Climate Change Impacts and Adaptation Through the Lens of Okanagan Hydrology, Fish and Fisheries

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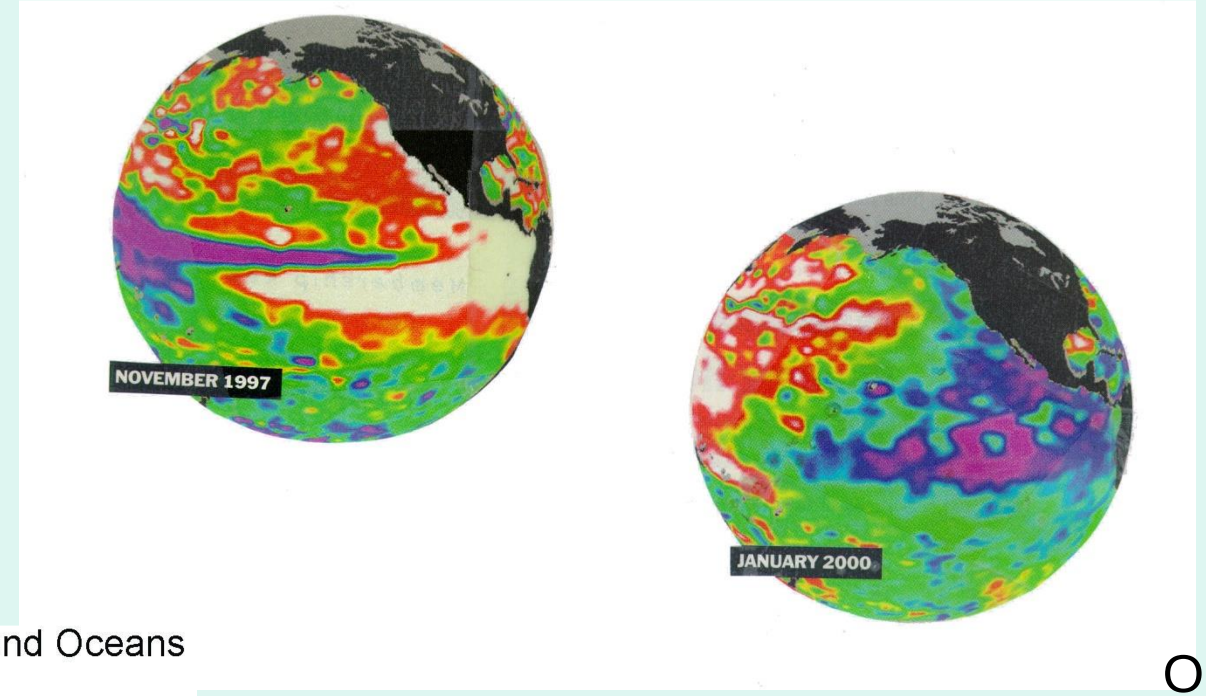


