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

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TECHNICAL REPORT 5A

Summary of Information for Evaluating Impacts of Salmon Farms on Survival of Fraser River Sockeye Salmon

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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

The main objective of this report is to summarize spatial and temporal trends in salmon farm data the commission compiled for its evaluation of effects of salmon farms. This includes information on sea lice abundance and the frequency of bacterial and viral diseases. This report provides details on the provincial- and industry-based salmon farm monitoring program, and comments on the utility of these data for meeting the objectives of the commission's salmon farm investigation.

The majority of information on pathogens on salmon farms in BC comes from a fish health database maintained by BC Ministry of Agriculture and Lands (BCMAL), and an industry fish health and production database maintained by the BC Salmon Farmers Association (BCSFA). As part of salmon farm license requirements in BC, all farms must monitor their fish and report the status of health at their farms on a monthly basis. These reports are standardized and include monthly information on the number of fish on each farm, total mortality, causes for the mortality, and data from sea lice monitoring. In addition, industry veterinarians and technicians must report all fish health events (FHEs), which are defined as an active disease occurrence or a suspected infectious event on a farm that triggers veterinary involvement and an action such as a request for a laboratory diagnosis or use of prescription medication. BCMAL conducts approximately 100 audits of randomly selected salmon farms each year. These audits are used to inspect records maintained by salmon farmers, obtain samples of fish that may have died of disease from bacterial and viral infections, and to ensure that lice counts are accurate. The monitoring program was initiated in 2002 and was fully operational by the last quarter of 2003.

Approximately 70% of salmon farm production in BC originates from sites located between the mainland and the east coast of Vancouver Island along the main migratory corridor for Fraser River sockeye. An average of about 75,000 tonnes of salmon is produced annually. Over the last five years, an average of 32 million fish per year were held in net pens in BC waters, and 91% of these fish were Atlantic salmon. Approximately 3 million fish died each year on BC salmon farms (12% mortality rate) over this period, with 20% of that mortality

comprised of fish classified as ‘fresh silvers’, which potentially died of disease. Thus, an annual average of approximately 600,000 farmed salmon potentially died due to disease.

Across all farms between 2003 and 2010, an annual average of 30 fish health events that indicated the presence of high risk diseases to sockeye salmon (Furunculosis, infectious hematopoietic necrosis virus, bacterial kidney disease, and Vibrio), were reported by industry. All these diseases are endemic in wild fish populations in BC. There was a statistically significant declining trend in the number of high risk diseases reported by salmon farms between 2003 and 2010 (slope = -5.81 events/yr, r^2=0.62, n=8, p=0.02). The BCMAL audit program recorded an annual average of 12 farm-level high risk disease diagnoses between 2003 and 2009, and there was a declining but non- significant trend in this frequency over time. In the vast majority of audit cases where ‘fresh silver’ dead fish from salmon farms were tested, bacterial and viral infections were not found and no sign of disease was observed. For example, between 2002 and 2007, BCMAL tested 496 groups of 5-8 ‘fresh silver’ dead fish from randomly selected farms for the presence of six types of viruses or bacteria that are pathogenic to wild salmon, but only two cases of the Infectious Hematopoietic Necrosis Virus (IHN) and two cases of Viral Haemorrhagic Septicaemia (VHS) were found.

An average of 30,000 farmed Atlantic salmon has been examined per year between 2004 and 2010 to quantify lice abundance. Averaged over all seasons and years, 1.7 motile salmon lice were found per fish examined. There has been a modest but significant decline in the number of lice found per fish examined between 2004 and 2010 in spring (slope=-0.32 lice/fish/yr, r^2=0.65, n=7, p=0.03) and throughout the year (slope=-0.25 lice/fish/yr, r^2=0.78, n=7, p=0.008). An average of 30,000 Atlantic salmon have escaped from salmon farms or juvenile production facilities annually between 1991 and 2008. 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.

Inferences from statistical analyses that correlate trends in abundance or survival of Fraser River sockeye with trends in pathogens found in salmon farms will be extremely limited by the number of years of available data. There are only 3-5 years of overlapping Fraser River sockeye survival and salmon farm data available for statistical evaluation. A simulation analysis was used to demonstrated that as sample size declines, there is an increasing probability of

obtaining a negative correlation between a trend in salmon farm pathogens and survival of Fraser River sockeye due to chance alone, and not because a true relationship exists. However, the estimated statistical reliability of such false positive relationships are low when sample size is small, often leading to the correct conclusion that that that there is very little evidence for a relationship between variables if one does not exist. Conversely, the simulation showed that tests based on short-time series have very limited power to detect a negative relationship should one exist.

Our ability to make informed statements about the effects of salmon farms on wild salmon in BC will improve over the next decade as the number of years of monitoring data increases. However, correlation alone cannot be used to establish causation. Research on pathogen transmission from farmed to wild salmon, along with meaningful evaluations of the fraction of wild fish infected and the additional mortality associated with infection, are required to determine if cause-and-effect relationships between Fraser River sockeye returns and pathogens on fish farms exist. Financial resources are always limiting, and there are number of other factors that could have caused the decline in Fraser River sockeye productivity, some of which can be improved by management actions. Investment in research on effects of salmon farms and other factors on Fraser River sockeye should be consistent with the scientific consensus on the most likely causes of the decline in productivity and the feasibility of obtaining useful information.

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Introduction

In a recent review of evidence for declines in Fraser Sockeye, an expert panel concluded that physical and biological conditions inside the Strait of Georgia during the juvenile early marine life stage were very likely causes of the poor return in 2009, and also likely the major cause for the long-term decline since the early 1990s (Peterman et al. 2010). The panel deduced that freshwater and marine pathogens (i.e., viruses, bacteria, and/or parasites) were important contributors to the poor return in 2009 and the longer-term decline. The panel suggested that salmon farms located along migratory pathways for Fraser sockeye provide a possible mechanism for amplifying endemic pathogens such as the IHN virus and sea lice, but that data on pathogens on salmon farms were not available to evaluate this hypothesis in detail.

The Cohen Commission was established to evaluate potential causes for the low return of Fraser River sockeye in 2009 and the long-term decline. Members of the public were invited to express their views on issues related to the commission's mandate. Of an initial 153 submissions, over 61% were related to the effects of salmon farms on Fraser River sockeye, with the majority of those identifying concerns about effects of sea lice and disease (Cohen 2010a). The evaluation of the effects of salmon farms is one of twelve investigations supported by the commission. The investigation will evaluate the linkage between salmon farm operations and Fraser River sockeye returns and consider the impact of sea lice exposure, other pathogens, Atlantic salmon escapees, and other factors. This report summarizes information provided by BC Ministry of Agriculture and Lands, the BC Salmon Farmers Association, and Fisheries and Oceans Canada, to support the commissions' investigation of salmon farm impacts on Fraser River Sockeye. The main objective of this report is to summarize spatial and temporal trends for some important elements of the salmon farming data, such as sea lice abundance and the frequency of bacterial and viral diseases, which could affect wild sockeye salmon. This report provides details on the provincial- and industry-based salmon farm monitoring program, and comments on the utility of these data for meeting the objectives of the commission's salmon farm investigation. This report does not attempt to statistically relate trends in these data to Fraser River sockeye returns or survival rates, which is part of the work of other independent scientists engaged by the Cohen commission. Reports from the latter investigations will be available in July 2011.

Methods

History of Data Requests by the Commission

The Cohen commission requested data to evaluate salmon farming impacts from BC Ministry of Agriculture and Lands (BCMAL), the BC Salmon Farmers Association (BCSFA), and Fisheries and Ocean Canada (FOC). The majority of information on pathogens from salmon farms that is summarized in this report comes from a fish health database maintained by BCMAL, and an industry fish health and production database maintained by BCSFA. For the most part, FOC provided manuscripts and results from scientific investigations on the prevalence and effects of pathogens found on wild fish. This information is not included in this summary report, but will be utilized in the commission's ongoing investigations on salmon farming impacts. Data on and escapes of Atlantics salmon from fish farms compiled by FOC is included in this report.

Initially, the commission obtained data from BCMAL and BCSFA for 21 fish farms proximate to the main migration routes of Fraser sockeye between the east side of Vancouver Island and the mainland, for the period 2004-2009. These 21 farms were selected based on their proximity to the main Fraser River sockeye migration routes, and therefore represent a "worst-case" scenario as far as potential pathogen exposure for wild fish. Data collected prior to 2004 was not requested because the standardized provincial- and industry-based monitoring program, initiated in 2001, was not fully operational until the last quarter of 2003.

Pursuant to Rule 18 of the commission's rules of practice and procedure, the Aquaculture Coalition and Conservation Coalition asked commission counsel to expand the scope of the data request. Specifically, they argued that the number of farms should be expanded to a total of 120, all of which were within a 30 km radius of existing migration routes, and that data back to 1988 be made available. Their rationale was that the additional spatial and temporal replicates and contrast provided by the expanded data set would greatly strengthen inferences from the salmon farm-Fraser River sockeye evaluation. Commissioner Cohen agreed with most of the main arguments for expanding the dataset, but had concerns about the utility of early data because: 1) it was collected before a standardized monitoring program was in place; 2) would likely not be available in a standardized electronic format, and perhaps not even in hardcopy format; and 3) obtaining older documents and summarizing them in a useable format would likely result in

excessive time delays that were not compatible with the commission's schedule. Given these issues, on December 8, 2010, Commissioner Cohen ruled that data from all 120 farms be provided for the period January 1, 2000 to September 1, 2010, and that this information be made available by January 21, 2011. Additional details on the commission's work on data acquisition for the salmon farm analysis can be found in "Ruling Re: Rule 19 Application for Production of Aquaculture Health Records" (see Annex I in Appendix 1 or Cohen 2010b).

