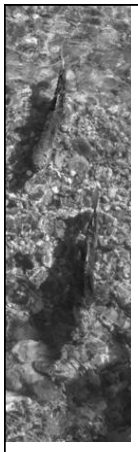
Cohen Commission
Fraser River Sockeye Salmon

Technical Report 6: Data Synthesis and cumulative impacts



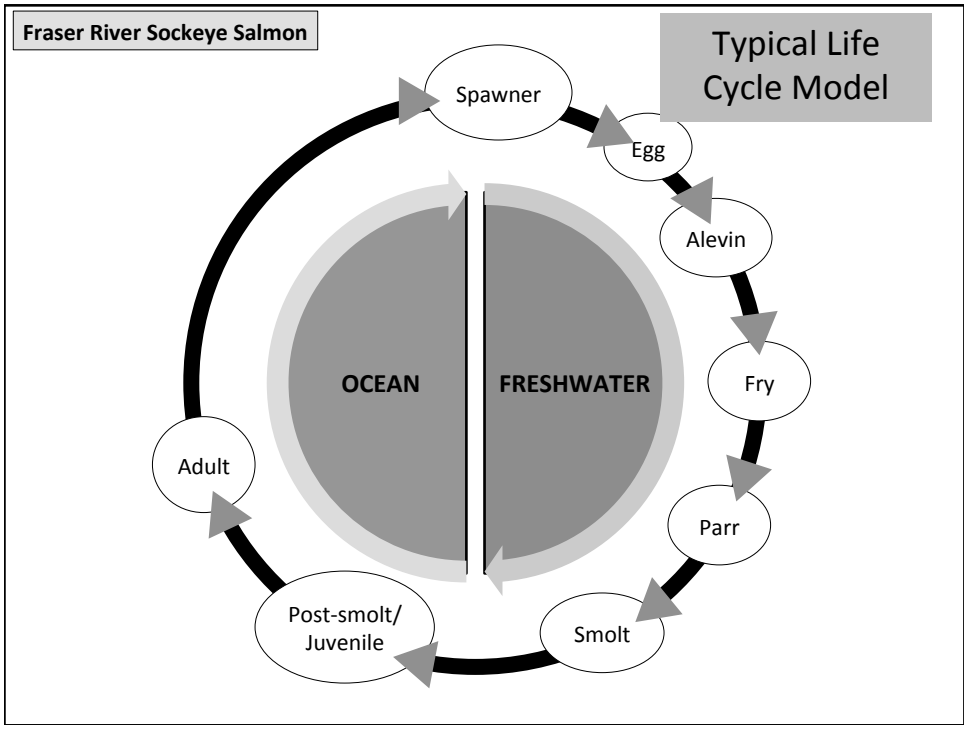
Study Objectives

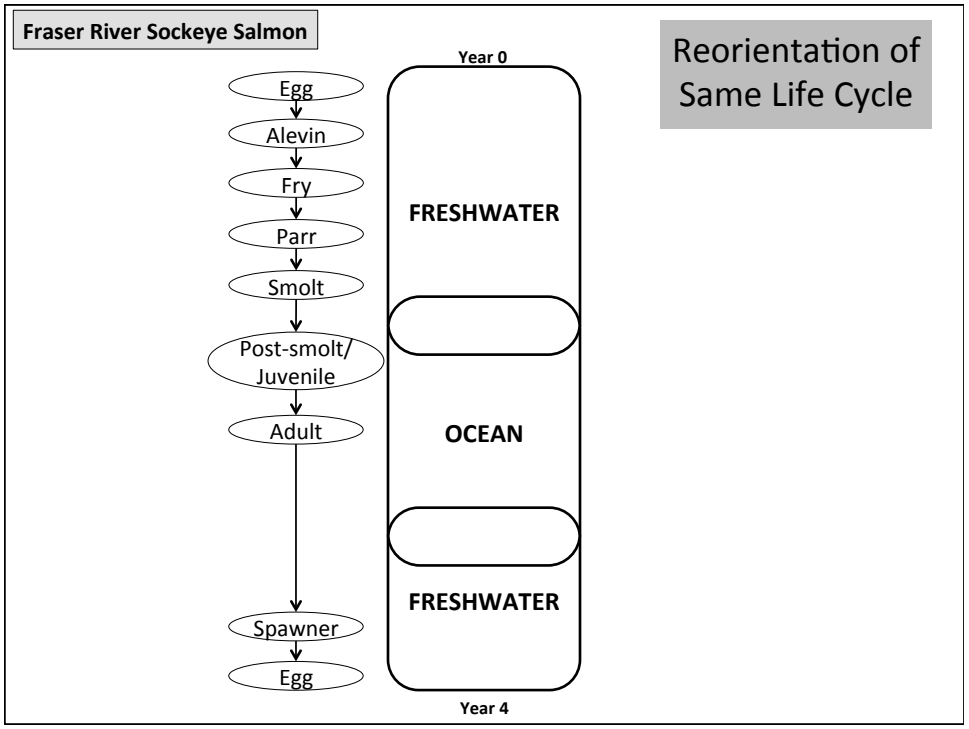
- Synthesize and integrate Cohen Commission technical reports (~2400 pages)
- Assess cumulative impacts of various factors over period of declining productivity
- Assess evidence – what's relative support for different possible causes of the decline?