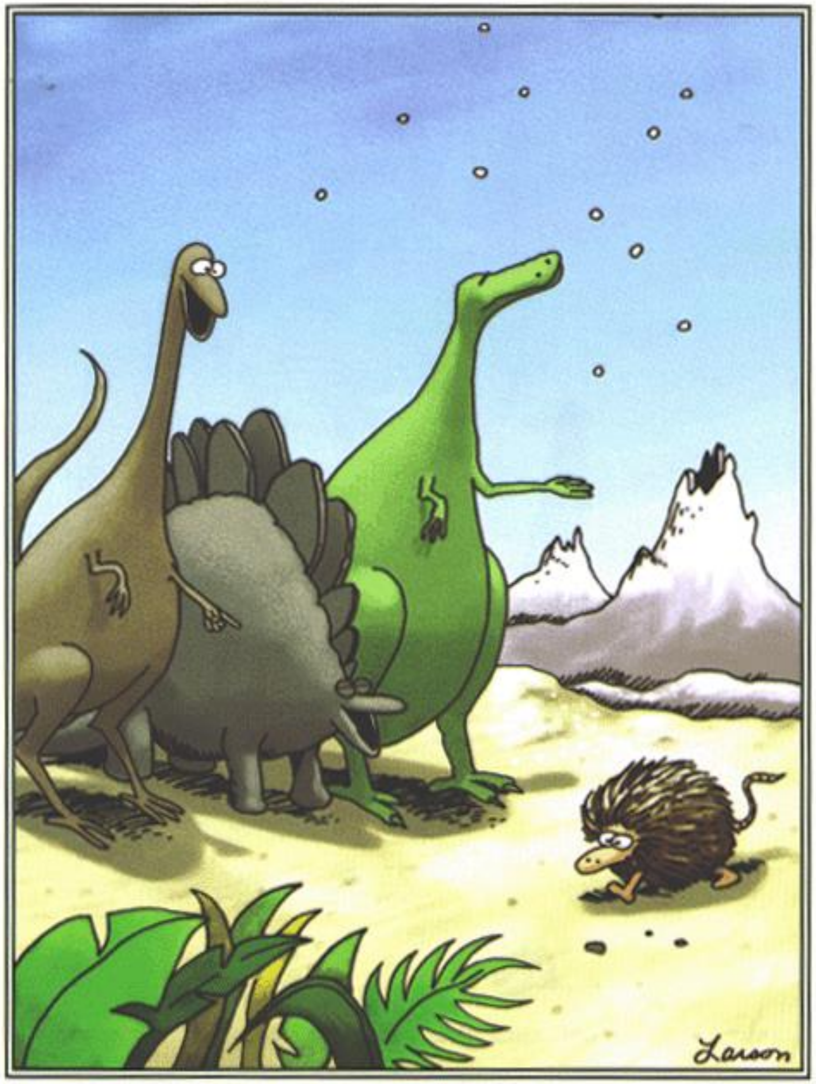
Fisheries and Oceans Canada

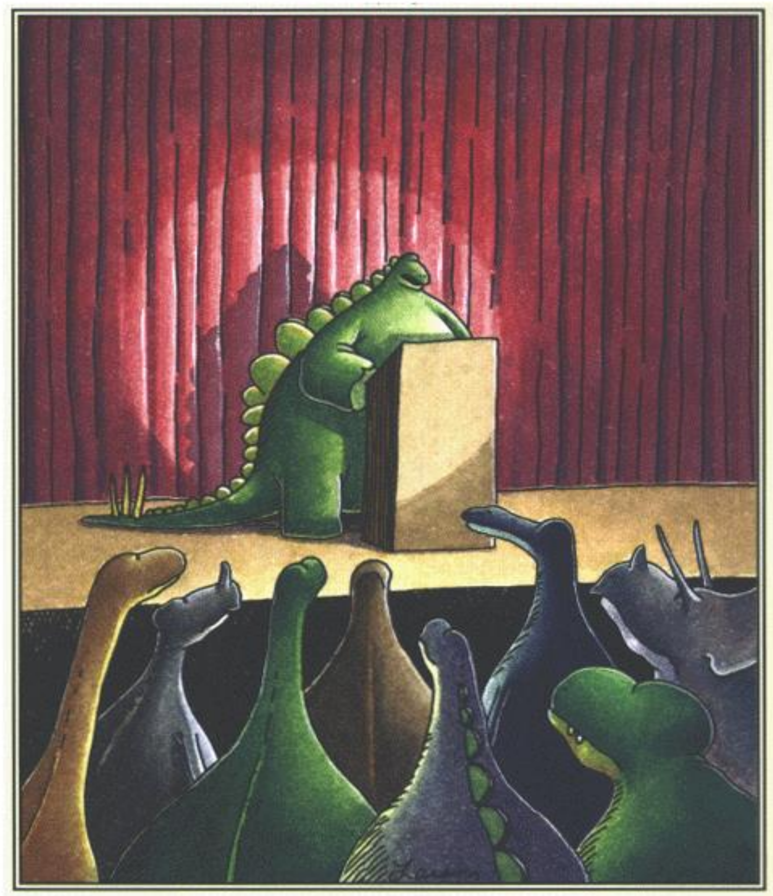
Oct. 16, 2018.

Outline for this talk

1. Brief perspective on climate change from the IPCC.
2. Provide an overview of atmosphere and freshwater systems responses to climate variation and change (CVC) events in British Columbia and the Okanagan.
3. Identify basis for cascading effects of climate change on hydrological systems, ecosystem structure and function, fish and fisheries responses in the Okanagan (and western North America).
4. Discuss current and future adaptation options to climate change.
5. Summarize thoughts and sources of additional information.