Data Sources

The BC Ministry of Agriculture and Lands initiated the development of a health management program for salmon farms in 2001 and has been verifying compliance and reporting on the program since 2003 (BCMAL 2009). The program documents the health status of salmon farms and supports monitoring, reporting, and governance of fish disease and health concerns that may arise in farmed fish. The main objectives of the program are to 1) monitor and minimize the risks of disease in farmed fish; 2) facilitate public and agency confidence that aquaculture health management in BC occurs at a high standard; and 3) ensure access to accurate data on disease status of farmed salmon. The two main elements of the program are described below and include industry-based monitoring and reporting, and a fish health audit and surveillance program conducted by BCMAL. Information provided to the commission for 2000, prior to the initiation of the health management program, is briefly described, as is the data compiled by Fisheries and Oceans Canada on Atlantic salmon escapes.

BCSFA Database

As part of salmon farm license requirements in BC, all farms must monitor their fish and report the status of health at their farms on a monthly basis. These reports are standardized and include monthly information on the number of fish on each farm, total mortality, causes for the mortality, and data from sea lice monitoring. In addition, industry veterinarians or technicians must report all fish health events (FHEs), which are defined as an active disease occurrence or a suspected infectious event on a farm that triggers: 1) veterinary involvement and 2) an action, such as: lab diagnosis, recommendation/report, husbandry change, prescription medication, further investigation, etc. where such action is intended to reduce or mitigate risk associated with that event (BCMAL 2009). Monitoring data collected by industry is submitted to the BCMAL

and is compared to data and trends on fish health collected through audits of randomly selected farms.

BCMAL requires industry to conduct lice assessments at each active Atlantic salmon farm on a monthly basis based on internationally accepted standards for sea lice monitoring. The frequency of sampling is increased to twice per month if the trigger level of three motile salmon lice per fish is exceeded. Lice are counted on a maximum of 60 live fish obtained from 3 net pens per farm each month. The lice monitoring program assesses the abundance of two types of sea lice found on farmed fish: the 'salmon louse', *Lepeophtheirus salmonis,* and the 'herring louse', *Caligus clemensi.*

BCMAL Fish Health Database

The BCMAL fish health audit and surveillance program consists of three main components (BCMAL 2009):

1. Provincial fish health technicians monitor activities and review health-related records at randomly selected salmon farms;
2. Provincial technicians collect samples from recently dead fish that have diagnostic value (called 'fresh silvers') to monitor for bacteria, viruses, and farm-level disease events, and monitor live fish for sea lice; and
3. Results from the audit are compared to results provided by the industry, such as fish health events and lice counts, to verify that the data collected by the industry is accurate.

The BCMAL audit system does not sample all farms each month. Instead, a multistage random selection system is used to sample approximately 30 farms per quarter with the aim of auditing 120 farms annually. A sub-set of recently dead fish is selected for standard histopathology, bacteriology, and virology testing. The approach of targeted disease sampling on recently dead fish ('fresh silvers') increases the likelihood of finding disease, compared with random sampling of all live fish which would mostly be healthy. Tests on these fish are used to establish the presence or absence of specific diseases-of-concern, and this information can be compared with the industry-reported health information. Pathogens that are sampled for include Infectious Salmon Anemia Virus (ISA), Infectious Pancreatic Necrosis Virus (IPN), Infectious Hematopoietic Necrosis Virus (IHN), Viral Haemorrhagic Septicaemia (VHS), and

Piscirickettsia salmonis (P. salmonis). See Kent (2011) for a description of these pathogens and their effects on wild salmonids and Fraser River sockeye in particular.

All tissue samples for histopathology are examined for signs of inflammation and other abnormalities. Histopathology can help determine the cause of mortality for individual fish, provides a mechanism for validating the significance of pathogen testing results, and can identify new diseases. Farm-level diagnoses from the fish farm audits are determined by BCMAL veterinarians based on pathogen testing, histopathology, and observations about causes of mortality obtained during the audit.

Lice counts are conducted by BCMAL and farm staff during site audits and are compared to determine if data from farm technicians is accurate. As well, estimates of lice abundance by provincial fish health sub-zone and quarter from audits of randomly selected farms are compared to the industry-based estimates. The lice monitoring program began with a limited number of farms on the west and east coasts of Vancouver Island, and was expanded to all farms in BC beginning in 2004. Data collected in 2003 and 2004 confirmed scientific reports that farmed Pacific salmon harbour very few lice (BCMAL 2005), so lice monitoring since 2005 has been restricted to Atlantic salmon only.

Fish Health Records Prior to Initiation of Fish Health Management Program

BCMAL provided hardcopies of records of results from histopathology, bacterial, and viral testing on individual fish from the BCMAL Animal Heath Centre (AHC) in 2000, prior to the initiation of the fish health management program. These fish were sent to the AHC by farm veterinarians for the most part. This information was not available in database format and contains little useful data for the purposes of the commission's sockeye salmon –salmon farm evaluation. For example, many records do not include a diagnosis, and none of the records specified the farm or location that the sample was obtained from.

Atlantic Salmon Escapes

Data from the Atlantic Salmon Watch Program (ASWP) were obtained to summarize the number of Atlantic salmon that are reported to have escaped from salmon farms in BC and information on sightings and capture of these fish in marine and freshwater. The purpose of the ASWP is to study the abundance, distribution and biology of escaped Atlantic salmon in British

Columbia and its adjacent waters. The ASWP monitors commercial and sport catches and observations of Atlantic salmon throughout British Columbia, Alaska and Washington in co-operation with the Alaska Department of Fish and Game and the Washington Department of Fish and Wildlife. The program relies on fishers, fish processors, government field staff and hatchery workers to report observations of Atlantic salmon (see http://www.pac.dfo-mpo.gc.ca/science/aquaculture/aswp /index-eng.htm).

Results

Trends in Production

Production from salmon farms in BC increased rapidly beginning in the late 1980s (Fig. 1). Although no new tenures were given after the 1995 moratorium was imposed, production continued to increase through the 1990s as existing farms expanded. The 1995 moratorium was lifted in 2002, but this did not result in a substantive increase in production. Average production over the last five years of available data (2004-2008) has been approximately 75,000 tonnes. About 70% of the production originates from salmon farms between the mainland and the east coast of Vancouver Island. The majority of salmon farm production in BC comes from farms located in or near Johnstone Strait within BCMAL fish health reporting sub-zones 3-3 and 3-2 (Fig. 2).

Production and mortality information provided to the Cohen commission by the BCSFA is available for individual farms on a monthly interval. However, for brevity, the summaries that follow aggregate data over the entire province on an annual time scale for the most part. Over the last five years, an average of 32 million salmon were held in net pens in BC salmon farms (Fig. 3). Development of the BCSFA database began in 2001in response to mandatory reporting requirements. The low numbers of fish between 2000 and 2002 in Figure 3 only reflect production from the limited number of farms that were included in the industry database in early years. The proportion of Atlantic salmon held in BC salmon farms has increased over the last decade, and the average for the last five years of available data (2006-2010) was 91%.

Trends in Mortality and Disease

Each salmon farm records the number of dead salmon removed from net pens each month and classifies the mortalities by suspected cause. Over the last five years of available data (2006-2010), approximately 3 million fish per year have died on salmon farms (Fig. 4). The average mortality rate between 2000 and 2010, determined based on the ratio of total dead fish per year to the average number of fish in the water, was 12%. The total mortality rate has been relatively stable across years and has ranged from 9-13%, with the exception of 2003, when mortality was 30%. Approximately 20-25% of the total mortality on fish farms is classified as 'fresh silvers', which are fresh carcasses that are suspected to have died due to disease or unknown causes. A sub-sample of these fish are collected by provincial biologists during random audits to establish potential causes of the mortality based on histopathology and tests for bacterial and viral diseases. The annual farm mortality rate based on fresh silvers only, which represent the maximum number of fish that may have died due to disease, averaged 2% between 2000-2010, and has ranged from approximately 1-5% (with the exception of 2003, when the fresh silver mortality rate was 13%). Over the last five years, an annual average of approximately 600,000 farmed salmon potentially died due to disease.

Across all farms, an average of 130 fish health events (FHEs) per year were reported by BCSFA (Fig. 5). Approximately 35% of these events were associated with mandatory lice treatments or use of anaesthetic to handle fish to conduct lice counts. In addition, separate fish health events at a farm were recorded in situations where a disease outbreak or results from treatment were monitored over time. Thus, the number of fish health events in any year is larger than the number of unique disease outbreaks. Approximately 25% of the FHEs (30 events per year) were caused by bacterial and viral diseases that were classified as high risk to Fraser River sockeye (Kent 2011) which include Furunculosis, IHN, BKD, and Vibrio. All these diseases are endemic in wild fish populations in BC and have likely been present for centuries, so it is not surprising that they are found in farmed fish as well (BCMAL 2009, Kent 2011). There was a statistically significant declining trend in the number of high risk diseases reported by salmon farms between 2003 and 2010 (slope = -5.81 events/yr , r^2=0.62, n=8, p=0.02).

