Salmon in a Changing Salmonsphere…. Examining the Likely Suspects: Holistic Understanding of Salmon Marine and Freshwater Survival.

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Salmon in a Changing Salmonsphere

see Thomas Quinn lecture in 2020 Symposium (matsusalmon.org)

Tom Quinn: "Changing Themes in Salmon Conservation: a 40-year personal perspective"... it is clear that risk is increasing with climate and associated environmental change. These changes imply that using past knowledge may not reliably predict the future. Furthermore, how and why we make decisions is changing.

- Changing Environmental Context:

  "mother nature on the run in the 1970s" … continues today: Land use and water use degrading habitat, fisheries, contaminants and disease, aquaculture, invasive species, predation by marine mammals, freshwater ecosystem requirements from bears to invertebrates, climate change, big (e.g. PDO, ENSO) and small scale (e.g. local salinity, DO, temperature, habitat complexity) changes in the ocean.

- Changing Human Context:

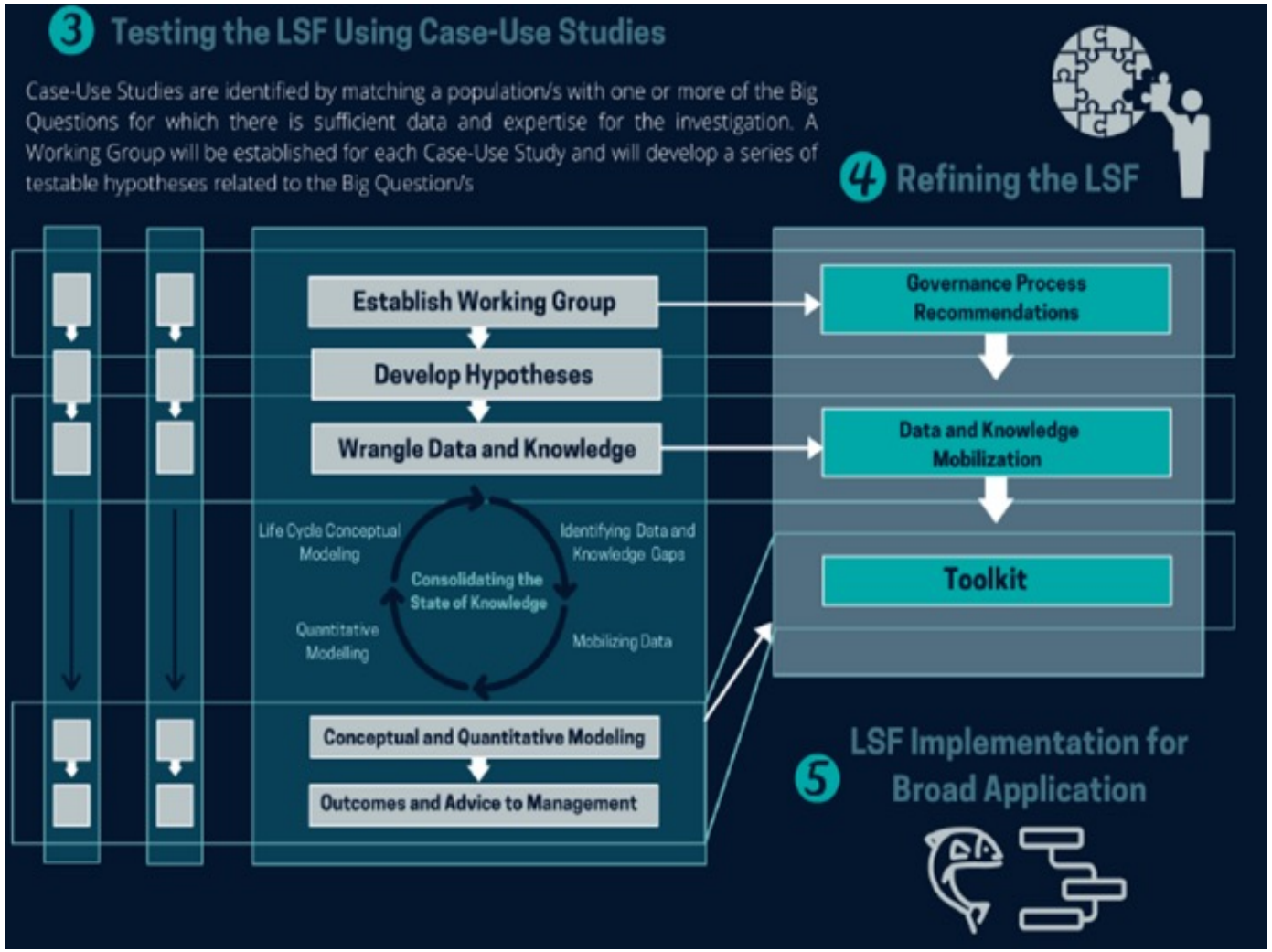
  recognition of obligations to First Nations, changing legal/legislative landscape, shifting jurisdictional management responsibilities, technology has enriched learning around the world, inclusion of LEK and TEK, increasing integration with social science, population growth and need for food, recognition of the lack of racial and gender diversity in the people studying and managing salmon.

- Changing Perspectives:

  Years ago, all the limitations of salmon production were thought to be in freshwater, marine survival was relatively stable, and the ocean had no apparent capacity limit. Recognition and subsequent shift in scientific focus to big scale processes in the ocean. But the importance of freshwater can't be over-emphasized… issues associated with the 4Hs of issues with habitat, harvest, hatcheries, hydro. Watersheds need cool, clean, complex, connected aquatic habitat to function properly. Increasing realization of the importance of bio-diversity from stronghold biomass management; should we "protect the best = stronghold approach" or "regain and rebuild habitat" (e.g. dam removal in the US)? We need to work up and down the spatial scales.