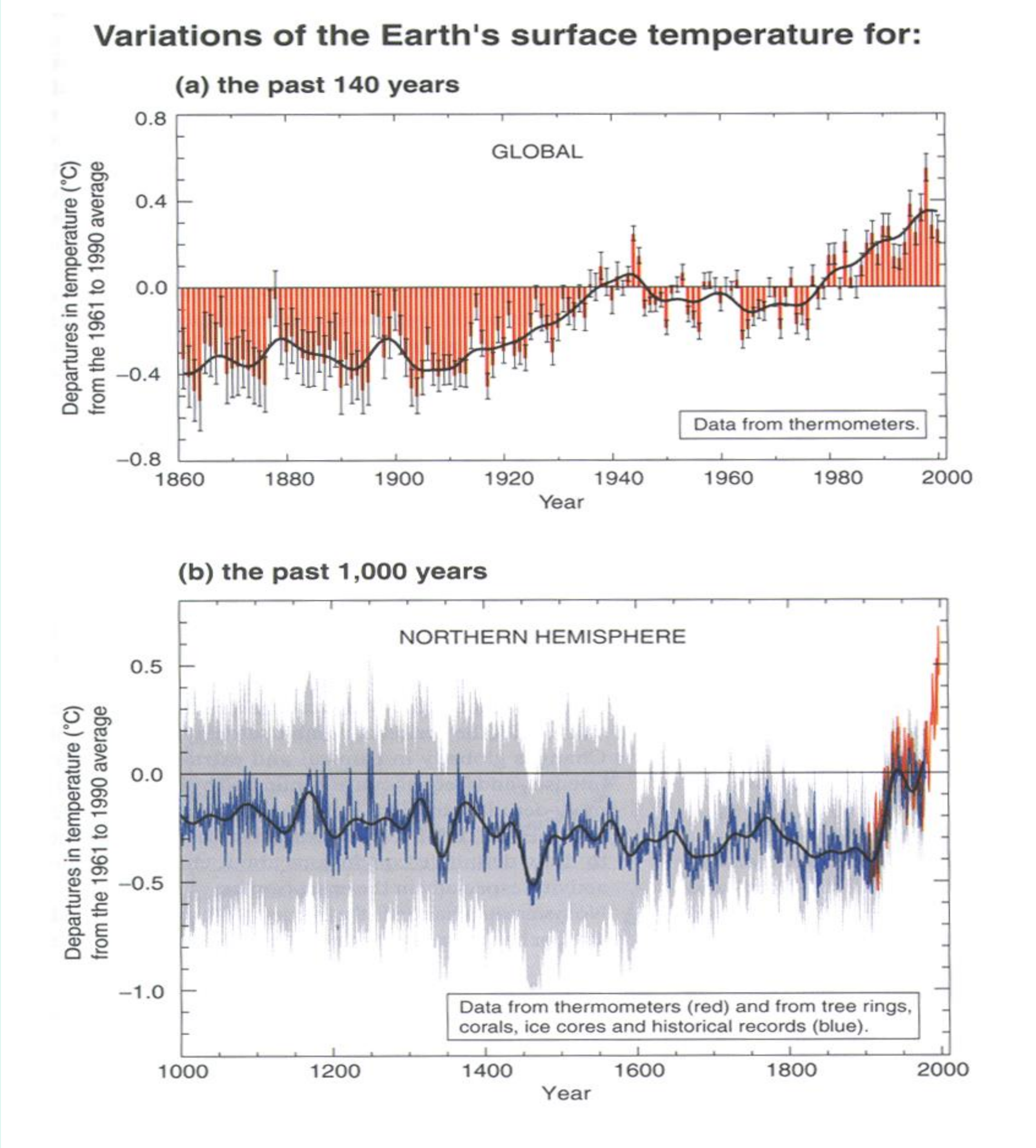
On a Geological Time Scale Climate, Ecosystem and Species Changes are Nothing New





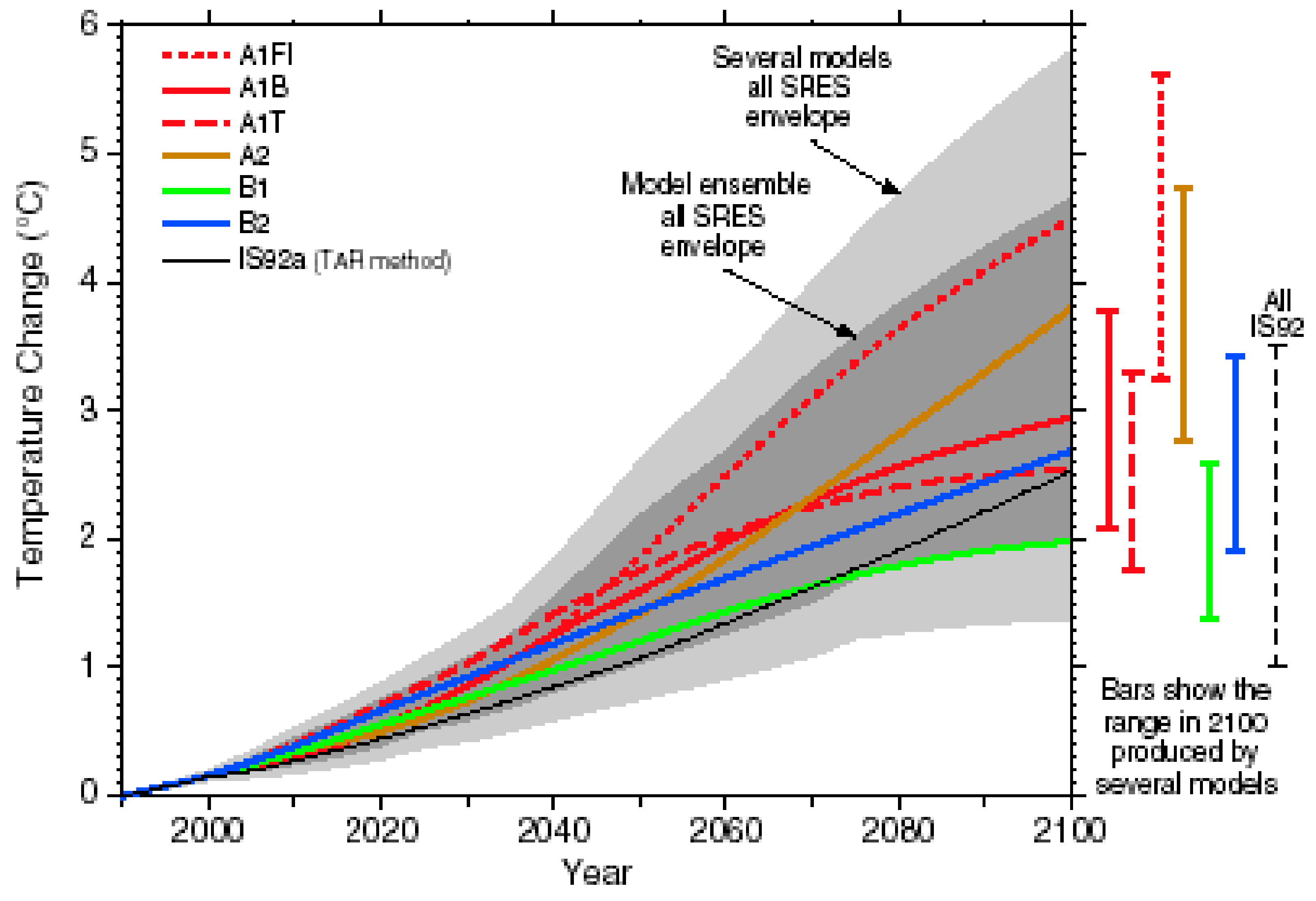
“The picture’s pretty bleak, gentlemen. ... The world’s climates are changing, the mammals are taking over, and we all have a brain about the size of a walnut.”