Information on disease from BCMAL salmon farm audits is based on a random sub-sample of farms, however, the analysis of dead fish collected from those farms is more rigorous

than those from industry-submitted fish health events, because all these fish are subjected to a standard set of tests for bacteria and viruses as well as histopathological examination. Since the inception of the salmon farm monitoring program, approximately 800 audits have been conducted (~ 100/year). An average of 12 disease events classified as high risk to Fraser sockeye salmon (Kent 2011) were found per year between 2003 and 2009 (data from 2002 and 2010 excluded due to incomplete reporting), and there was a declining trend across years which was not significant (slope=-0.11 events/yr, r^2=0.37, p=0.15, Fig. 6). In the vast majority of audit cases where 'fresh silver' dead fish from salmon farms were tested, bacterial and viral results were negative and no sign of disease was observed in the histopathological examinations. For example, between 2002 and 2007, BCMAL tested 496 groups of 5-8 'fresh silver' dead fish from randomly selected farms for the presence of six types of viruses or bacteria that are pathogenic to wild salmon (see methods), but only two cases of IHN and two cases of VHS were found.

The average number of motile salmon and herring lice per Atlantic salmon for the period 2004-2010 from the industry database was used to summarize the trend in lice abundance on salmon farms. Lice counts collected prior to 2004 were excluded from the summary presented here because they were only available for a limited number farms participating in the pilot program, which were not sampled throughout the year. The summary is based on lice counts on Atlantic salmon only, since few lice are present on Pacific farmed salmon, Pacific salmon make up a limited amount of the total farmed production (Fig. 3), and lice sampling on farmed Pacific salmon was discontinued beginning in 2005.

An average of 30,000 farmed Atlantic salmon has been examined per year between 2004 and 2010 to quantify lice abundance. Averaged over all seasons and years, 1.7 motile salmon lice were found per fish examined (Table 1a). Infection rates (# lice/fish examined) were lower in the most southern fish health sub-zones (2-3 and 3-1), and there has been a modest but significant decline in infection rates between 2004 and 2010 in spring (slope=-0.32 lice/fish/yr, r^2=0.65, n=7, p=0.03) and throughout the year (slope=-0.25 lice/fish/yr, r^2=0.78, n=7, p=0.008, Fig. 7a). Infection rates were highest during fall and lowest during spring (Table 1b). This pattern was likely caused by transmission of naturally occurring lice on migrating adult wild Pacific salmon to fish on salmon farms in the late summer and fall, and the subsequent decline on salmon farms in later months once the primary infection source is no longer present, coupled

with further reductions due to the production cycle (harvest of older fish with lice and stocking of younger fish without lice) and lice treatments (Marty et al. 2010).

Herring lice were more abundant on salmon farms than salmon lice and did not show the same seasonal and inter annual patterns. Averaged over all seasons and years, 7.3 motile herring lice were found per fish examined (Table 2a), approximately four-fold higher than the number of salmon lice. Infection rates (# lice/fish examined) were highly variable among fish health sub-zones and there were no significant trends in infection rates between 2004 and 2010 in spring (slope=-0.19 lice/fish/yr, r^2=0.02, n=7, p=0.74) and throughout the year (slope=-0.20 lice/fish/yr, r^2=0.07, n=7, p=0.57, Fig. 7b). Infection rates were generally highest during summer (Table 2b).

Trends in Atlantic Salmon Escapes

An average of 30,000 Atlantic salmon have escaped from salmon farms or juvenile production facilities annually between 1991 and 2008 (Fig. 8). Approximately 70 and 15% of those fish were adults and juveniles escaping from net pens, respectively, with the balance made up of escapes of juvenile fish from freshwater rearing facilities. The average number of escapees between 2003 and 2008 was less than half the average between 1991 and 2002. The average number of captures or sightings of Atlantic salmon in BC waters has declined from 1573 for the period 1991-2002, to 162 for the period 2003-2008. A total of 33 adult Atlantic salmon have been caught or sighted in the Fraser River drainage since 1991, and reproduction of Atlantic salmon (based on capture of juveniles) in the Fraser River drainage has never been documented.

Discussion

Reliable information on pathogens in salmon farms that could potentially infect wild salmon is available for the period 2002/2004-2010. This information includes data from statistically representative audit samples from provincial salmon farm regulators (BCMAL), and data from all farms sampled on a more frequent basis provided by the industry. The combined government-industry monitoring program is impressive in terms of the fraction of farms that are audited, the number of pathogens that are tested for, the intensity of industry-based sampling and reporting, and the annual reporting and comparison of audit and industry-based results by regulators. Some information on pathogens in salmon farms was available for 2002 and 2003 during the pilot years of the salmon farm monitoring program. The information is limited to

fewer farms in specific areas, but was collected in a manner consistent with the current information and therefore does have some utility. Records on fish health provided to the commission for years prior to implementation of the monitoring program (2000) for the most part consisted of results from laboratory tests from fish sent in by biologists and veterinarians working on the farms. These records do not show the presence of new or novel high risk pathogens to wild salmon, which is not surprising considering that sampling of fish from salmon farms has been quite intensive since the provincial- and industry-based monitoring program was initiated. Further, as there was no standardized sampling protocol for collecting fish prior to the monitoring program, or a set of standardized tests applied to these samples, this information cannot be combined with data from the existing monitoring program to extend the time series. At best, it provides information on the presence or absence of specific pathogens that were tested for in individual fish. However, spatial or temporal trends in presence/absence could be driven as much by differences in reasons why fish were sent to the laboratory or the requested tests, than by real patterns. Given these issues, it is not defensible to include this information in an analysis of the effects of salmon farms on Fraser River sockeye.

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. Fraser River sockeye returns show a declining trend over this period, with exceptionally low and high returns in 2009 and 2010, respectively. The number of mortalities on salmon farms potentially caused by disease has remained relatively constant over this same period with the exception of the higher mortality in 2003. The frequency of disease events considered to be high risk for Fraser River sockeye showed a declining trend between 2003 and 2010 based on industry data, and no trend based on provincial audit data. The number of salmon lice infecting farmed salmon in spring and throughout the year declined significantly between 2004 and 2010. Salmon lice infection rates in spring 2007, when juvenile sockeye from the Fraser River that formed the poor adult return in 2009 migrated past the farms, was 40% below the 2004-2010 average. The salmon lice infection rate in spring 2008, when Fraser sockeye that formed the exceptional strong adult return in 2010 migrated past the farms, was very close to the multi-year average rate. A forthcoming statistical analysis by scientists hired by the Cohen commission will provide a more thorough evaluation of potential the effects of salmon farms on Fraser sockeye returns.

At the present time, inferences from statistical analyses that correlate trends in abundance or survival of Fraser River sockeye with trends in pathogens found in salmon farms will be extremely limited by the number of years of available data (Appendix 2). Fraser River sockeye salmon can spend up to 3 years in the ocean before returning to spawn, so calculating generational survival rates lags 3 years behind the year when juveniles enter the ocean. 2006 is the last ocean entry year for which generational survival rates can be calculated (i.e., the 2004 brood year, data forthcoming for 2005 brood year). Given that the salmon farm monitoring program was not fully operational until 2003/2004, there are only 3-4 years of overlapping survival and salmon farm data available for statistical evaluation. Given this short time series, there is a relatively high probability of obtaining a negative correlation between a trend in salmon farm pathogens and survival of Fraser River sockeye due to chance alone, and not because a true relationship exists (i.e., a false positive). Conversely, the short-time series provides very limited power to detect a negative relationship should one exist (i.e., a false negative). However, the estimated statistical reliability of false positive relationships are low when sample size is small, often leading to the correct conclusion that that that there is very little evidence for a relationship between variables if one does not exist. However, persons without an understanding of basic statistics, which for the most part represent the general public and the media, can be quite convinced that strong correlations based on small sample sizes (without p-values) imply a strong cause-and-effect relationship. Such an interpretation is unfounded.

Our ability to make informed statements about the effects of salmon farms on wild salmon in BC will improve over the next decade as the number of years of monitoring data increases. That said, correlation alone cannot be used to establish causation. Research on pathogen transmission from farmed to wild salmon, along with meaningful evaluations of the fraction of wild fish infected and the additional mortality associated with infection, are required to determine if cause-and-effect relationships between Fraser River sockeye returns and pathogens on fish farms exist. Financial resources are always limiting, and there are number of other factors that could have caused the decline in Fraser River sockeye productivity, some of which can be improved by management actions. Investment in research on effects of salmon farms and other factors on Fraser River sockeye should be consistent with the scientific consensus on the most likely causes of the decline in productivity and the feasibility of obtaining useful information.