Likely Suspects Framework

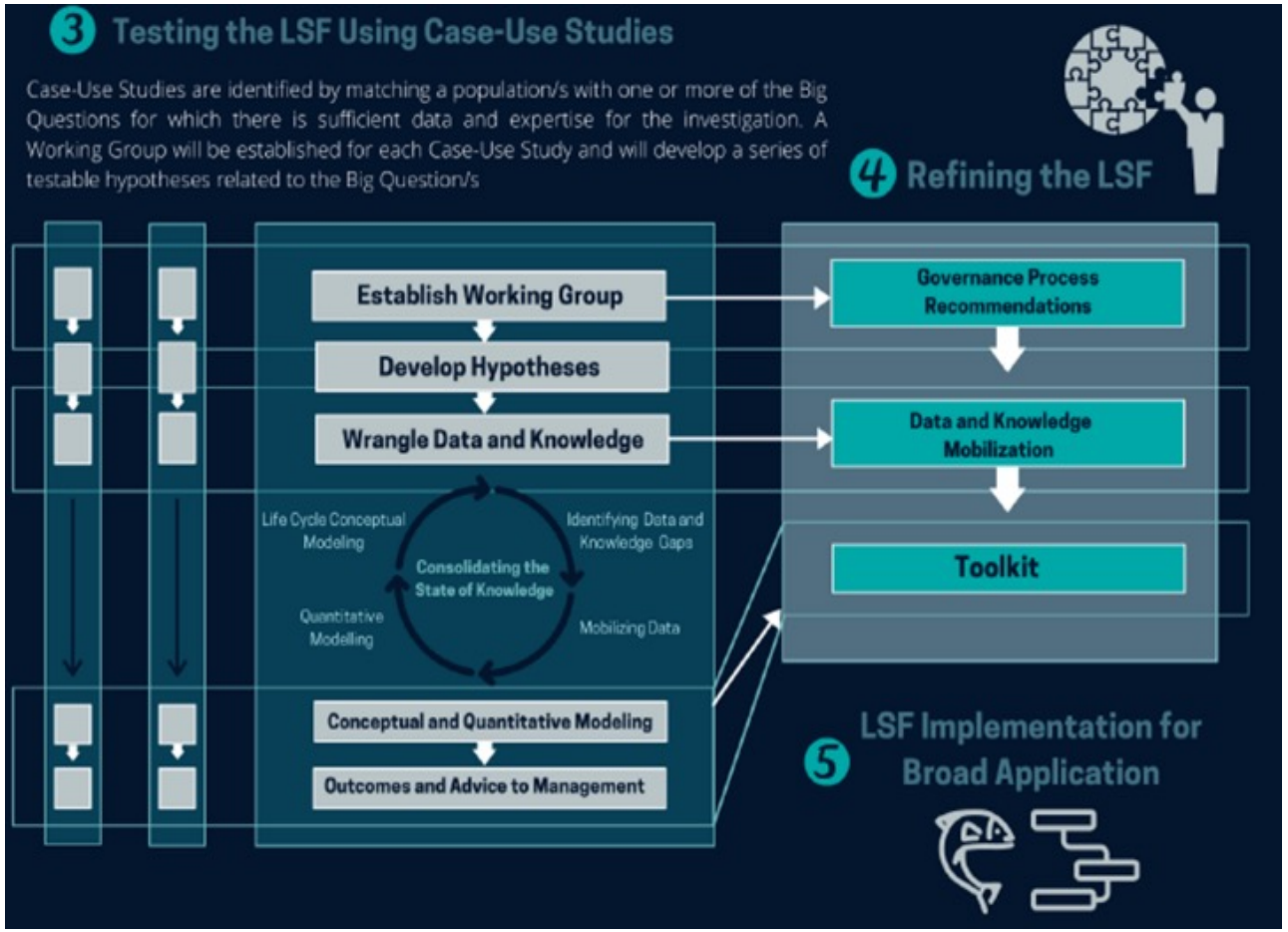
A review and interpretation relative to case studies on Vancouver Island (Cowichan Chinook and West Coast Vancouver Island Chinook)



The term “Likely Suspects” creates the image of a detective working to solve a crime. In fact, in the The Ecological Detective, Hilborn and Mangel (1997), urge us to investigate population ecology much as a detective would investigate a crime scene by trying different hypotheses until a coherent picture emerges…

