

Errata

MacDonald D,D. J. Sinclair, M. Crawford, H. Prencipe, and M. Meneghetti. Potential Effects of Contaminants on Fraser River Sockeye Salmon. Cohen Commission Tech. Rep. 2. *In prep.*. Vancouver, B.C. www.cohencommission.ca

Text

Page 1, paragraph 2, line 8, incorrectly cites: (Peterman et al. 2010). The correct citation is (Peterman and Dorner 2011).

Page 115, first line, incorrectly cites: Peterman et al. (2011). The correct citation is Peterman et al. (2010)

Page 118, paragraph 2, line 1, incorrectly cites: Peterman et al. (2011). The correct citation is Peterman et al. (2010)

Page 121, last two lines of the page incorrectly cites: Nelitz et al. (2010). The correct citation is Nelitz et al. (2011). The citation in the References Cited section of the report is correct.

Page 131, paragraph 1, line 6, incorrectly cites: (Peterman et al. 2010). The correct citation is (Peterman and Dorner 2011).

Tables

4.2. Selected toxicity screening values (TSV) for assessing sediment quality conditions in the Fraser River Basin.

The units presented for Organochlorine Pesticides, Pesticides, Polycyclic Aromatic Hydrocarbons (PAHs), Polychlorinated Biphenyls (PCBs), and Plastics-related Chemicals are incorrectly stated in the “Units (dry-weight)” column as mg/kg. The correct units for these chemical classes are µg/kg; the values presented in this table are correct.

5.20. Hazard quotients for contaminants of concern in Weaver and Adams sockeye and Thompson chinook salmon populations.

The units presented for metals are incorrectly stated in the “Contaminant of Concern” and “Toxicity Reference Value” columns as mg/g. The correct units for this chemical class is µg/g; the values presented in this table are correct.

Chapter 1 Introduction

1.0 Background

On the west coast of North America, sockeye salmon utilize freshwater habitats from the Sacramento River in California to Kotzebue Sound in Alaska (Burgner 1991). Their unique life history means that sockeye salmon distribution and abundance are, for the most part, related to the availability of watersheds that contain linked riverine (for spawning) and lacustrine (for juvenile rearing) habitats. As a result of this unique habitat use, the two largest spawning complexes of sockeye salmon are found within the Bristol Bay watershed of southwestern Alaska and the Fraser River drainage basin of British Columbia (Burgner 1991). These populations of sockeye salmon have supported substantial aboriginal, commercial, and recreational fisheries for thousands of years.

While the productivity of Bristol Bay sockeye salmon populations has varied over the past 20 years, catches over this period have typically exceeded long-term averages (Eggers and Irvine 2007). In contrast, the productivity of sockeye salmon utilizing habitats within the Fraser River Basin has declined markedly over the past 20 years (Figure 1.1). Concerns over the productivity of Fraser River sockeye salmon intensified in 2007 and 2008, when low returns severely curtailed the fisheries on this species (McKinnell *et al.* 2011). The return of only 1.5 million adult sockeye salmon in 2009 - the lowest number since 1947, about 10% of the pre-season forecast of 10.5 million fish (Peterman and Dorner 2011) - reinforced these concerns and prompted the Governor General in Council to establish a Commission of Inquiry into the Decline of Sockeye Salmon in the Fraser River (i.e., Cohen Commission). In accordance with its terms of reference, the Cohen Commission is required to:

- Consider the policies and practices of Fisheries and Oceans Canada with respect to the sockeye salmon fishery in the Fraser River;
- Evaluate the causes for the decline of Fraser River sockeye salmon;
- Investigate the current state of Fraser River sockeye salmon and the long-term projections for those stocks; and,
- Develop recommendations for improving the future sustainability of the sockeye salmon fishery in the Fraser River.

Peterman *et al.* (2010) also indicated that poor productivity of Smiths Inlet and Rivers Inlet sockeye stocks since the mid-1990's, despite little industrial development in these regions, provides evidence of the absence of co-occurrence between cause (exposure to contaminants) and effect (declines in sockeye salmon abundance). For this postulation to be correct, freshwater survival of sockeye salmon must not have been the limiting factor in the overall productivity of these stocks. The results of an analysis by McKinnell *et al.* (2001) appears to confirm that freshwater abundance of Owikeno Lake stocks (Rivers Inlet) has been relatively consistent between about 1970 and 1998. Therefore, declines in the abundance of these stocks since about 1970 are most likely the result of poor marine survival. The relevance of this comparison may be limited, however, because Fraser River sockeye salmon did not exhibit the consistent declines over the period 1970 to 1990 that were observed for Owikeno Lake fish (as would be expected if factors defining ocean conditions were the same for the two sockeye production areas). Hence, it is not clear that patterns of sockeye decline in the Smiths Inlet and Rivers Inlet sockeye stocks provide evidence for or against co-occurrence of cause and effect for Fraser River sockeye salmon stocks.