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Table 1. Average number of motile salmon lice per Atlantic salmon examined from all active salmon farms by fish health zone (a) and by season (b, spring=Apr-June, summer=July-Sep, fall=Nov-Dec, winter=Jan-Mar). See Fig. 2 for the location of fish health zones. . 'WCVI', 'ECVI', and 'CC' denote the West and East coast of Vancouver Island and the central coast, respectively.

a)

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

b)

	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
Avg.	1.1	1.2	2.7	1.8	1.7

Table 2. Average number of motile herring lice per Atlantic salmon examined from all active salmon farms by fish health zone (a) and by season (b, spring=Apr-June, summer=July-Sep, fall=Nov-Dec, winter=Jan-Mar). See Fig. 2 for the location of fish health zones. 'WCVI', 'ECVI', and 'CC' denote the West and East coast of Vancouver Island and the central coast, respectively.

a)

	Fish Health Zone							
	WCVI		ECVI				CC	
Year	**2-3**	**2-4**	**3-1**	**3-2**	**3-3**	**3-4**	**3-5**	**Avg.**
2004	8.1	0.5	0.0	4.8	19.7	7.8	0.0	10.6
2005	3.4	0.8	0.0	8.7	10.5	4.2	0.0	6.6
2006	3.2	4.7	0.0	14.3	8.1	1.7	3.9	7.2
2007	2.8	3.5	0.0	8.5	5.3	4.0	3.4	5.1
2008	20.5	1.0	0.0	5.5	5.0	6.3	0.6	7.2
2009	4.8	1.2	0.0	21.5	5.3	7.7	0.9	7.6
2010	3.2	4.1	2.1	16.4	9.3	7.8	1.1	8.1
Avg.	6.3	2.2	0.5	11.4	9.2	5.3	2.9	7.3

b)

	Season				
Year	**Spring**	**Summer**	**Fall**	**Winter**	**Avg.**
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
Avg.	6.1	9.6	6.7	7.2	7.3

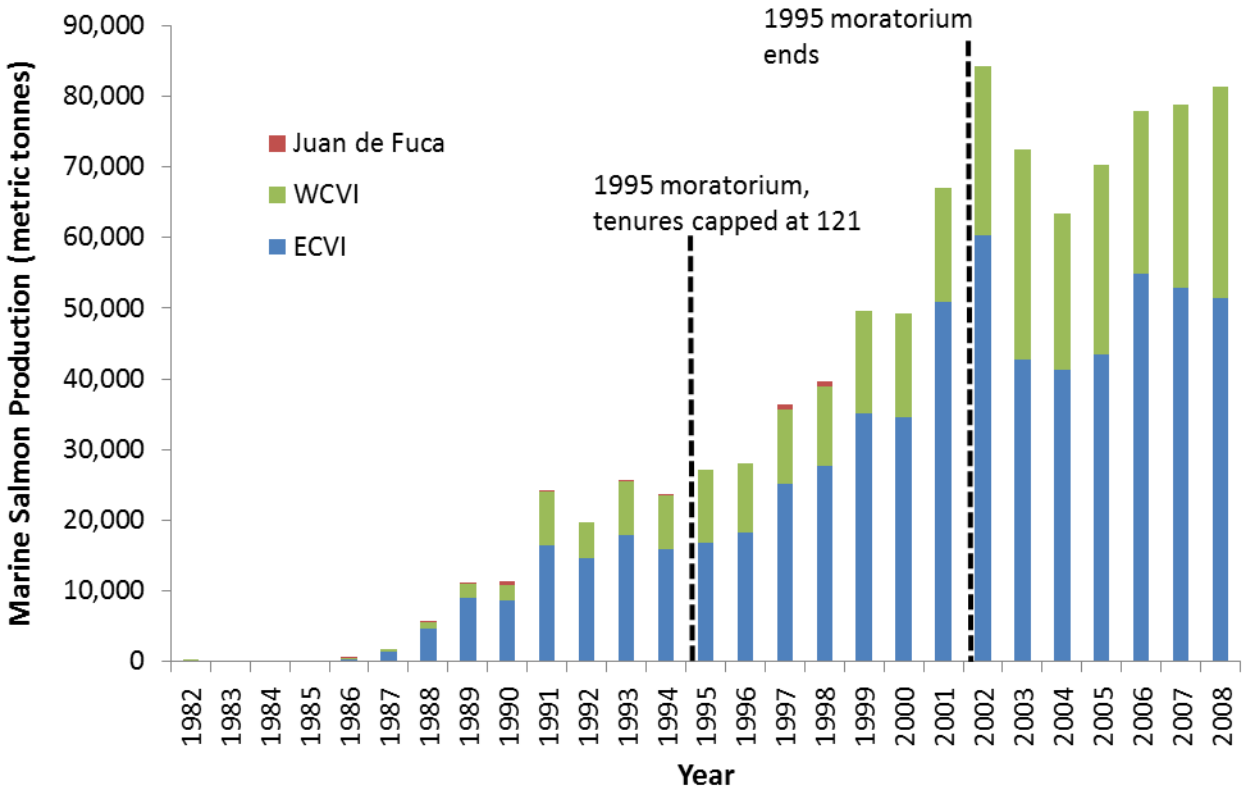


Figure 1. Trend in production of salmon from farms in British Columbia between the mainland and the East Coast of Vancouver Island (ECVI), off the West Coast of Vancouver Island (WCVI), and in Juan de Fuca Strait. Production from ECVI includes all farms in the Strait of Georgia, Johnstone Strait, and Queen Charlotte Strait (source: Fisheries and Oceans Canada, annual surveys of licensed farms). Vertical lines denote the beginning and end of the moratorium on new salmon farm tenures.

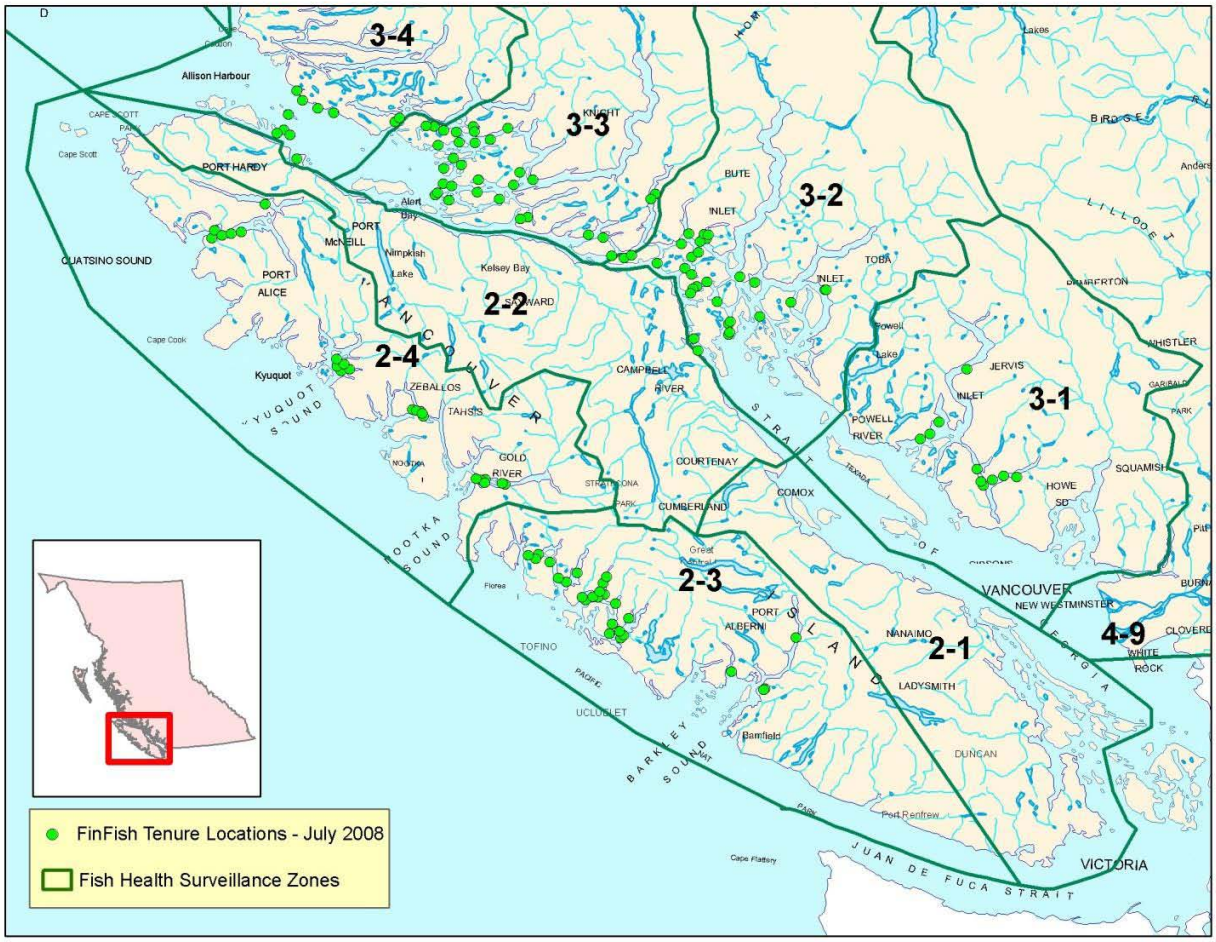


Figure 2. Map of BC Ministry of Agriculture and Lands fish health sub-zones and location of salmon farm tenure locations in 2008 (from BCMAL 2009, Appendix 7.2). Sub-zone 3-5 is not shown on the map but covers the entire BC coast north of 3-4.