However, reports from the intergovernmental panel on climate change (IPCC) indicate changes on the human time scale involving recorded history are unprecedented (current air temps are the warmest in a 1000 years)

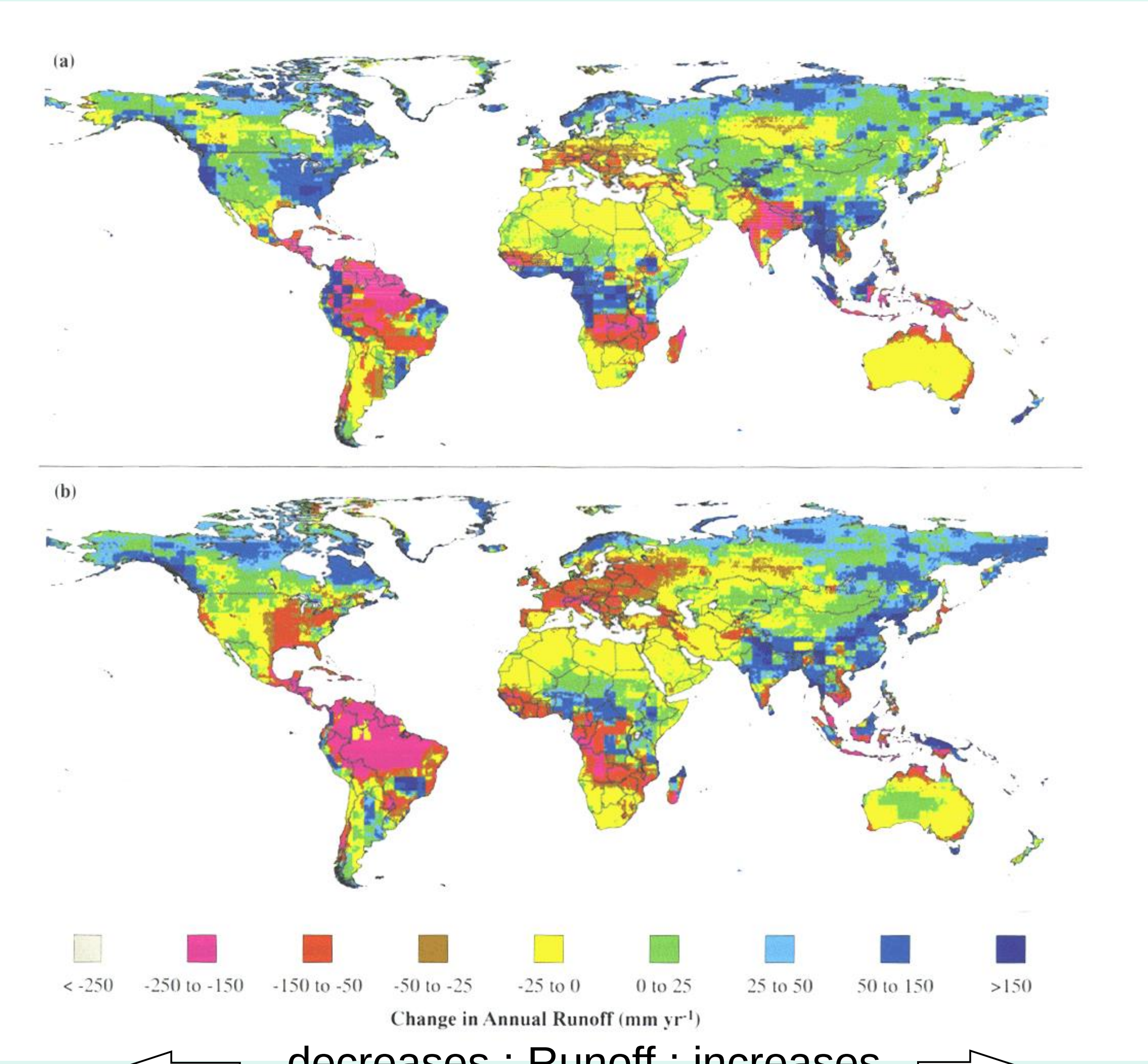


The IPCC has made a persuasive case given various GCM's that global climate in the 21st century will be 1-3 degrees warmer by 2050 even with Kyoto reductions of GHG's so impact & adaptation responses of natural resource and human systems to climate change are inevitable (globally, as of 2018, we're on track for a >4 degree air temperature increase by 2100!).