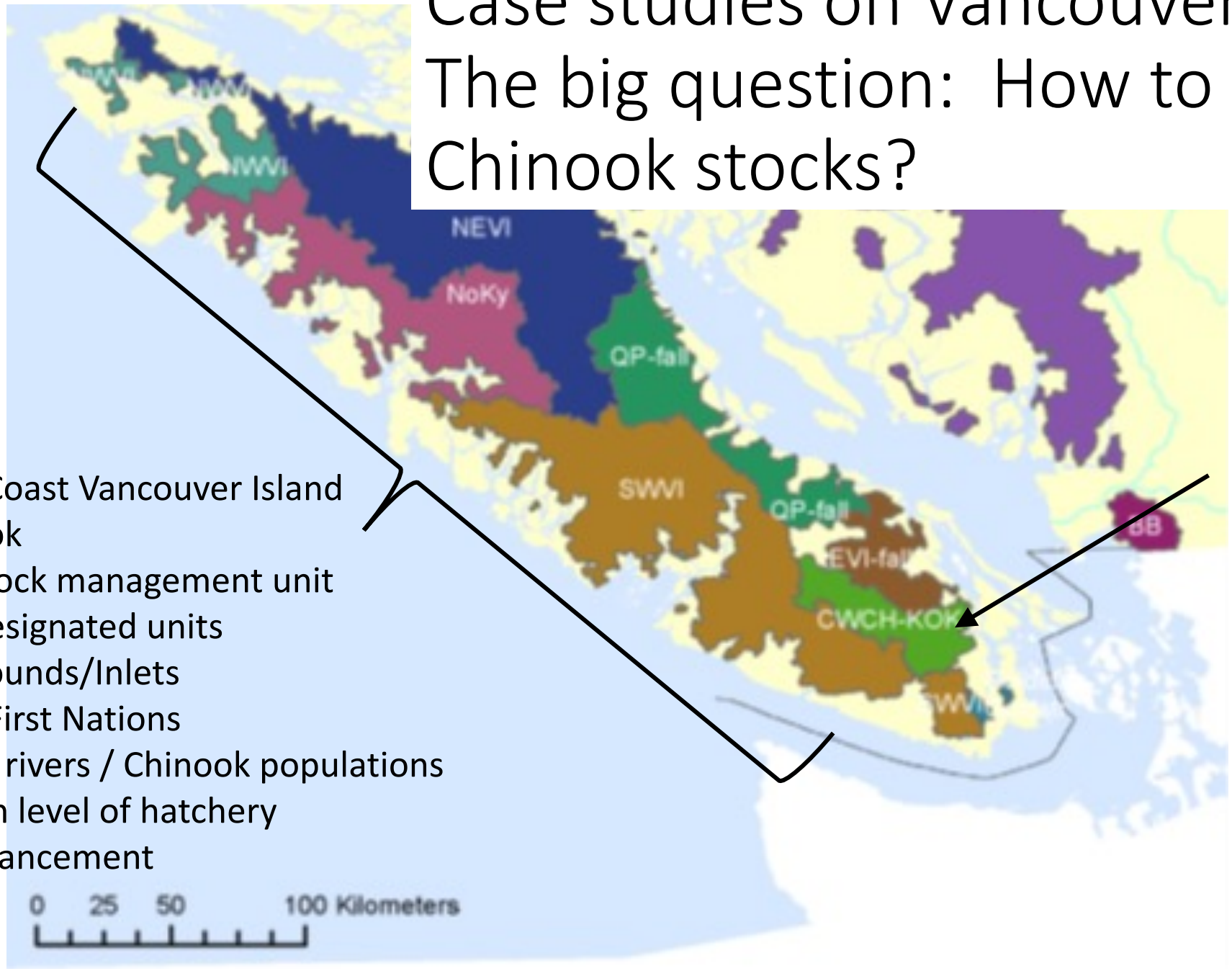
Likely Suspects Framework

outline of this talk



1. Establish working group and governance. *(or this needs to be a team approach)*
2. Develop Hypotheses. (*RAMS has a list of probable hypotheses by salmon life stage for Limiting Factor Analysis*)
3. Wrangle Data and Knowledge. (*or gather and collate existing information and expertise to support Limiting Factor Analysis using RAMS or other method.*)
4. Conceptual and Quantitative Modeling. (*or use population ecology models to assess risk, to develop benefit cost, and to evaluate mitigation options.*
5. Outcomes and Advice to Management. (*or report on highest risks, initiating discussions with appropriate jurisdictional authorities, calling in specialists such as habitat practitioners and engineers, evaluating feasibility and benefit/cost of mitigations.*
6. Implementation.

Case studies on Vancouver Island. The big question: How to rebuild Chinook stocks?



West Coast Vancouver Island Chinook

- 1 stock management unit
- 3 designated units
- 5 Sounds/Inlets
- 17 First Nations
- 60+ rivers / Chinook populations
- High level of hatchery enhancement

Cowichan/Koksilah Chinook

- Part of a stock management unit
- 1 designated unit
- 2 rivers, but only Cowichan has high Chinook potential
- Low level of hatchery enhancement

Establish Working group and Governance Process

implementation in the Cowichan and West Coast Vancouver Island Chinook Rebuilding Processes.

- Central steering … usually inter-governmental to ensure broad collaboration, funding, etc.
- Central coordination… operational and process coordination
- Community Round tables for communication out… regular meetings with open participation to communicate to the community and stakeholders. To look for opportunities and linkages. For freshwater we worked through local round tables. For marine we work through specific areas/topics of expertise.
- Risk assessment workshop for knowledge holders and technical experts… input was stock and habitat status assessments, objective was to create broad understanding using local and technical knowledge holders such as First Nation fishers, elders, biologists, or locals who work on or near the water such as fishing guides, or staff from other agencies or provincial and local governments. Example of the fishing guide who has been monitoring benthic invertebrate density and water alkalinity in rivers over several years. He had important insights into fish production.
- Experts to lead research, modeling, etc.… specific skill sets to lead research, analysis, laboratory testing, modeling, expert practitioners for evaluation of mitigation options and implementation,
- Facilitators and meeting coordinators to keep the whole thing going, and
- Champions for funding and action. Local community members and local government officials who would look for funding. Or would demand or lobby for action. One of the outcomes of the work was a pilot Cowichan Watershed Board… tasked with implementation and ongoing coordination of management and restoration activities on the Cowichan.