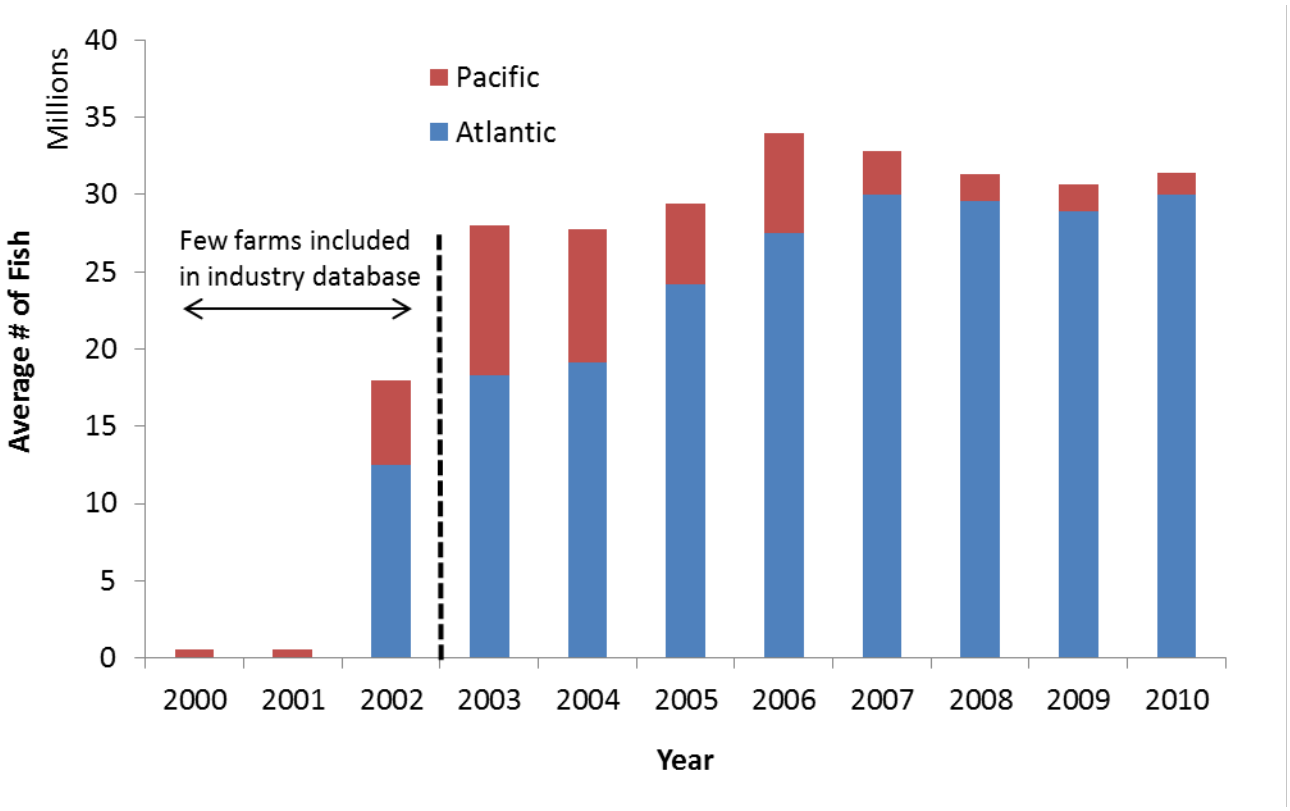


Figure 3. Average number of Atlantic and Pacific salmon held in net pens in BC salmon farms by year (source: BCSFA database). Database development was completed in 2003, so low numbers of fish from 2000-2002 do not reflect production but instead the limited number of farms included in the database during the development period.

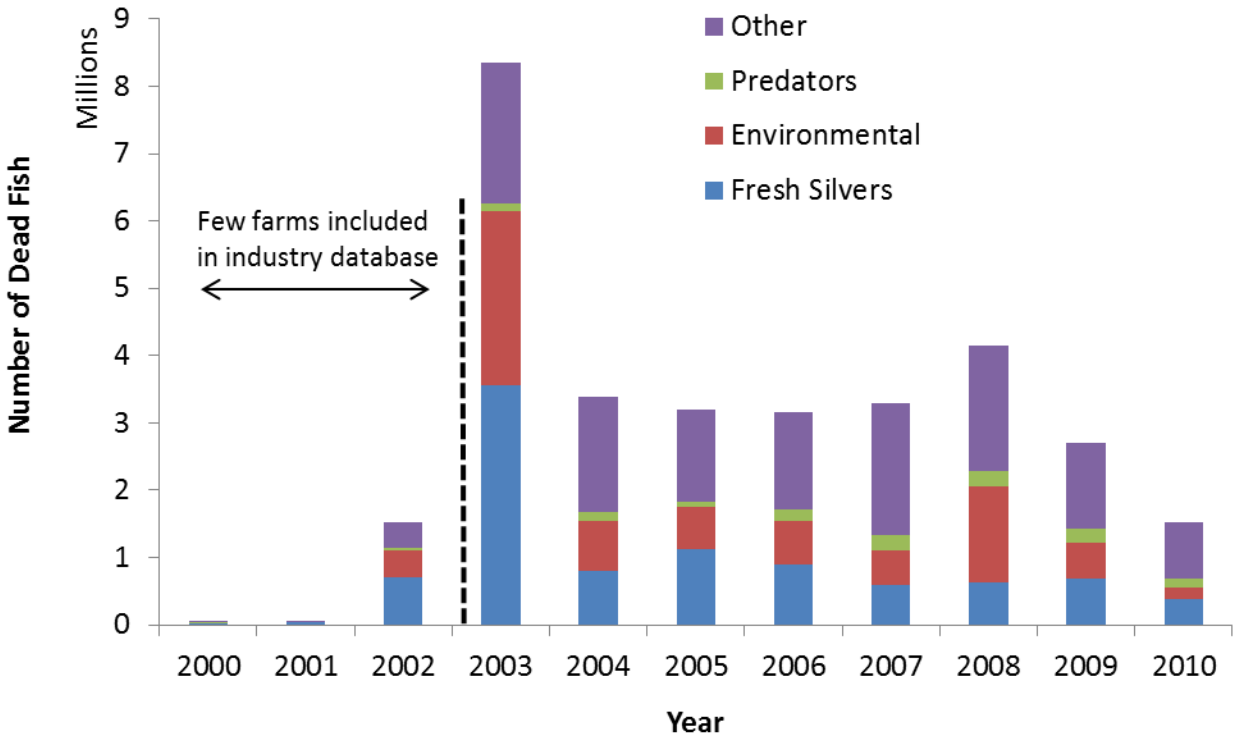


Figure 4. Total number of salmon mortalities on BC salmon farms by mortality type (source: BCSFA database). 'Fresh Silvers' denote fresh carcasses where mortality is suspected to be caused by disease or unknown causes. 'Predator' and 'Environmental' refer to losses caused by predators and environmental conditions (algae, low dissolved oxygen), respectively.

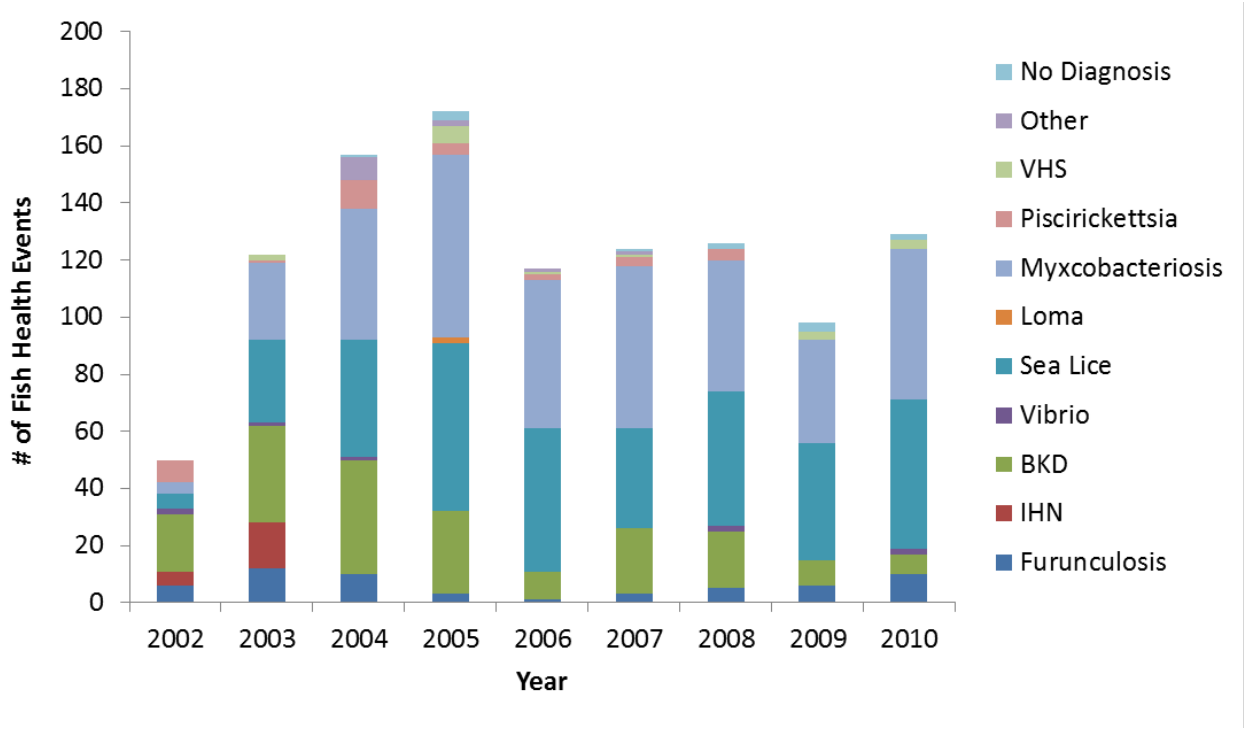


Figure 5. Total number of fish health events reported by the BCSFA by year and disease (source: BCSFA database). Note that the first 4 diseases (Furunculosis-Vibrio) were classified as high risk to Fraser River sockeye salmon by Kent (2011), sea lice was classified as moderate risk, and the remaining diseases were classified as low risk. The low number of fish health events in 2002 occurred due to the limited number of farms included in the BCSFA database prior to 2003.