Collectively, the available data are not sufficient to demonstrate that co-occurrence between cause and effect do not exist for the general decline of sockeye salmon in the Fraser River over the past 20 years. Reliable exposure data are needed to further resolve this question.

There is no evidence that the low returns of sockeye salmon to the Fraser River in 2009 were the result of elevated exposure of smolts to endocrine disrupting compounds during the spring of 2007. Therefore, evidence of co-occurrence between cause and effect is not available for sockeye salmon returning to the river in 2009. Finally, returns of sockeye salmon to the Fraser River in 2010 were among the highest on record. However, there is not enough data available to suggest that these fish had lower exposure to endocrine disrupting compounds or other contaminants of emerging concern than the fish that returned to the river between 1990 and 2009. While exceptional ocean conditions could have compensated for contaminant-mediated mortality during ocean transition, such high returns generally argue against co-occurrence of cause and effect for contaminant exposures.

infection by various disease agents and that infections lead to increased mortality during the transition to residence in the marine ecosystem. Therefore, the relationship between cause and effect is consistent with the existing scientific data and information.

Peterman *et al.* (2010) indicated that it is highly unlikely that there were direct kills of sockeye salmon from exposure to toxic chemicals in the Fraser River. These authors also indicated that sublethal effects on sockeye salmon are possible and could be a secondary factor contributing to reduced productivity. Furthermore, the potential influence of persistent bioaccumulative and toxic contaminants (such as PCBs, PCDDs, and PCDFs) on the growth, development, and reproduction of sockeye salmon was identified. Evidence for such effects on sockeye salmon reproduction was provided by DeBruyn *et al.* (2004), who demonstrated that the levels of 2,3,7,8-TCDD toxic equivalents in sockeye salmon eggs can exceed the levels that are associated with increased egg mortality. Therefore, it is reasonable to believe that exposure to endocrine disrupting compounds and/or other contaminants could have caused or, more likely, contributed to declines of sockeye salmon in the Fraser River.

6.4 Summary

Insufficient data were available to evaluate relationships between exposure (i.e., concentrations in surface water, sediment, or fish tissues) and response (i.e., productivity indicators for Fraser River sockeye salmon) for any of the endocrine disrupting compounds and contaminants of emerging concern that were identified in the Fraser River Basin. Therefore, it is not possible to conclude that exposure to these contaminants caused the declines in the abundance of Fraser River sockeye salmon over the past two decades or the low returns of Fraser River sockeye salmon in 2009. In addition, the results of the ecoepidemiological evaluation indicate that it is unlikely that exposure to endocrine disrupting compounds or other contaminants of emerging concern is the sole cause of the observed patterns in sockeye salmon abundance. The lack of co-occurrence between possible exposure to such contaminants and the productivity of Harrison River chinook salmon provides evidence that contaminant-related effects may not be the most important factor controlling sockeye salmon abundance in the Fraser River. Nevertheless, traditional knowledge compiled by the Siska Traditions Society (2009) on physiological indicators reveals that the length, weight, and girth of sockeye salmon have changed over the last couple of decades. In addition, changes in skin condition (blotchy colour, increased scarring, scab formation, reduced slime) and in the colour of internal organs

Chapter 7 Uncertainty and Data Gap Analysis

7.0 Introduction

There are a number of sources of uncertainty in assessments of risk to sockeye salmon associated with exposure to contaminants in the Fraser River Basin, including uncertainties in the conceptual model (i.e., pathway analysis), uncertainties in the effects assessment, and uncertainties in the exposure assessment. As each of these sources of uncertainty can influence the estimations of risk, it is important to describe and, when possible, quantify the magnitude and direction of such uncertainties. The purpose of this section is to evaluate the uncertainty in a manner that facilitates the attribution of the level of confidence that can be placed in the assessments conducted using the various lines of evidence. Accordingly, the uncertainties associated with the assessment of risks to Fraser River sockeye salmon are described in the following sections. Key data gaps are also identified.