Issue. Who is the lead detective(s) on the case?

- Beat cop (the local biologist)? This is the guy or group which has the most contact with the salmon in the environment and the most street cred with local community and stakeholders
- Regional detective (regional coordinator)? (hopefully a specialist in process, someone who knows the process and maybe the species, but recognizes that they don't have the local knowledge and must work with the beat cop.
- Generalist scientist? (like a family doctor, someone who knows and can bring in specialists)
- SWAT team?

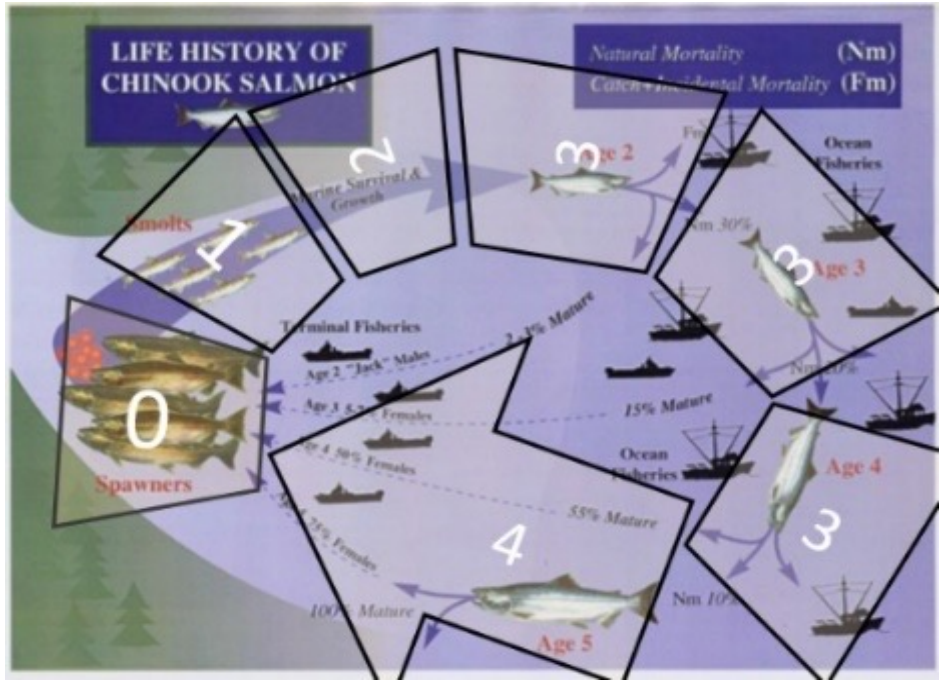
Issue. Stock Assessment for fishery management vs population ecology? There is a lack of basic population ecology info.

- Current focus on precision and accuracy of abundance to meet fishery management needs not rebuilding needs. Few people in stock assessment take that next step to understand the population ecology, to investigate reasons for interannual variability or trends. Many write it off to ocean conditions with the idea that nothing can be done.

- Change focus to more population ecology and become good ecological detectives. The people on the ground may be best to record changes in the local physical environment and processes, water flow levels, water quality, salmon demographics such as sex ratios, fecundity, size at age, hatchery %, maturation rate, level of over-winter scour of the spawning grounds, etc. Is this DFO or First Nations or local stewardship groups or all of us?

Develop Hypotheses ≈ Limiting Factors

follow the fish through each stage of their life cycle. Done for ocean type chinook.



Marine split into risk topics.

- Big ocean processes
- Local ocean processes
- Parasites, Pathogens, & Contaminants
- Nutrition and Prey
- Predation
- Hatchery
- Harvest

Freshwater.

Stage 0 = freshwater life stages split into:

a)upriver migration,
b) spawning,
c) egg incubation,
d) rearing,
e) smolts out migration.

Marine.

Stage 1= early marine / first spring-summer in the estuary and ocean

Stage 2= early marine / first overwinter survival

Stage 3= subsequent ocean rearing to maturation

Stage 4= return migration

Identify all possible limiting factors – hypotheses by life phase. For example:

Life stage: Freshwater Adult migration up-river
Limiting factor hypothesis: *Limited or delayed spawner access causes mortality or stress and reduces the effective spawn.*
Habitat requirements:
Potential Indicators-info:
Benchmarks – habitat status:
Risk: Exposure x Biological impact scores
Causal mechanisms:
Jurisdiction:
Mitigation options:

Wrangle data and knowledge. Link life stages with specific habitat ecosystem requirements and state indicators

Ecosystem Units	Life Stage/metric	Chinook abundance natural	Average Mortality
0.estuary - inriver	Migrating adults	500	25%
0.upper river spawning area	Effective spawners	375	
0.upper river spawning area	Eggs laid	510,000	
0.lower river - estuary	Smolts out	76,500	85.0%
1.nearshore local marine	Juveniles first fall	3,825	95.0%
2.ocean shelf	Prefishery Age 2	1,148	70.0%
3.ocean shelf	Adults age 3+	689	40.0%
3.ocean shelf	Ocean Catch	255	37.0%
4.Return to Terminal Area	Return to Estuary	434	
	Rate of change	-13%	
	Recruits / Spawner	1.8	
	Marine Survival smolt-adult	0.9%	

Simple version of a Life cycle model with best estimates of mortality rate at each life stage.

- Ocean catch rate is known well
- Marine survival smolt to adult known well
- Age 3+ ocean mortality from PSC CTC
- Others from general observation compared to literature.

Example freshwater factors/indicators potentially limiting upstream adult migration to spawning grounds.