What we did

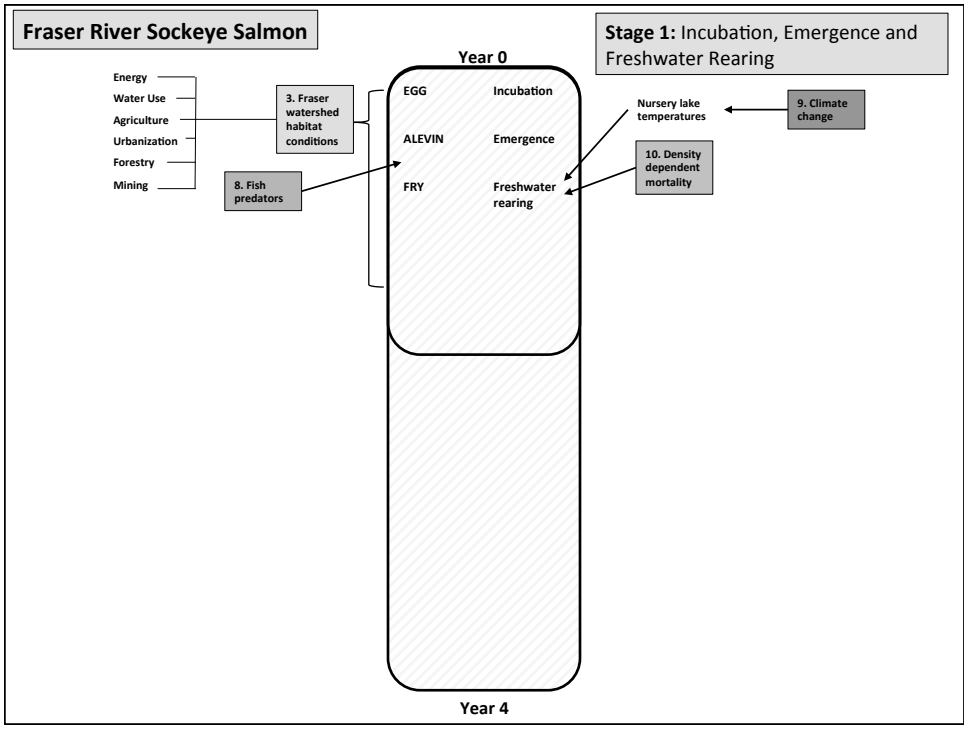
- held workshop with all Cohen Commission researchers (Nov 30-Dec 1, 2010)
- developed conceptual model of stressors affecting each life history stage
- built database: stock productivity and stressor data
- *qualitative* synthesis of the technical reports
- *quantitative* analyses of what stressors appear best related to productivity
- wrote report, recommended research & monitoring