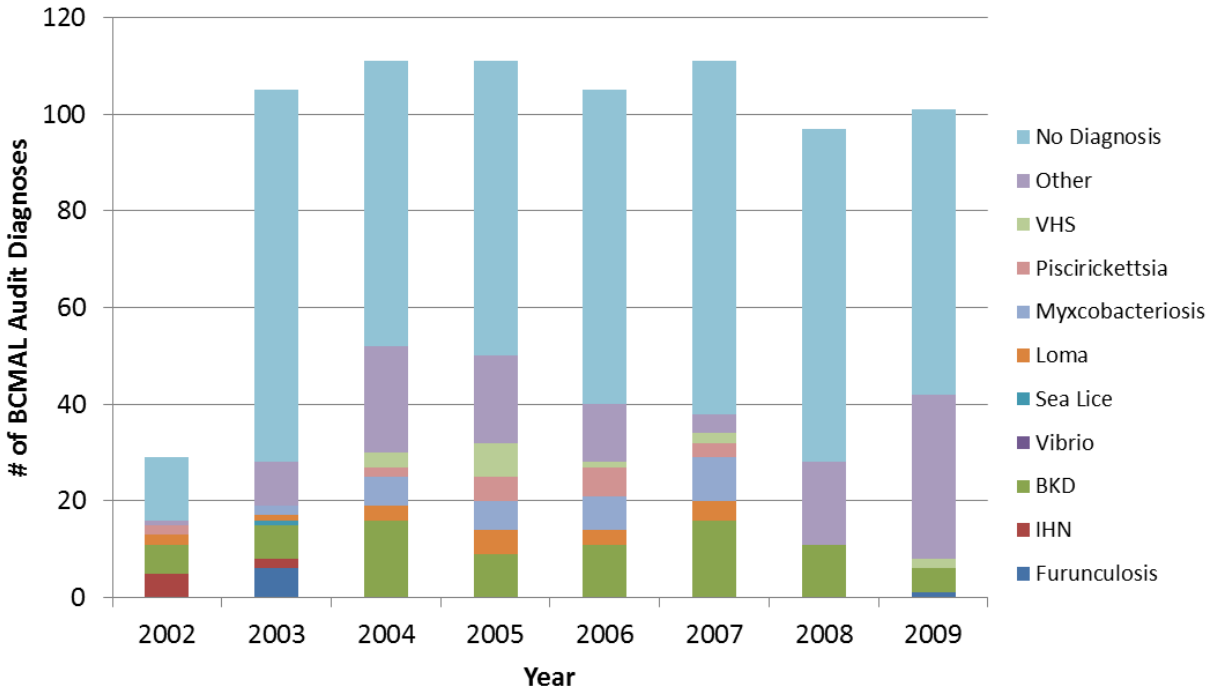
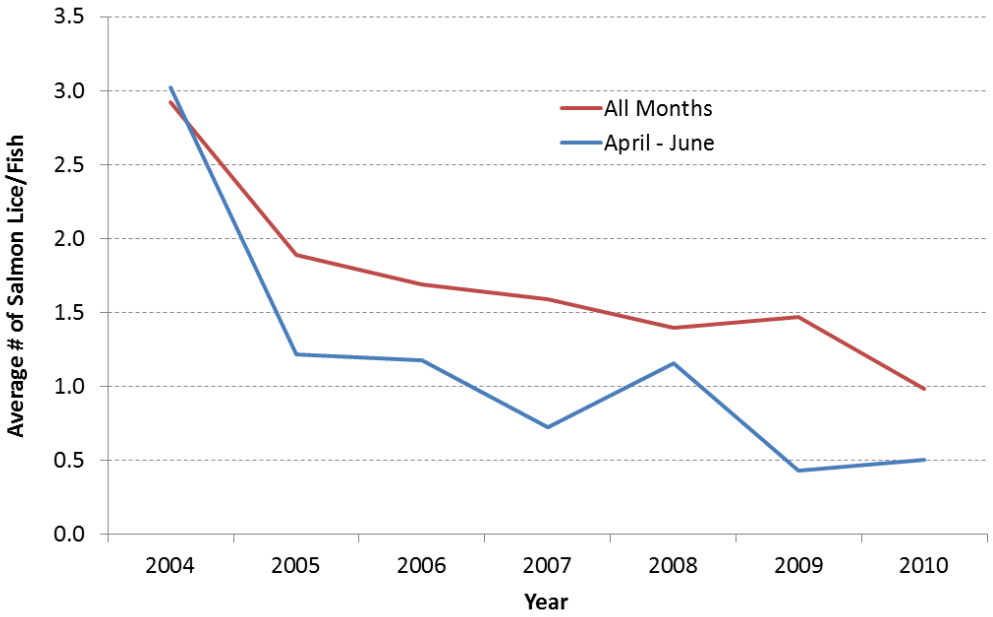


Figure 6. The number of farm-level diagnoses from BC Ministry of Agriculture and Land audits of fish farms by year and disease. The low number of diagnoses in 2002 occurred because few farms were sampled in the first year of the monitoring program (source: BCMAL database).

a)



b)

Figure 7. Average number of salmon (a) and herring (b) lice per farmed Atlantic salmon examined by year based on data from all months, and for months in spring (April-June) when Fraser River sockeye that have recently entered the ocean migrate past salmon farms in BC (source: BCSFA database).

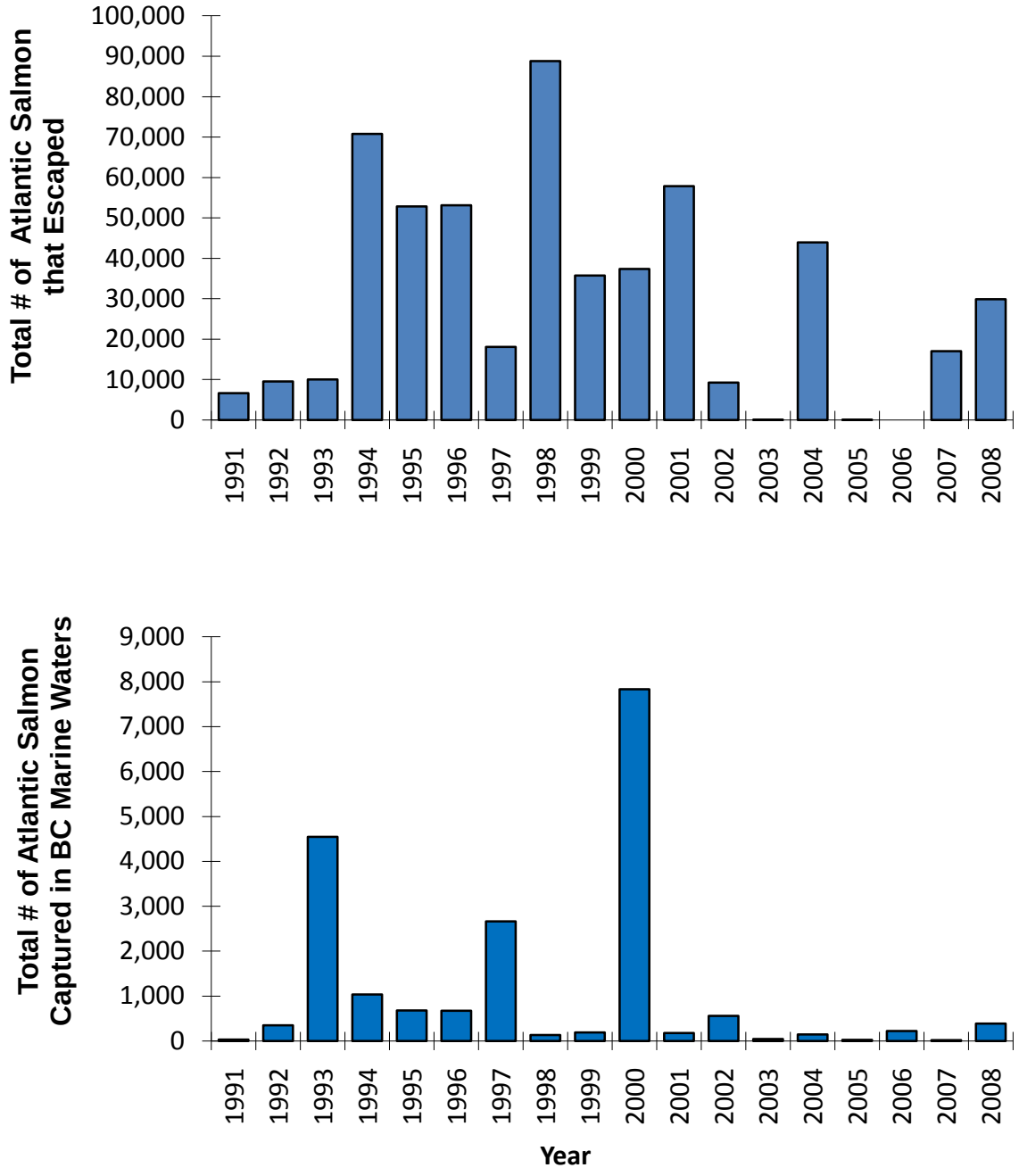


Figure 8. Trends in the annual number of Atlantic salmon reported to have escaped from BC salmon farm net pen or rearing facilities (top) and the number of Atlantic salmon captured in marine waters in BC (bottom, source: Atlantic Salmon Watch Program).