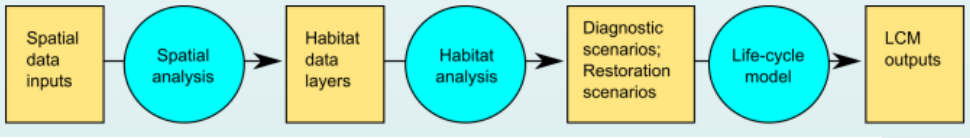
- Part of Habitat Status Report for workshop.
- Assess indicators relative to adult migration.
- Provide an initial estimate of mortality rate.

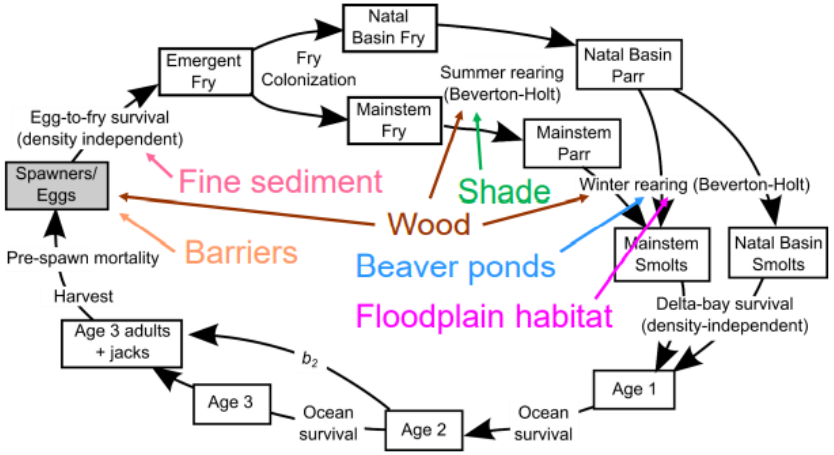
Water quality - High temperature & Low DO - Suspended sediment - Harmful algae, contaminants, toxins, heavy metals,	**Hydrology** - Flows to support migration e.g. days below minimum 7cms in the Cowichan
Physical Habitat - Gravel aggradation or other barriers preventing access - Edge habitat – cover - Instream refugia – cover, pools, complexity - Spawning habitat	**Biological Community** - Salmon demographics such as size, related to flow. - Food availability - Predator abundance
Anthropogenic - Fishing - Disturbance - Hatchery introgression	

There are more complicated models!

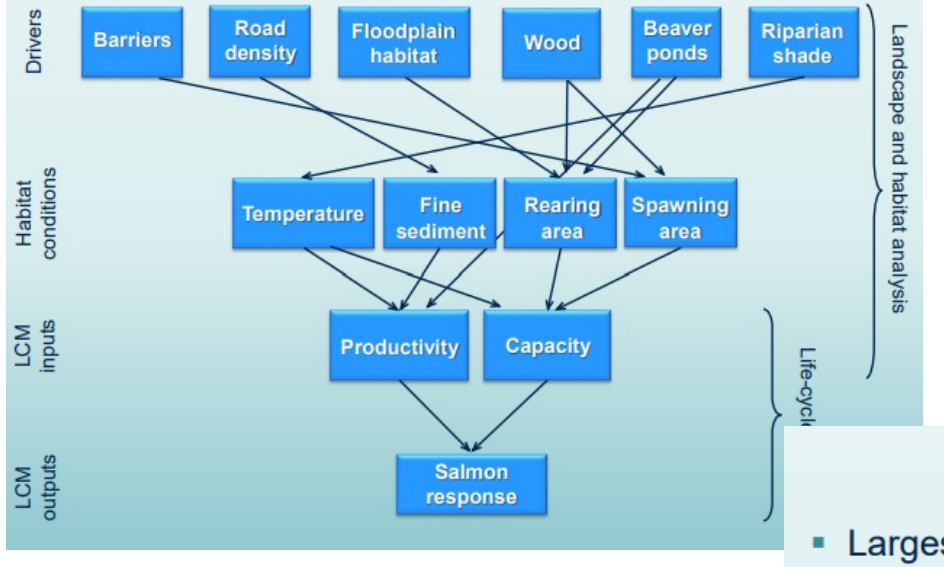
Source: Beechie TJ, Fogel C, Nicol C, Timpane-Padgham B (2021) A process-based assessment of landscape change and salmon habitat losses in the Chehalis River basin, USA. PLOS ONE 16(11): e0258251. https://doi.org/10.1371/journal.pone.0258251