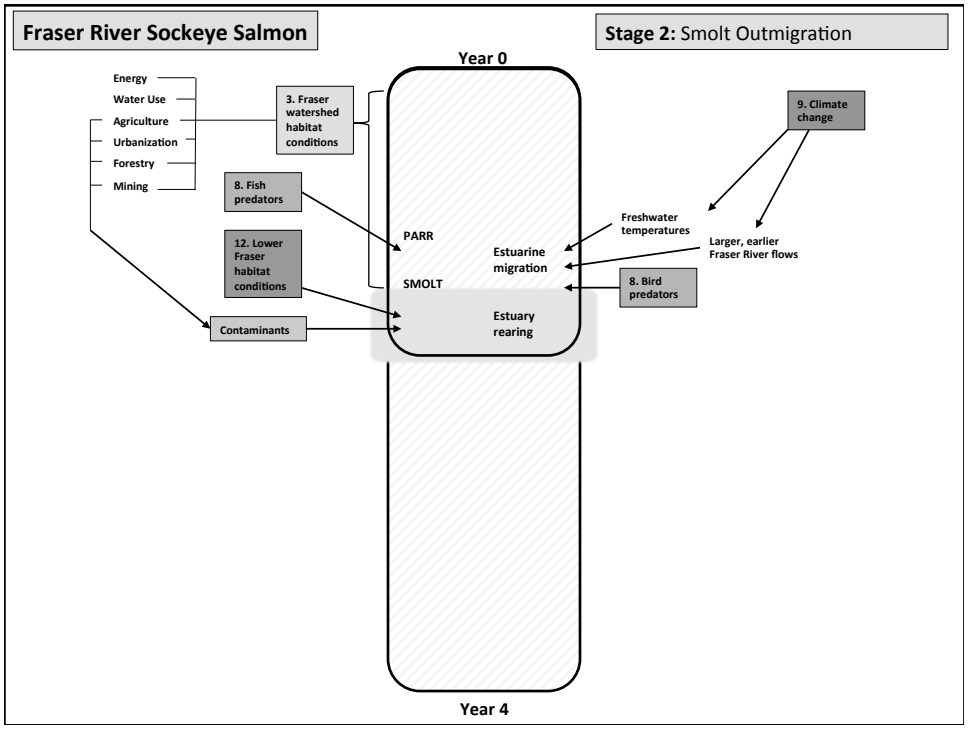
Conceptual Model

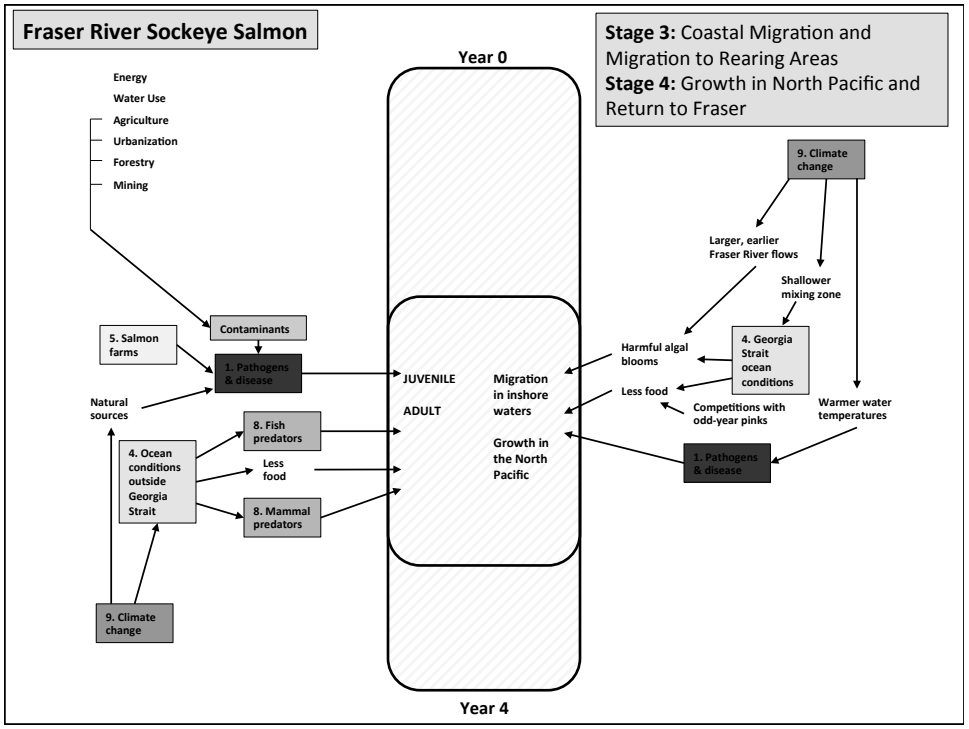

Fraser River Sockeye Salmon
Typical Life Cycle Model
Spawner
Egg
Alevin
Fry
Parr
Smolt
Post-smolt/ Juvenile
Adult
OCEAN
FRESHWATER