Appendix 1: Statement 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 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, if any, 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 the Canadian Food Inspection Agency (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 Annex 2, respectively.

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

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

- Queen Charlotte Strait: 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:

- 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.

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 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 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 may 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:

> the Province:
> …
> - 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.
>
> the BCSFA:
> …
> - 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. …
>
> Canada:
> … 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) The likely quality of data prior to 2004. 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) The likely availability of data prior to 2004. 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) The likely format of additional information. 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 2: Effect of Sample Size on Evaluating the Relationship between Fraser Sockeye Returns and Salmon Farms

Evaluation of the effects of aquaculture on Fraser River sockeye will be in part based on correlations between trends in sockeye abundance or survival and variable such as lice abundance or the frequency of disease occurrence on salmon farms. There are a variety of statistical techniques that can be used to examine such relationships. The simplest approach is to compute the coefficient of determination (r^2), which in this context, is the fraction of year-to-year variation in a dependent variable, such as Fraser River sockeye survival rates (e.g., log recruits/spawner), explained by year-to-year variation in an independent or predictor variable, such as the average number of lice per farmed salmon in the spring when sockeye smolts migrate past the farms. More advanced techniques include the use of mixed linear models where the effects of multiple independent variables can be jointly examined and where random effects can be incorporated. Regardless of the complexity of the statistical method, all approaches depend in large part on the amount and contrast in data available for the analysis, and in particular, the number of years for which time series information is available. For example, inferences about potential relationships between Fraser River sockeye survival and predictor variables derived from salmon farm data will be more robust if based on a comparison of 20-yr trends relative to an analysis based on 5-yr trends. When the number of years, or replicates, in the analysis is low, the true variation in the dependent and predictor variables will be poorly characterized. In such cases, correlative analyses may indicate a strong relationship between variables when one doesn't exist, or a weak relationship when a strong one is truly present.

The purpose of this analysis is to use computer simulation to describe how sample size impacts the utility of salmon farming data to explain trends in Fraser River sockeye abundance and survival. Two simulation analyses were conducted. The first simulates time series that are completely independent, and computes the fraction of cases where an analyst would incorrectly conclude that that a relationship between the variables exists. This is a false positive result, and is called a type I error rate in the field of statistics. The second analysis simulates time series that are correlated with each other, and computes the fraction of cases where an analyst would incorrectly conclude that there is no relationship between the variables, when in fact one does exist. This is a false negative result or type II error.

Sample size is a major factor which determines the probability of obtaining false positive or negative results, and is low (3-5 years) in the case of the Fraser River sockeye survival – salmon farm analysis. Data that indexes Fraser River sockeye survival is available for individual stocks or the Fraser River aggregate stock, but can only be computed on an annual time step (i.e., there is one data point for each year). Generational survival rates are computed based on the ratio of returning adults (prior to fishing) to the number of spawners that produced those fish four and five years earlier. Because Fraser River sockeye can return as four and five year-old fish, and recruitment estimates for specific stocks for 2010 are not yet available, 2004 is the last brood year (year of spawning) for which generational survival can be computed. Most correlative analyses regarding salmon farm impacts on wild salmon populations in BC have focused on hypotheses related to the effects of the farms on smolts that migrate past the farms (e.g., Marty et al. 2010). Almost all Fraser River sockeye stocks enter the ocean as smolts after two years in freshwater. Thus, statistics on salmon farms from year *t* (say 2006) would be correlated with the survival rate for smolts that entered the ocean in that year, which were derived from the ratio of recruits in year *t+2* and *t+3* to spawners in year *t-2* (2004 in this example). Due to this lag, the last year of available salmon farming data that can be used in a Fraser River sockeye-salmon farm analysis is 2006. The Cohen commission has amassed a considerable amount of information on salmon farms, and much of the data are available for each farm on a monthly time step, from approximately 2003/2004-2010. However, for the sockeye-salmon farm analysis, data from individual farms and months needs to be aggregated into annual statistics to relate to the annual sockeye time series, and data after 2007 cannot be used because there are no corresponding survival estimates for the associated smolt outmigration years. Hence, for salmon farm data series that begin in 2004, there are only 3 years of data that can be related to survival of Fraser sockeye (2004-2006), or 4 years of data for salmon farm time series that begin in 2003 (2003-2006). These are very small sample sizes.

The first analysis examines the probability of incorrectly determining a relationship between two variables exists when none is simulated. It begins by simulating a random time series for a dependent variable that represents sockeye survival rates, and then a large set of random time series for a predictor variable that represent salmon farm data. The correlation between each predictor time series and the dependent time series, and the statistical p-value for that relationship, is then computed. The p-value is the estimated probability that the relationship

could have arisen due to chance alone, that is, the probability of obtaining a false positive. As the dependent and predictor simulated time series are all independent, the mean correlation between the two across trials should be close to 0. However, for some trials, two time series will be strongly correlated due to chance alone, and the number of such cases increases as sample size declines. The simulation works as follows:

1. A 'n' year sequence of random numbers is drawn from a normal distribution with a mean of 0 and standard deviation of 1, and represents a potential time series for a dependent variable, like the number of log recruits/spawner for the Fraser River aggregate per year;
2. An 'n' year sequence of random numbers is drawn from the same normal distribution to represent a potential time series for a predictor variable, like the average number of motile lice per farmed fish examined per year. Note that time series 1) and 2) are completely independent;
3. The coefficient of determination between 1) and 2) is computed and multiplied by the direction of the correlation (-1 represents a negative relationship, 1 represents a positive relationship). This statistic is referred to as the directional correlation coefficient. The statistical p-value for the relationship is also computed;
4. 100 random sequences for the dependent variable (1) are computed and 500 random sequences for the independent variable (2) are computed for each dependent variable sequence, for a total of 50,000 simulation trials.
5. Statistics from individual simulations in 4) are summarized using cumulative probability distributions, and distributions based on 3-, 5-, 10-, 15-, and 20-yr time series are compared. The former two sets represent the sample size currently available for the Fraser sockeye survival – salmon farm analysis, while the latter three represent what will be available in the future.

As anticipated, the probability of obtaining stronger correlations when there was no real underlying relationship was much higher when sample size was low (Fig. A4.1). For example, when sample size was limited to three and five years, there was a 33% and 20% probability of obtaining datasets that indicated a negative relationship with the predictor variable explaining 25% or more of the variation in the dependent variable (directional coefficient of determination <=-25%), respectively. That probability declined to 7% when the sample size was increased to

10 years, and to 3% and 1.5% when sample size was further increased to 15 and 20 years, respectively. However, under all scenarios, the computed type I error rates were very high, either because sample size was small or because the estimated relationship between the variables was weak. For example, only 5% and 20% of the simulations had estimated type I error rates less than 0.05 and 0.2, respectively. Thus, in the majority of cases, an analyst would come to the correct conclusion that there is very little evidence for a relationship between variables. However, persons without an understanding of basic statistics, which for the most part represent the general public and the media, can be quite convinced that strong correlations based on small sample sizes (without p-values) imply a strong cause-and-effect relationship. This analysis demonstrates that such an interpretation is unfounded and will most often lead to the incorrect conclusion that a relationship exists when it does not.

Low sample size also reduces the probability of detecting a relationship between two variables when one in fact does exist. The following simulation was used to demonstrate this in the context of Fraser sockeye-salmon farm relationships:

1. Two 'n' year time series were simulated from a bivariate normal distribution with means of 0, standard deviations of 1, and a directional coefficient of determination of -25%. On average, the time series' will be correlated at the specified coefficient of determination;
2. The coefficient of determination and p-value for the simulated data was then computed;
3. 1) and 2) were repeated 5,000 times for 3-, 5-, 10-, 15-, and 20-yr time series, and cumulative frequency distributions were used to summarize the estimated p-values across all trials.

As expected, the probability of incorrectly concluding there was no relationship between dependent and predictor variables increased with reductions in sample size (Fig. A4.2). When sample size was only three and five years, only 30% and 40% of simulations with negative correlations had p-values < 0.2, indicating that a true relationship does exist (at a type I error rate of 0.2). Thus, in these examples, there was a greater chance of concluding there was no relationship between the variables even though a moderate correlation was simulated (i.e., a false negative result). The percentage of correct assessments increased to 60% for simulations based on 10 years, and 75% and 85% for 15- and 20-year simulations, respectively. Thus, the probability of obtaining false negative results declined with increasing sample size.

