP002976, BCP002977), which according to the World Organization of Animal Health (OIE) should make any one of these what they call a ‘suspect case’”. Again, given the impact that ISA has had on wild (and farmed) salmon in other parts of the world, this evidence deserves considerable attention.

Many diseases have similar symptoms and that’s why specific tests have been developed to confirm a diagnosis. ISA is an important issue and monitoring and testing should continue. Based on the information presented, it does not appear that any confirmed cases of ISA have been found or reported.