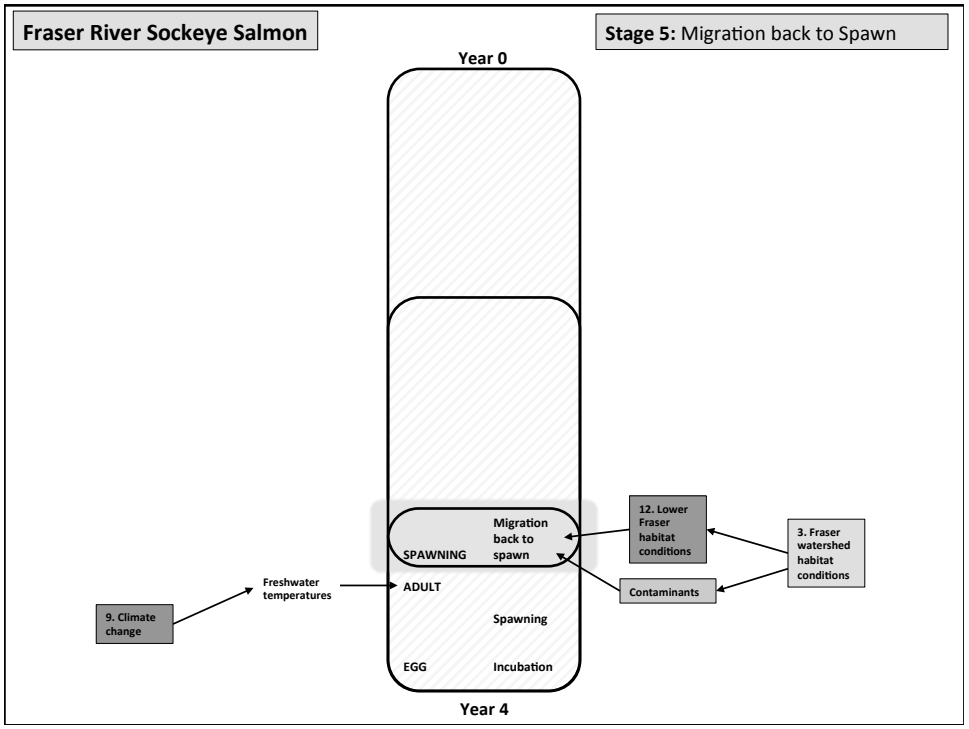

Fraser River Sockeye Salmon
Reorientation of Same Life Cycle
Year 0
Egg
Alevin
Fry
Parr
Smolt
Post-smolt/ Juvenile
Adult
Spawner
Egg
FRESHWATER
OCEAN
FRESHWATER
Year 4