7.1 Uncertainties Associated with the Conceptual Model

The conceptual model (i.e., including the pathways analysis) is intended to define the linkages between stressors, potential exposure, and predicted effects on ecological receptors. As such, the conceptual model provides the scientific basis for selecting assessment and measurement endpoints to support the risk assessment process. Potential uncertainties arise from lack of knowledge regarding ecosystem functions; failure to adequately address spatial and temporal variability in the evaluations of sources, fate, and effects; omission of stressors; and overlooking secondary effects (USEPA 1998). The types of uncertainties that are associated with the conceptual model used to link contaminant sources to effects on Fraser River sockeye salmon include those associated with the identification of chemicals of potential concern, environmental fate and transport of these chemicals, and exposure pathways.

Identification of chemicals of potential concern represents an important source of uncertainty in the conceptual model for the Fraser River Basin. In this study, an Inventory of Aquatic Contaminants was developed using information on the sources and releases of chemicals of potential concern based on the land-uses which comprise the Fraser River Basin. Information on land and water uses in the Fraser River Basin was acquired from many sources and verified using the results of an independent analysis conducted by Nelitz *et al.* (2011). As such, it is likely that the majority of potential sources of chemicals of

Chapter 8 Summary and Conclusions

8.0 Introduction

The productivity of sockeye salmon utilizing habitats within the Fraser River Basin has declined markedly over the past 20 years (Figure 1.1). Concerns over the productivity of Fraser River sockeye salmon intensified in 2007 and 2008, when low returns severely curtailed the fisheries on this species (McKinnell *et al.* 2011). The return of only 1.5 million adult sockeye salmon in 2009 - the lowest number since 1947, about 10% of the pre-season forecast of 10.5 million fish (Peterman and Dorner 2011) - reinforced these concerns and prompted the Governor General in Council to establish a Commission of Inquiry into the Decline of Sockeye Salmon in the Fraser River (i.e., Cohen Commission). In accordance with its terms of reference, the Cohen Commission is:

- Considering the policies and practices of Fisheries and Oceans Canada with respect to the sockeye salmon fishery in the Fraser River;
- Evaluating the causes for the decline of Fraser River sockeye salmon;
- Investigating the current state of Fraser River sockeye salmon and the long-term projections for those stocks; and,
- Developing recommendations for improving the future sustainability of the sockeye salmon fishery in the Fraser River.

To assist it in fulfilling this mandate, the Cohen Commission have engaged a team of scientists to evaluate the potential causes of the decline of Fraser River sockeye salmon. This study was conducted to develop an Inventory of Aquatic Contaminants for the Fraser River Basin and to evaluate the potential effects of those contaminants on Fraser River sockeye salmon (See Appendix 1 for information on the Statement of Work for this project). To achieve these objectives, a work plan was developed that consisted of four distinct tasks, including:

- Preparation of an Inventory of Aquatic Contaminants in the Fraser River in relation to the distribution of sockeye salmon conservation units;
- Comparison of data on water quality conditions in the Fraser River to toxicity data for sockeye salmon;

Table 4.2. Selected toxicity screening values (TSV) for assessing sediment quality conditions in the Fraser River Basin.