Source: Climate change 2001: the scientific basis. Summary for policy makers. Contribution of Working Group I to the Third Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) J. T. Houghton, Y. Ding, D.J. Griggs, M. Noguer, P. J. van der Linden and D. Xiaosu (Eds.) Cambridge University Press, UK. 2001. Figure 5: p. 14.

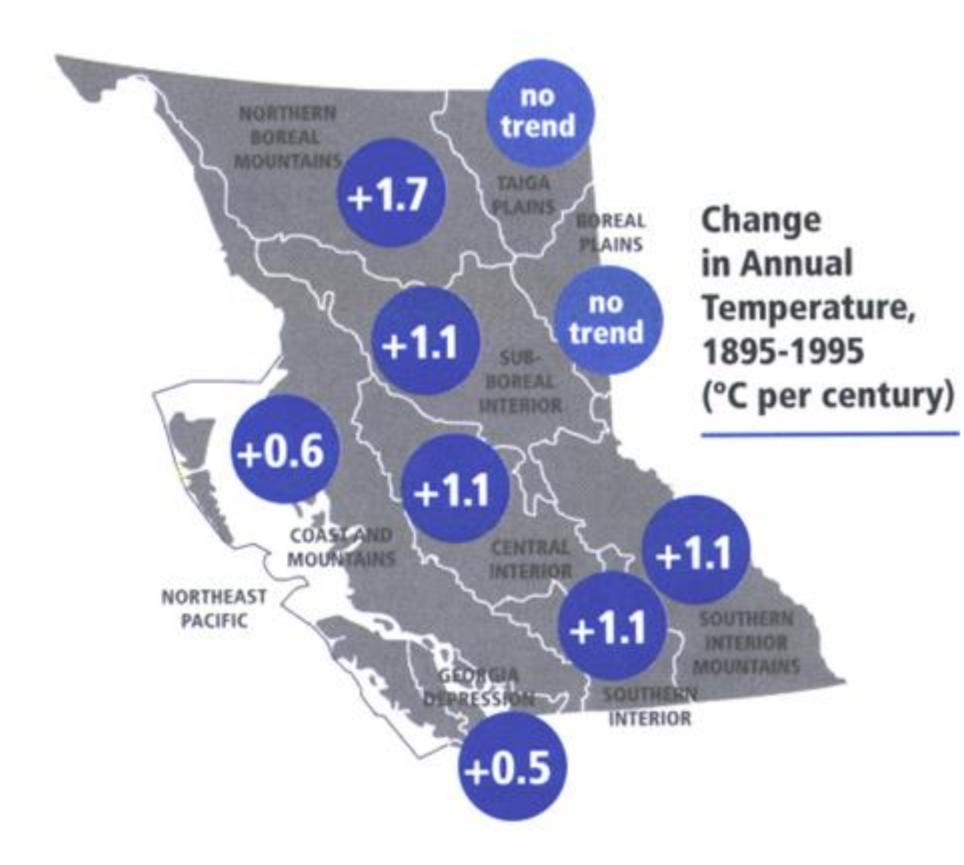


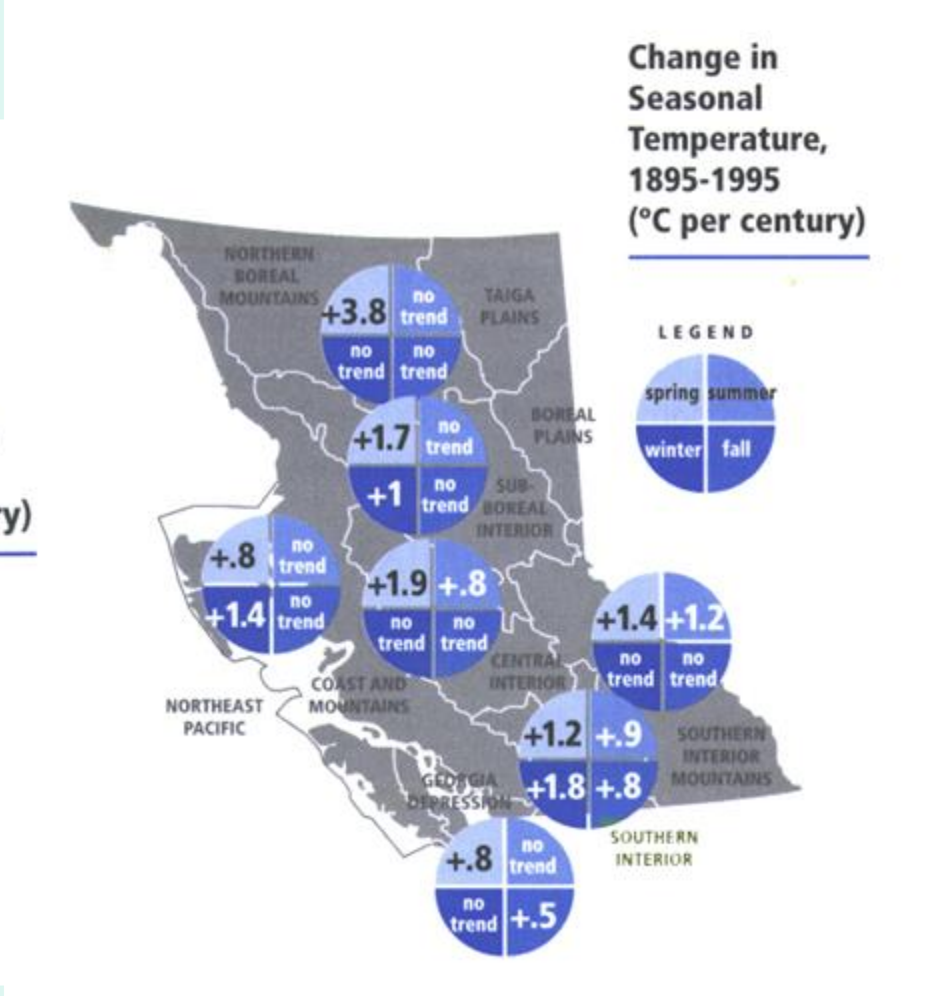