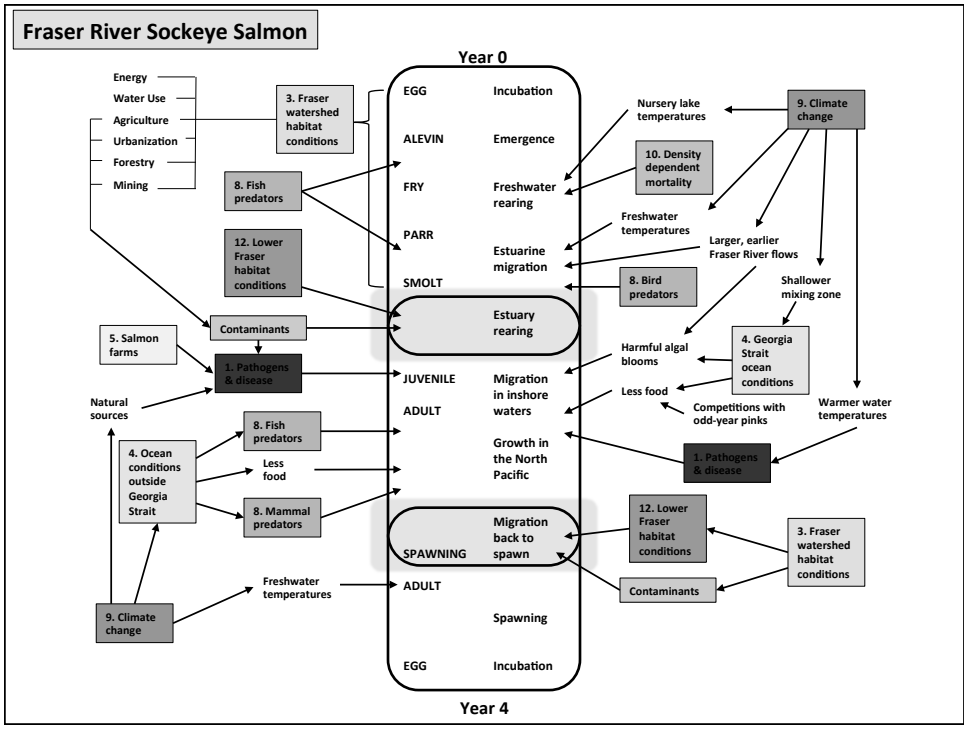
Stressors by life stage



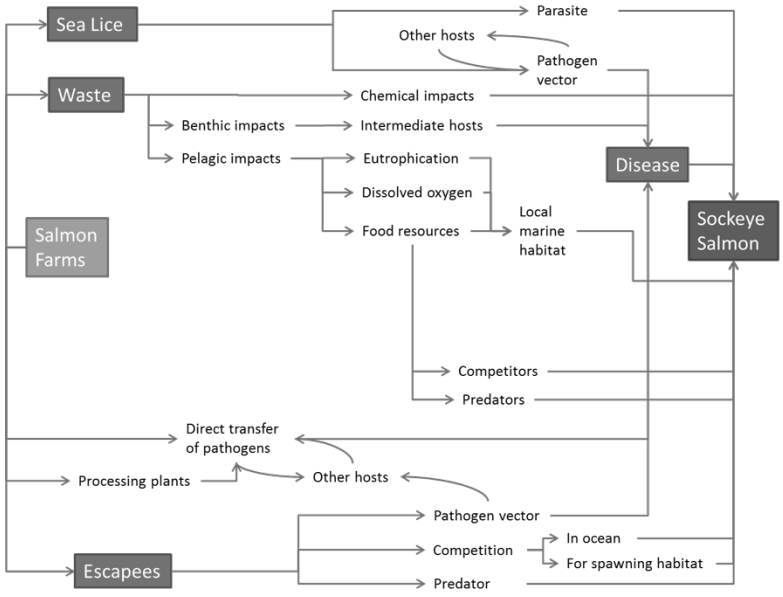

Fraser River Sockeye Salmon
Stage 2: Smolt Outmigration
Year 0
Energy
Water Use
Agriculture
Urbanization
Forestry
Mining
3. Fraser watershed habitat conditions
8. Fish predators
12. Lower Fraser habitat conditions
Contaminants
PARR
SMOLT
Estuarine migration
Estuary rearing
9. Climate change
Freshwater temperatures
Larger, earlier Fraser River flows
8. Bird predators
Year 4


Fraser River Sockeye Salmon
Stage 3: Coastal Migration and Migration to Rearing Areas
Stage 4: Growth in North Pacific and Return to Fraser
Year 0
Energy
Water Use
Agriculture
Urbanization
Forestry
Mining
Contaminants
5. Salmon farms
1. Pathogens & disease
Natural sources
8. Fish predators
4. Ocean conditions outside Georgia Strait
Less food
8. Mammal predators
9. Climate change
JUVENILE
ADULT
Migration in inshore waters
Growth in the North Pacific
9. Climate change
Larger, earlier Fraser River flows
Shallower mixing zone
Harmful algal blooms
4. Georgia Strait ocean conditions
Less food
Competitions with odd-year pinks
Warmer water temperatures
1. Pathogens & disease
Year 4

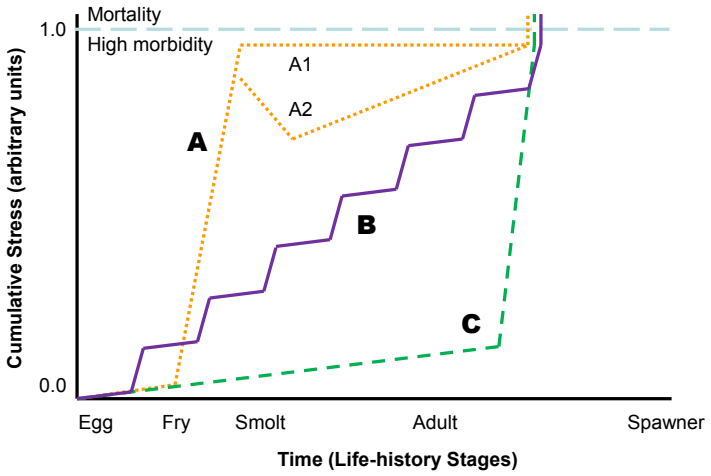

Fraser River Sockeye Salmon
Stage 5: Migration back to Spawn
Year 0
Migration back to spawn
SPAWNING
ADULT
Spawning
EGG
Incubation
Year 4
12. Lower Fraser habitat conditions
3. Fraser watershed habitat conditions
Contaminants
Freshwater temperatures
9. Climate change