Chemical of Potential Concern	Selected TSV	Units (dry-weight)	TSV Type	Reference
Metals				
Arsenic	9.79	mg/kg	TEC	MacDonald <i>et al.</i> (2000a)
Cadmium	0.99	mg/kg	TEC	MacDonald <i>et al.</i> (2000a)
Chromium	43.4	mg/kg	TEC	MacDonald <i>et al.</i> (2000a)
Copper	31.6	mg/kg	TEC	MacDonald <i>et al.</i> (2000a)
Lead	35.8	mg/kg	TEC	MacDonald <i>et al.</i> (2000a)
Mercury	0.18	mg/kg	TEC	MacDonald <i>et al.</i> (2000a)
Nickel	22.7	mg/kg	TEC	MacDonald <i>et al.</i> (2000a)
Zinc	121	mg/kg	TEC	MacDonald <i>et al.</i> (2000a)
Iron	21,200	mg/kg	LEL	Nagpal <i>et al.</i> (2006)
Selenium	2	mg/kg	--	Nagpal <i>et al.</i> (2006)
Silver	0.5	mg/kg	--	Nagpal <i>et al.</i> (2006)
Organochlorine Pesticides				
Chlordane	3.24	µg/kg	TEC	MacDonald <i>et al.</i> (2000a)
Dieldrin	1.90	µg/kg	TEC	MacDonald <i>et al.</i> (2000a)
Endosulfan a	2.9	µg/kg	SQAL	USEPA (1997)
Endosulfan b	14	µg/kg	SQAL	USEPA (1997)
Endrin	2.22	µg/kg	TEC	MacDonald <i>et al.</i> (2000a)
Heptachlor epoxide	2.47	µg/kg	TEC	MacDonald <i>et al.</i> (2000a)
Lindane	2.37	µg/kg	TEC	MacDonald <i>et al.</i> (2000a)
Methoxychlor	19	µg/kg	SQAL	USEPA (1997)
Sum DDD	4.88	µg/kg	TEC	MacDonald <i>et al.</i> (2000a)
Sum DDE	3.16	µg/kg	TEC	MacDonald <i>et al.</i> (2000a)
Sum DDT	4.16	µg/kg	TEC	MacDonald <i>et al.</i> (2000a)
Total DDTs	5.28	µg/kg	TEC	MacDonald <i>et al.</i> (2000a)
Pesticides				
Aldrin	2.0	µg/kg	LEL	Nagpal <i>et al.</i> (2006)
Toxaphene	0.1	µg/kg	ISQG	CCME (1999)
Polycyclic Aromatic Hydrocarbons (PAHs)				
Acenaphthylene	5.87	µg/kg	ISQG	CCME (1999)
Acenaphthene	6.71	µg/kg	ISQG	CCME (1999)
Anthracene	57.2	µg/kg	TEC	MacDonald <i>et al.</i> (2000a)
Benz(a)anthracene	108	µg/kg	TEC	MacDonald <i>et al.</i> (2000a)
Benzo(a)pyrene	150	µg/kg	TEC	MacDonald <i>et al.</i> (2000a)
Chrysene	166	µg/kg	TEC	MacDonald <i>et al.</i> (2000a)
Dibenz(a,h)anthracene	33	µg/kg	TEC	MacDonald <i>et al.</i> (2000a)
Fluoranthene	423	µg/kg	TEC	MacDonald <i>et al.</i> (2000a)
Fluorene	77.4	µg/kg	TEC	MacDonald <i>et al.</i> (2000a)
Napthalene	176	µg/kg	TEC	MacDonald <i>et al.</i> (2000a)

Table 4.2. Selected toxicity screening values (TSV) for assessing sediment quality conditions in the Fraser River Basin.

Chemical of Potential Concern	Selected TSV	Units (dry-weight)	TSV Type	Reference
<i>Polycyclic Aromatic Hydrocarbons (continued)</i>				
Phenanthrene	204	µg/kg	TEC	MacDonald <i>et al.</i> (2000a)
Pyrene	195	µg/kg	TEC	MacDonald <i>et al.</i> (2000a)
Total PAHs	1610	µg/kg	TEC	MacDonald <i>et al.</i> (2000a)
<i>Polychlorinated Biphenyls (PCBs)</i>				
Total PCBs	0.04	µg/kg	TEC	MacDonald <i>et al.</i> (2000b)
<i>Plastics-Related Chemicals</i>				
Diethyl phthalate	630	µg/kg	SQAL	USEPA (1997)
Bis (2-ethylhexyl) phthalate	182	µg/kg	TEL	MacDonald (1994)

TEC - Threshold Effects Concentration; LEL - Low-effects Level; SQAL - Sediment Quality Advisory Level; ISQG - Interim Sediment Quality Guideline; TEL - Threshold Effects Level

Table 5.20. Hazard quotients for contaminants of concern in Weaver and Adams sockeye and Thompson chinook salmon populations¹.

Contaminant of Concern	Toxicity Reference Value	Fraser River Mouth		Spawning Grounds	
		Muscle	Roe	Muscle	Roe
Metals (µg/g)					
Mercury	0.4 µg/g ³	0.063	0.024	0.159	0.038
Selenium	1.58 µg/g ⁴	0.095	1.52	0.487	1.01
Chemical Mixtures					
ΣTEQ ²	3.0 pg/g lipid ⁵	NB	2.53	NB	1.48

NB = No available benchmark; TEQ = toxic equivalent; PCB = polychlorinated biphenyl; PCDD = polychlorinated dibenzo-*p*-dioxin; PCDF = polychlorinated dibenzofuran; TCDD = tetraochlorodibenzo-*p*-dioxin.

¹Data obtained from Siska Traditions Society 2009.

²ΣTEQ is calculated as the the sum of the PCB, PCDD, and PCDF TCDD-TEQ values.

³Toxicity reference value obtained from Dillon *et al.* (2010)

⁴Toxicity reference value obtained from USEPA (2010b); assuming 80% tissue moisture content.

⁵Toxicity reference value obtained from DeBruyn *et al.* (2004) and Giesy *et al.* (2002.)

Bolded values indicate hazard quotients > 1.0.