NOAA Model Structure





Diagnosis and Restoration

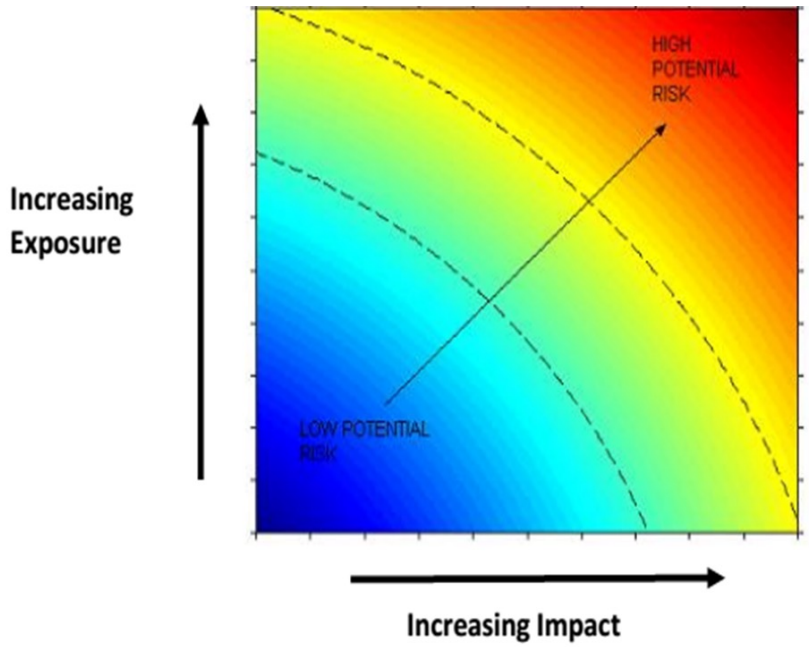


Summary: Fall Chinook

- Largest modeled effects from
  - Loss of wood
  - Increased fine sediment

LIMITING FACTOR ANALYSIS:

Use life cycle model whether conceptual, qualitative, or quantitative …
along with available status and trend information…
to initiate risk assessment scoring by experts, LEK, TEK…
encourage discussion, try for consensus, develop mitigation options.
Work to fill knowledge gaps, redo the Limiting Factor Analysis



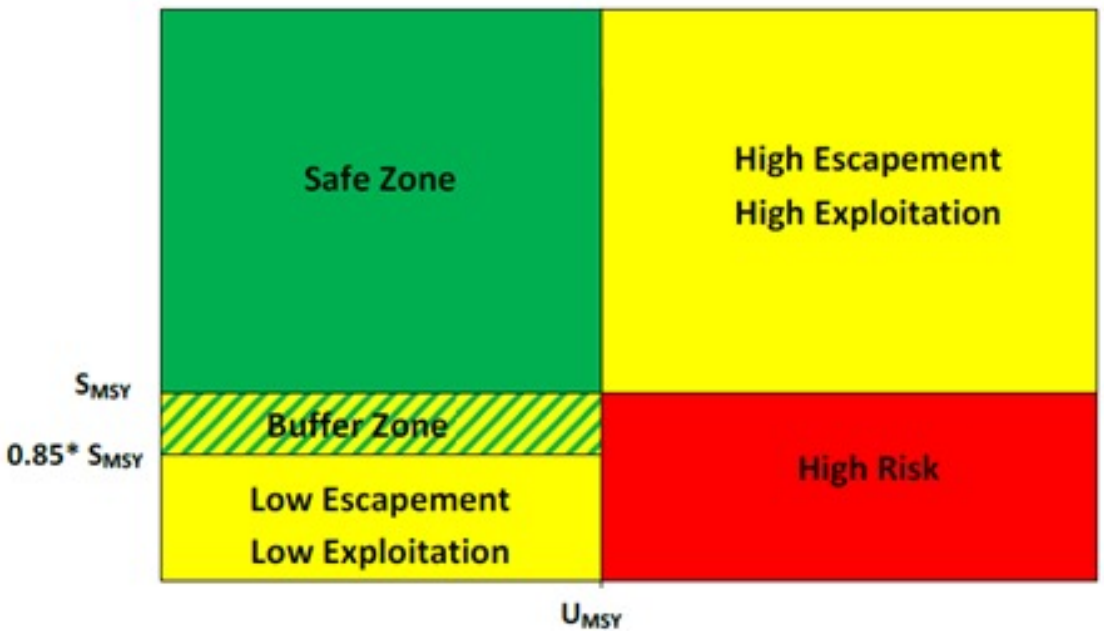
Example risk ranking for hypothesis that low water in the fall will delay or impede adult migration upriver and increase stress and/or mortality

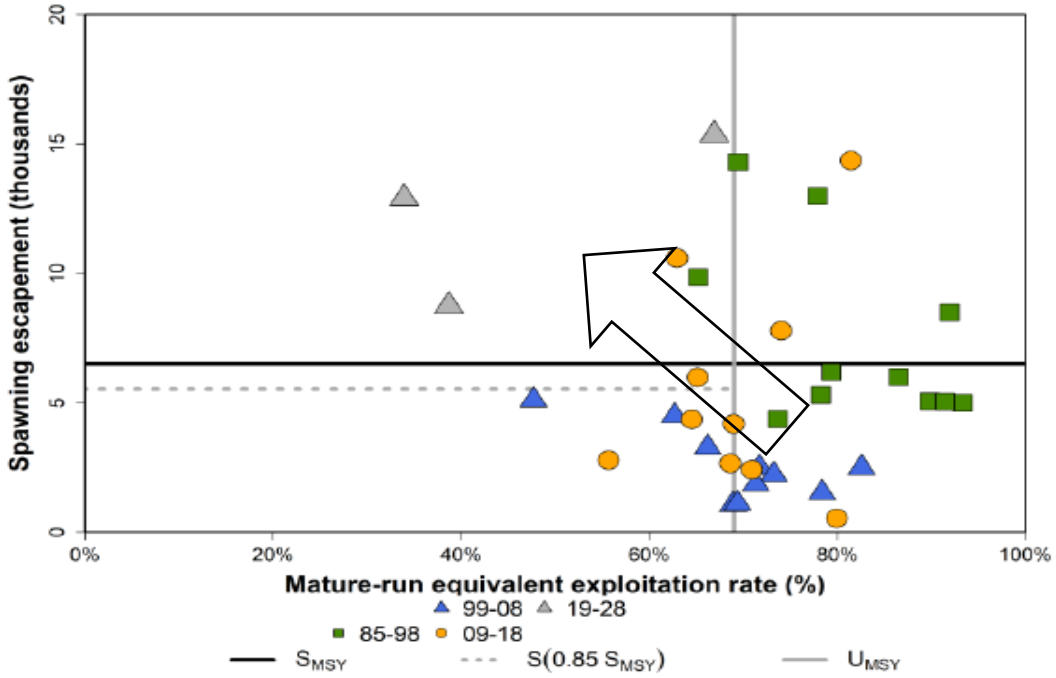
Current Risk based on scoring	**Risk Scores**	**Overall Risk**
Exposure (or likelihood) = spatial x temporal extent; 1-5 for each.	4, 5	Very High
Biological impact 1-5,	5	
Level of confidence and identify knowledge gaps L, M, H	High	
Future Risk based on scoring		
recent trend 1- 5	5	Very High
trend over next 50 years 1-5.	5	