Although less certain than temp change, Global Climate Models (GCMs) suggest precipitation & freshwater runoff patterns will change dramatically in 50-100 years



decreases : Runoff : increases

Signature effects of Pacific climate change are already apparent: BC regional-scale temperatures are increasing

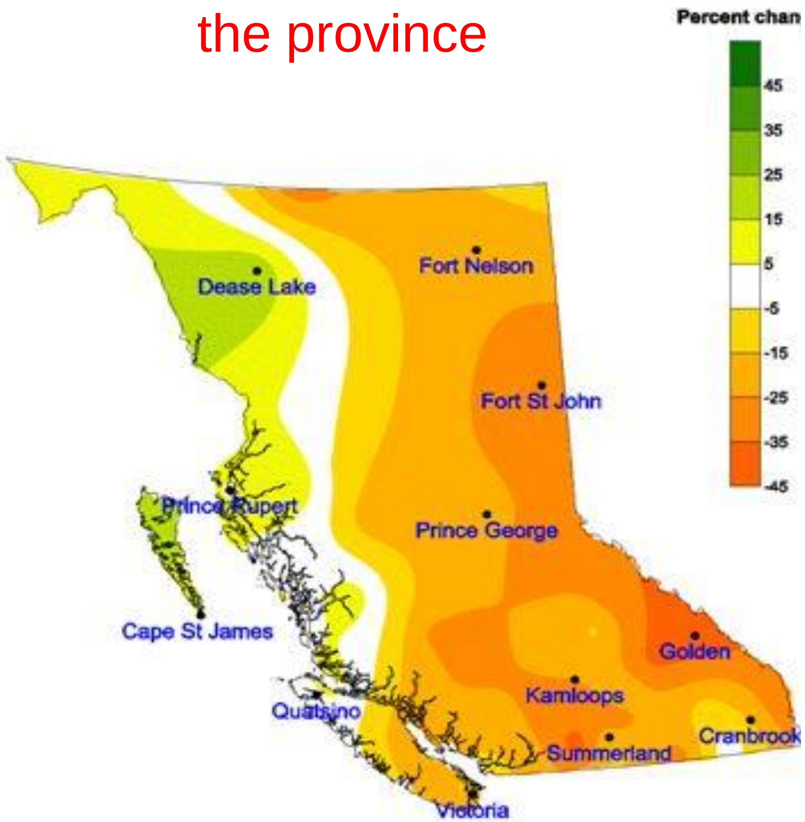




Regional-scale precipitation is decreasing in winter and increasing in summer over most of BC