Fraser River Sockeye Salmon
Year 0
EGG
Incubation
ALEVIN
Emergence
FRY
Freshwater rearing
PARR
Estuarine migration
SMOLT
Estuary rearing
JUVENILE
Migration in inshore waters
ADULT
Growth in the North Pacific
Migration back to spawn
SPAWNING
ADULT
Spawning
EGG
Incubation
Year 4
Energy
Water Use
Agriculture
Urbanization
Forestry
Mining
3. Fraser watershed habitat conditions
8. Fish predators
12. Lower Fraser habitat conditions
Contaminants
5. Salmon farms
1. Pathogens & disease
Natural sources
8. Fish predators
4. Ocean conditions outside Georgia Strait
Less food
8. Mammal predators
9. Climate change
Freshwater temperatures
Nursery lake temperatures
9. Climate change
10. Density dependent mortality
Freshwater temperatures
Larger, earlier Fraser River flows
8. Bird predators
Shallower mixing zone
Harmful algal blooms
4. Georgia Strait ocean conditions
Less food
Competitions with odd-year pinks
Warmer water temperatures
1. Pathogens & disease
12. Lower Fraser habitat conditions
3. Fraser watershed habitat conditions
Contaminants

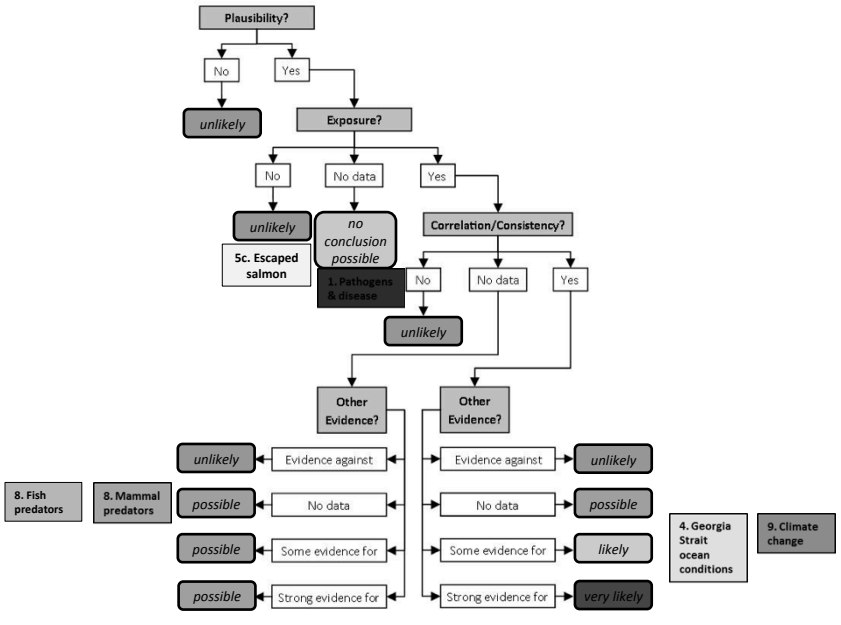
Salmon Farms

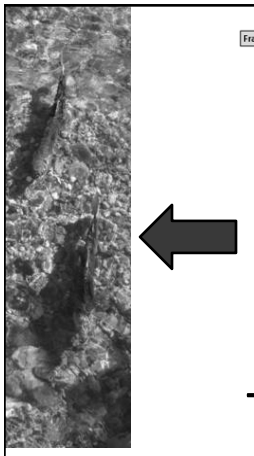


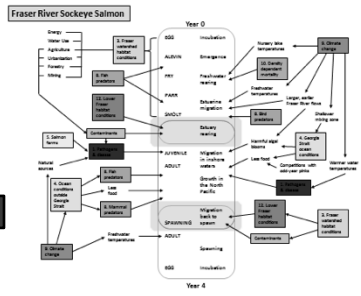
How do effects accumulate over the life of a salmon?