The key point from this analysis is that inferences about the effects of salmon farms on Fraser River sockeye abundance and survival from statistical analyses are extremely limited by the short time series of information on salmon farms combined with the lag-time required to compute sockeye generational survival rates. For most variables, there are 3-4 years of overlap between the available salmon farming data and information on Fraser River sockeye survival. Given this very limited sample size, there is a reasonably high probability of observing a moderate or strong correlation between salmon farm and Fraser sockeye metrics if no such relationship exists. However, most of these cases would not be statistically significant because of low sample size, leading to the correct conclusion that no relationship exists (if in fact there is no relationship). Limited sample size also leads to a high probability of incorrectly concluding that there is no relationship between salmon farming and Fraser sockeye, if in fact one exists.

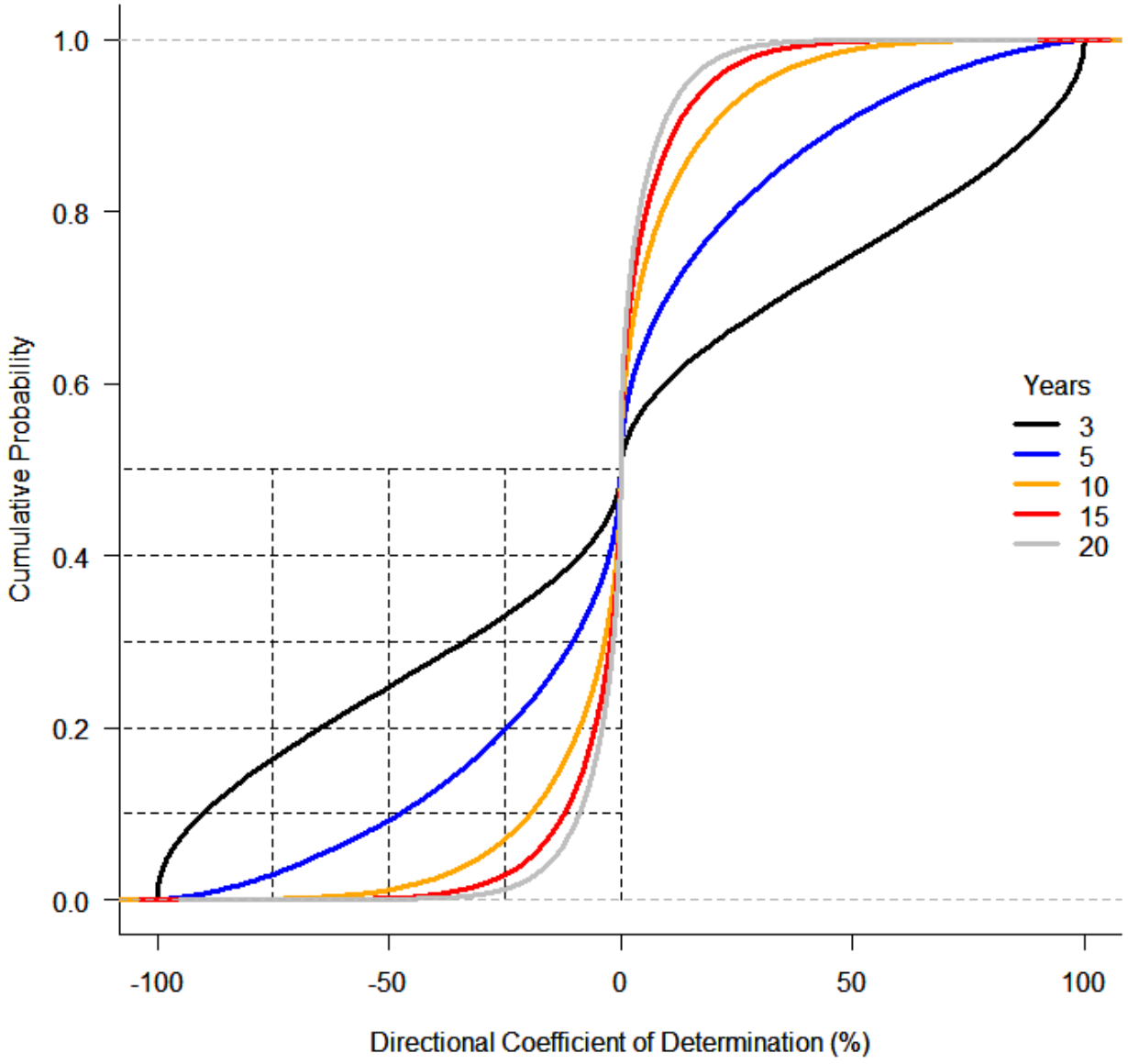


Figure A4.1. Cumulative probability distributions of the directional coefficient of determination (signed r2) between 50,000 simulations of two independent time series with no correlation. Each line represents the distribution based on a different sample size used in the simulation (years). The probability of obtaining modest or strong correlations between independent time series due to chance alone increases as sample size is reduced. In this example, when sample size for each time series is only 5 years, there is a 20% probability of obtaining a negative correlation between two independent variables with a coefficient of determination of 25% or higher (i.e., directional coefficient of determination <=-25%).

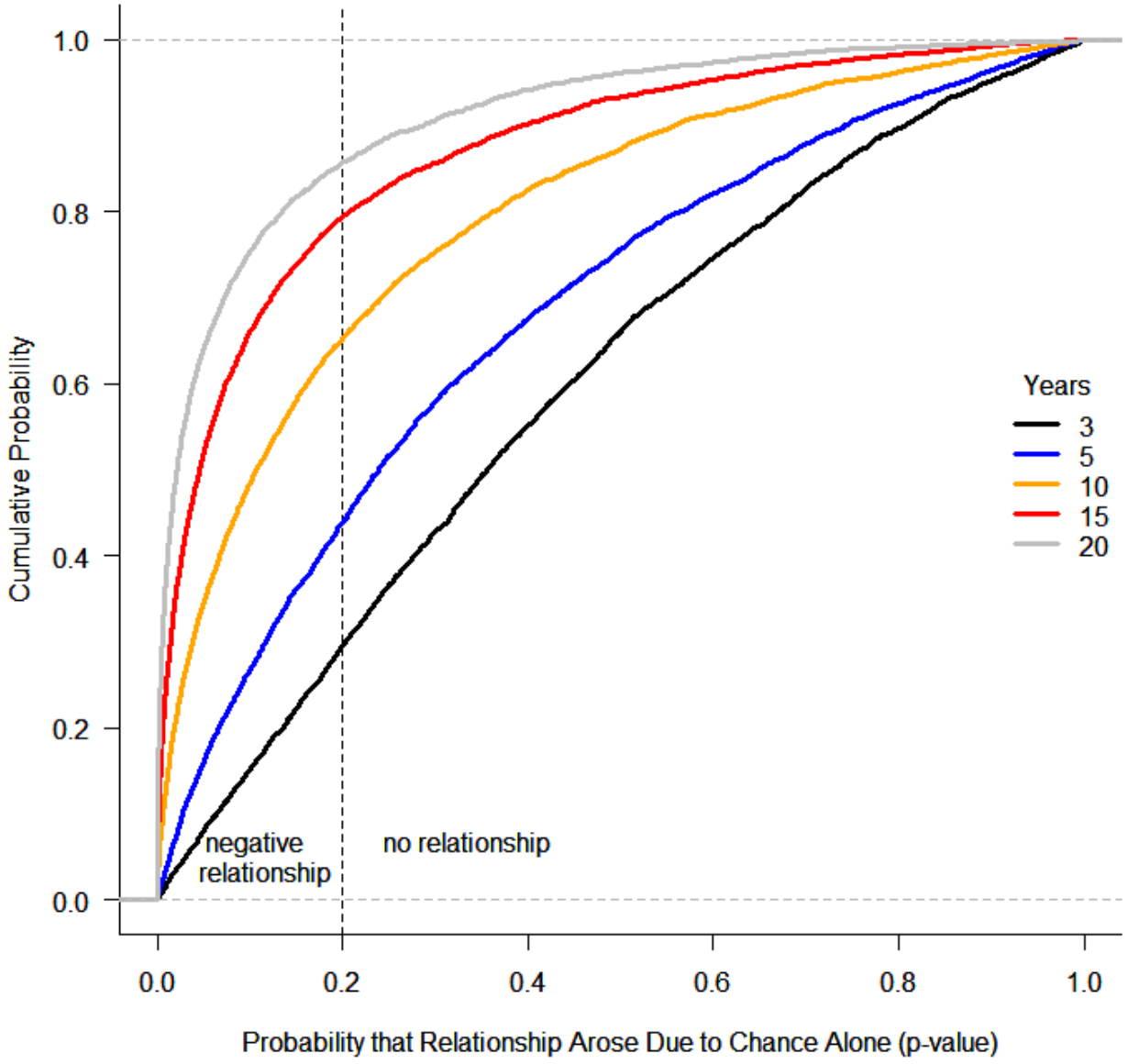


Figure A4.2. Cumulative frequency distributions of statistical p-values for 5,000 simulated negative relationships between two variables based on a true underlying coefficient of determination of 25%. Coloured lines show results from simulations with different sample sizes (years). The p-values that are plotted are the probabilities that the estimated negative relationships could have arisen due to chance alone. The vertical dashed line highlights a type I error rate of 0.2, and the cumulative probability at the vertical line represents the probability of correctly identifying a negative relationship at this error rate. One minus this probability is the probability of incorrectly concluding that a relationship does not exist (a false negative result or type II error).