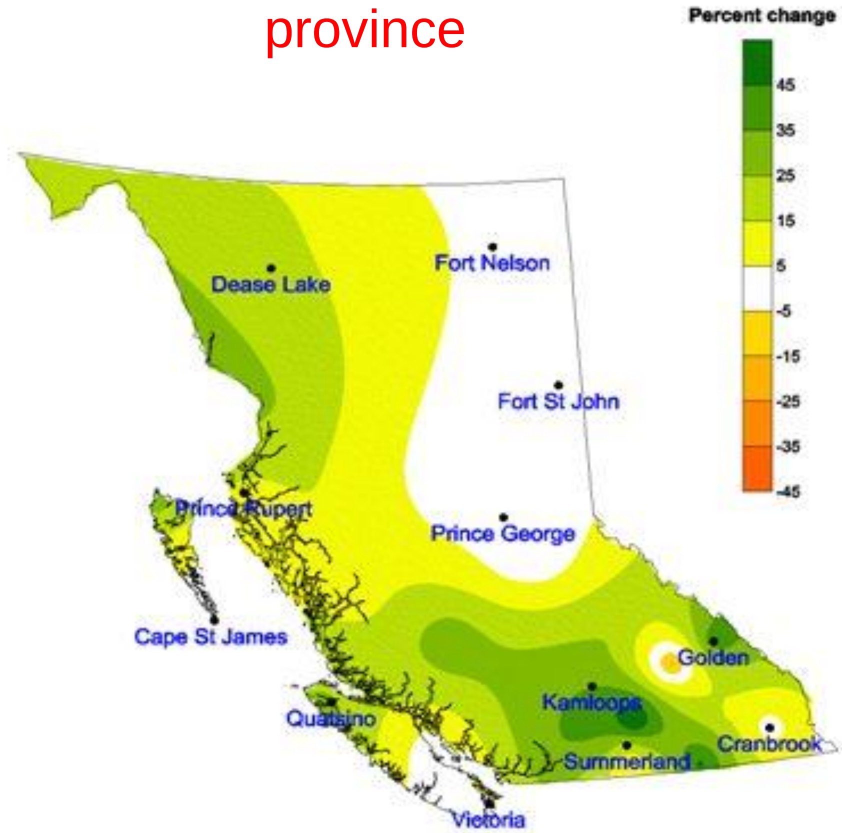
Trend in Winter Precipitation from 1950

Decreasing over most of the province



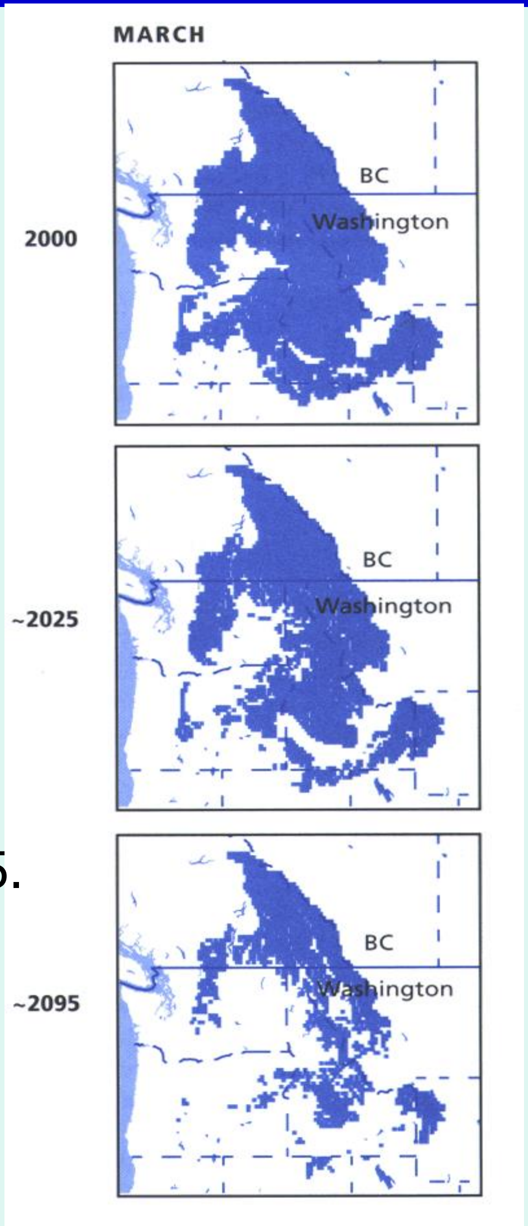
Trend in Summer Precipitation from 1950

Increasing over most of the province



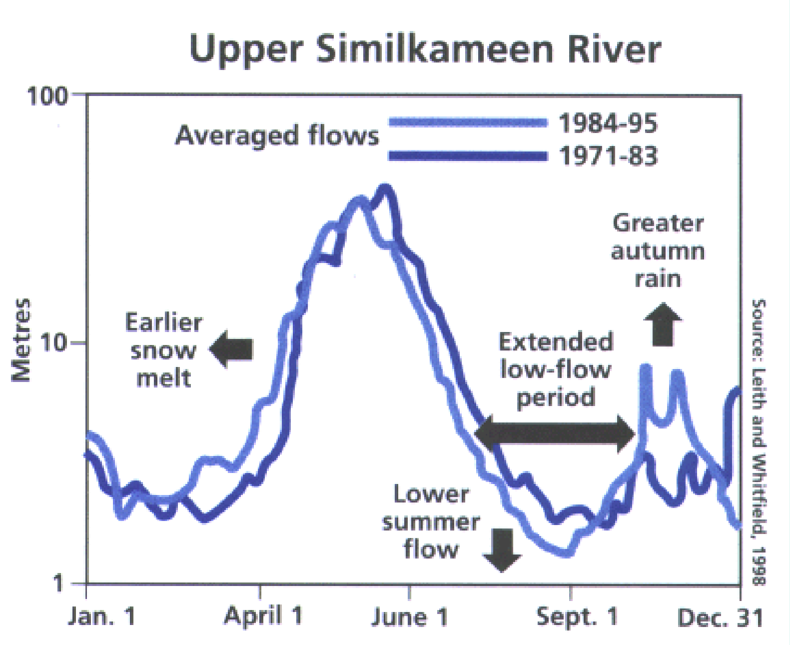
Regional changes in precipitation are reflected in shifts in seasonal hydrology of BC watersheds (e.g. the Similkameen).