Weight of Evidence Approach





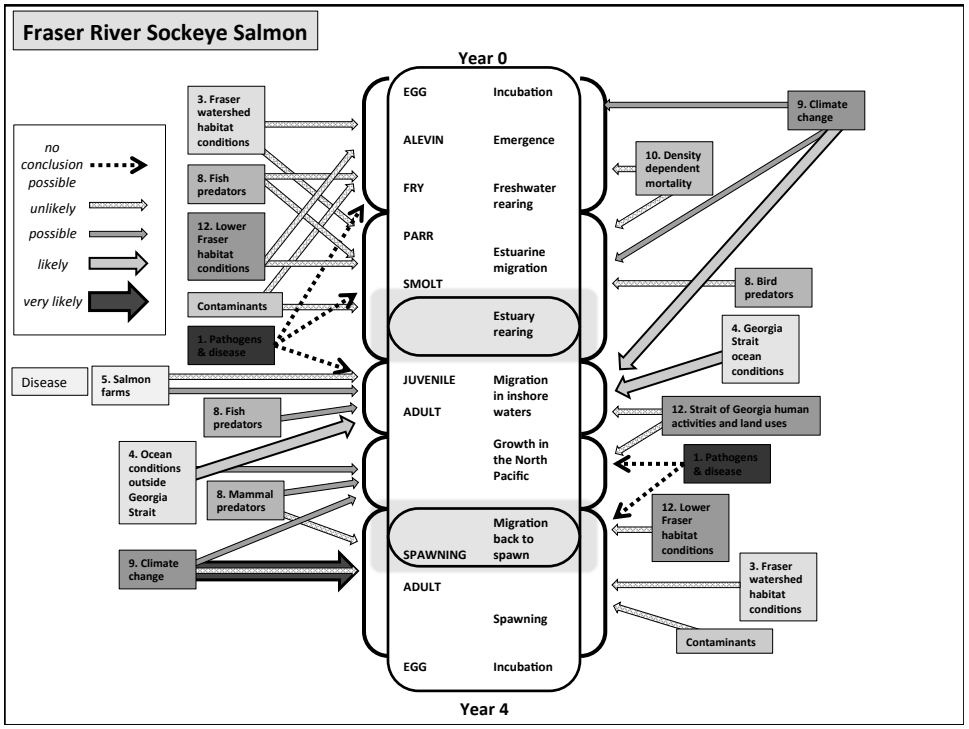


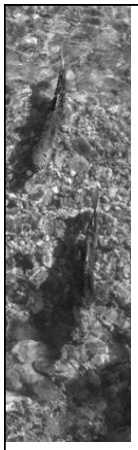
The Grand Synthesis of Results

Factor	Life History Stage				
	STAGE 1 Incubation, Emergence and Freshwater Rearing	**STAGE 2** Smolt Outmigration	**STAGE 3** Coastal Migration & Migration to Rearing Areas	**STAGE 4** Growth in N. Pacific and Return to Fraser	**STAGE 5** Migration back to spawn
Forestry[a]	Unlikely	Unlikely	n.a.	n.a.	Unlikely
Mining	Unlikely	Unlikely	n.a.	n.a.	Unlikely
Large hydro	Unlikely	Unlikely	n.a.	n.a.	Unlikely
Small hydro	Unlikely	Unlikely	n.a.	n.a.	Unlikely
Urbanization above Hope	Unlikely	Unlikely	n.a.	n.a.	Unlikely
Agriculture	Unlikely	Unlikely	n.a.	n.a.	Unlikely
Water Use	Unlikely	Unlikely	n.a.	n.a.	Unlikely
Contaminants	Unlikely	Unlikely	n.a.	n.a.	Unlikely
Density Dependent Mortality	Unlikely	Unlikely	Unlikely[b]	Unlikely[b]	Unlikely[b]
Pathogens	No conclusion possible	No conclusion possible	No conclusion possible	No conclusion possible	No conclusion possible
Predators	Unlikely	Unlikely	Possible	Possible	Unlikely[b]
L. Fraser land uses	Unlikely	Unlikely	n.a.	n.a.	Unlikely
Strait of Georgia human activity & land uses	n.a.	n.a	Unlikely	Unlikely	n.a.
Climate Change	Possible	Possible	Likely	Possible	Definitely[c] Unlikely[d]
Marine Conditions	n.a.	n.a.	Likely	Possible	n.a.
Salmon Farms – Waste	n.a.	n.a.	Unlikely	n.a.	n.a.
Salmon Farms – Escapees	n.a.	n.a.	Unlikely	n.a.	n.a.
Salmon Farms – Sea Lice	n.a.	n.a.	Unlikely	n.a.	n.a.
Salmon Farms – Disease	n.a.	n.a.	Possible Unlikely	n.a.	n.a.
Hatcheries - Disease	n.a.	n.a.	Unlikely	n.a.	n.a.

c: escapement and harvest

d: R/S productivity

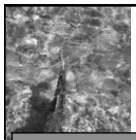




Research & Monitoring – 4 themes

- Coordinated, multi-agency collection of data on sockeye abundance, survival and stressors;*[70]
- Develop integrated database and cumulative assessments within / across life history stages*[70-73]
- Transparent dissemination of information annually to scientists and non-scientists*[75]
- Focus on early marine environment from Fraser R to Queen Charlotte Sound*[65-66]