Outcomes and Advice to Management

Limiting Factor Analysis -> risk ranking -> mitigation options and recommendations->

- FISHERY RISK. The first suspect in DFO has generally always been the fishery; in fact it has garnered a disproportionate amount of the analytical capacity compared to population ecology. The hypotheses related to the fishery include 1) the exploitation rate is / is not sustainable for the stock, and 2) the selective nature in the fishery negatively changes the demographics of the stock (e.g. size, sex ratio, age at maturity, etc.).
- For the fishery, analyses such as a Garcia plot (PSC Chinook Technical Committee 2021) become important to understand whether over-fishing is a risk. Example for the Cowichan River, actions were taken to reduce fishery exploitation rate while rebuilding spawning abundance.

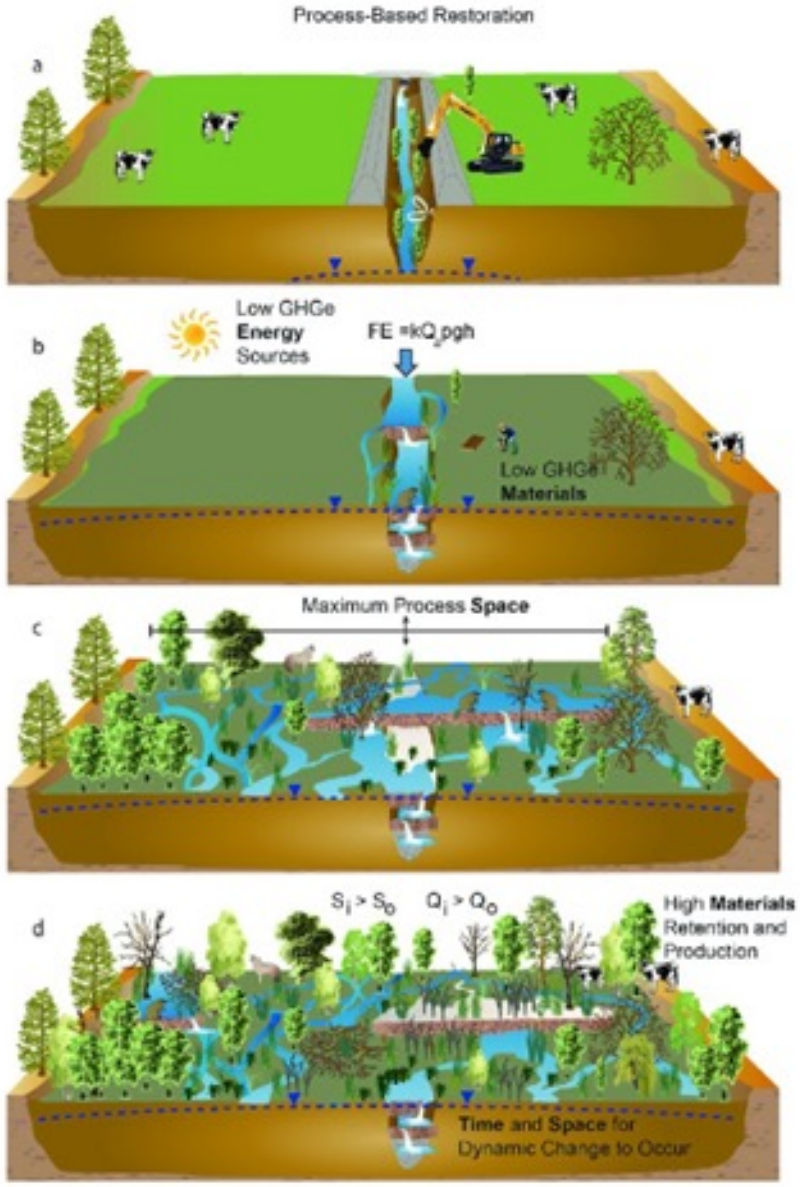




Outcomes and Advice to Management

Limiting Factor Analysis -> risk ranking -> mitigation options and recommendations->

HABITAT RELATED RISKS. Evaluate and implement habitat mitigation through a lens of Watershed Process Based Restoration.



Beechie *et al.* and Booth *et al.* and others have shown that much of the restoration work ends up failing because of lack of recognition and inclusion of watershed process-based principles. See the following:

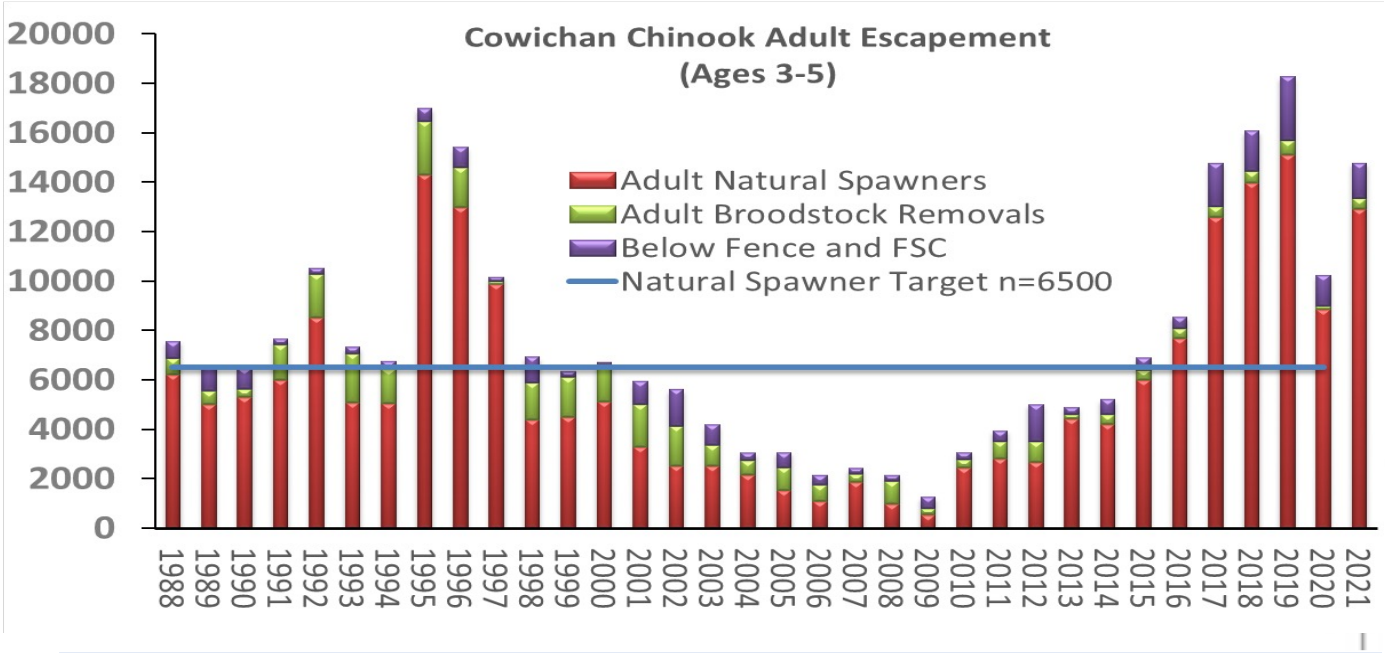
Timothy J. Beechie, David A. Sear, Julian D. Olden, George R. Pess, John M. Buffington, Hamish Moir, Philip Roni, Michael M. Pollock, Process-based Principles for Restoring River Ecosystems, *BioScience*, Volume 60, Issue 3, March 2010, Pages 209–222, https://doi.org/10.1525/bio.2010.60.3.7

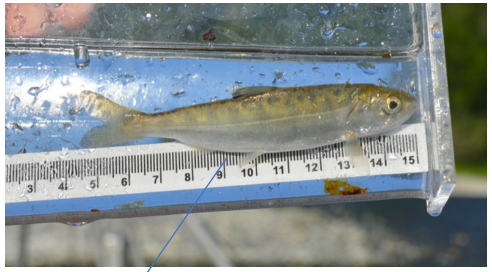
Booth DB, Scholz JG, Beechie TJ, Ralph SC. Integrating Limiting-Factors Analysis with Process-Based Restoration to Improve Recovery of Endangered Salmonids in the Pacific Northwest, USA. *Water*. 2016; 8(5):174. https://doi.org/10.3390/w8050174

Outcomes and Advice to Management

- This is a multi-jurisdictional problem… where everyone has the goal of ecosystem health and can use salmon as a keystone indicator species. It can be hard to influence local government to take on some responsibility for salmon rebuilding.

Cowichan Chinook rebuilding.





Reconstructed smolt size from otolith… 80% of natural origin spawners came from smolts 60+mm

Knowledge gain / Action taken to address highest risk limiting factors.
Remediation of Stoltz Bluff was a success, improved egg-fry incubation success from mid-river down.
Opportunistic emergency funding to rebuild dykes / flood control infrastructure actually used to set back dykes and create significant rearing habitat.
Water storage for Pulse flows and pumps installed in the Lake just in case water drops below minimum required.
No mitigation taken. Pellett PIT tag study identifies where and when
Beamish and Neville indicate local distribution into the fall and high mortality by July. Estuary eel grass restoration, causeway breach, attempted KELP restoration, …

Follow the Fish: Investigation into sources of mortality for WCVI Chinook through the first year of residence along the WCVI

Sampling in the nearshore WCVI to better understand:

- distribution and migration,
- size over time (growth) of hatchery vs wild,
- environmental conditions (e.g. physical conditions, biological conditions such as plankton, prey availability), and
- condition of fish (pathogens/ stress sampling, etc.

Sampling schedule:

- March-May/June. Down stream trapping of smolts in Sarita River(Barkley) and Bedwell River (Clayoquot). Some new projects such as in San Juan R.
- April-June. Beach seining and trapping in estuaries and near shore.
- May-July. 10-15 days purse seining nearshore using Nita Maria test boat (also testing other gear such as smaller JST sockeye seine, and potentially small mesh gillnet).
- August-March. Micro trolling along much of the WCVI.
- October. Trawl survey, with transects out of each Sound.