* Similar to Justice Cohen's recommendation #



Specific Research & Monitoring Recommendations

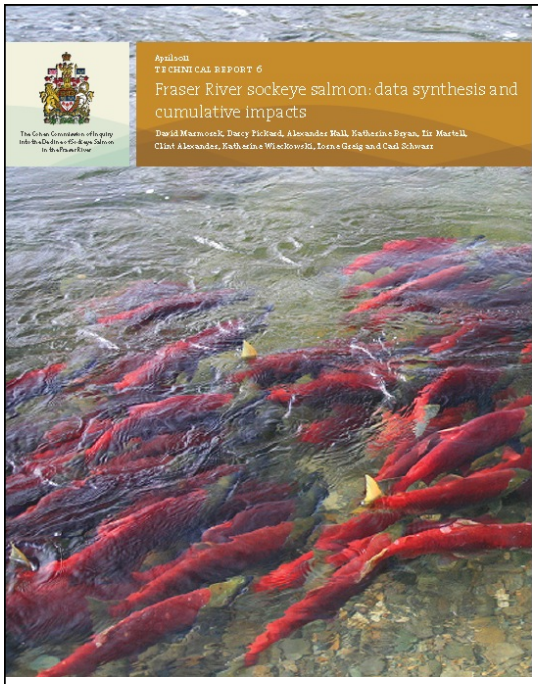
Life Stage	Highest priority recommendations (only top 12 of 23)
Spawner & eggs	• Understand status of small CUs[*9]
Fry to Smolt	• Assess smolt production for cross-section of stocks (>> 2 of 19) [*33]
Smolt to estuary	• Assess survival rates and travel time to estuary[*64]
Coastal migration	• Integrated oceanographic / ecological study of Georgia, Juan de Fuca & Johnstone Straits; plus Queen Charlotte Sound[*66] • Study residency, migratory paths and survival of sockeye post-smolts in SoG, SJF, JS and QCS.[*65] • Sockeye pathogen & contaminant levels vs marine conditions and exposure to fish farms[*68, 11-20, 53-55, 67] • Migratory paths of Harrison Lake sockeye post-smolts[*69]
N. Pacific	• Continue to assess returns, age at returns, harvest rates
Return migration	• Improve accuracy of in-season and post-season assessments[*32] • Accurate estimates of sockeye in-river mortality • Strategies to maximize sockeye persistence under climate change[*74]

* Similar to Justice Cohen's recommendation #

How to prioritize?

- What decisions will be made, when and where, with acquired information?
  - e.g., pre-season forecasts vs. in-season harvest decisions
- What's required precision / accuracy for these decisions?
- What's logical *sequence* of activities?
- What's most cost-effective research and monitoring program?

Thanks! Questions?



Marmorek, D. Pickard, A. Hall, K. Bryan, L. Martell, C. Alexander, K. Wieckowski, L. Greig and C, Schwarz. 2011. Fraser River Sockeye Salmon: Data Synthesis and Cumulative Impacts. ESSA Technologies Ltd. Cohen Commission Tech. Rept. 6: 273p. Vancouver, B.C. www.cohencommission.ca

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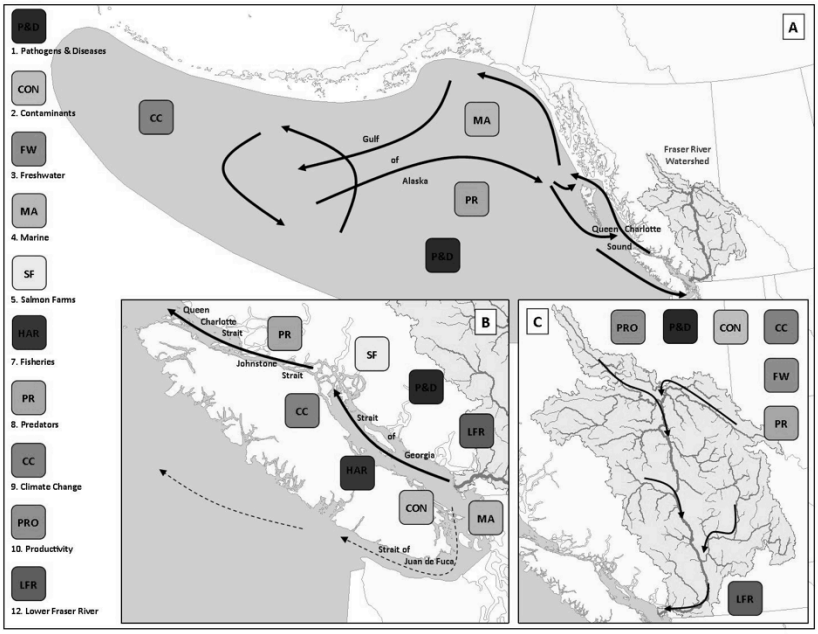

Best correlates with productivity

- Factors within coastal migration phase
  - Sea surface temperature
  - Salinity
  - Discharge
  - Chlorophyll
- QCS conditions had better explanatory power over 1980-2004 than SoG factors