Regional Snow pack (Mote– UW)



Snow-pack in 2000 versus projections to 2025 and 2095.

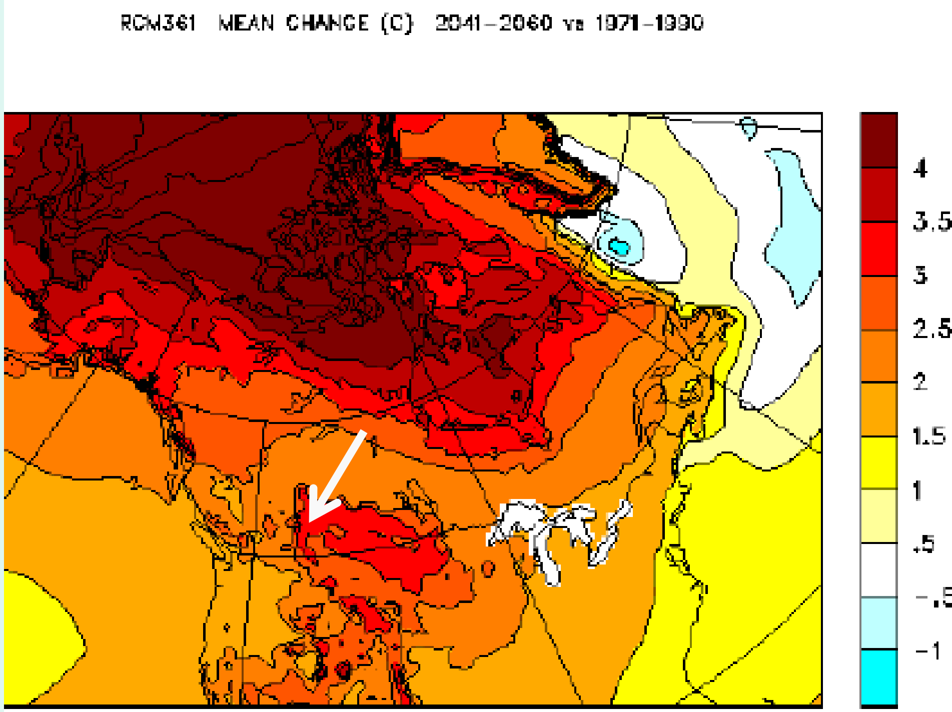
Flow Timing and Variability in Snow Fed Rivers (P. Whitfield)

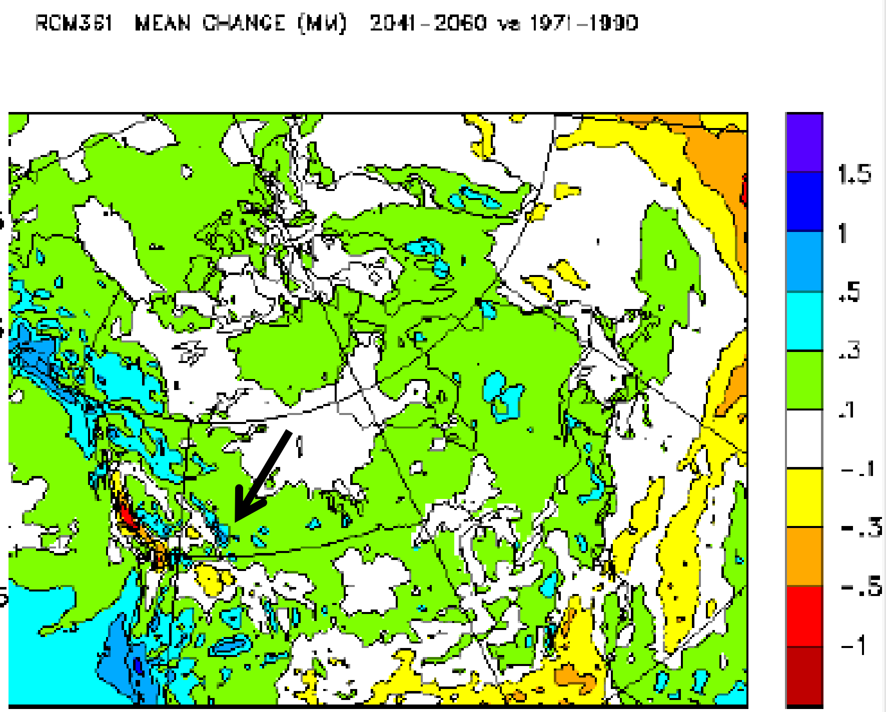


Temperature and precipitation projections by 2060 relative to present (from the Canada Centre for Climate Modeling)

Regional Climate Change Projections

- From the CCCMa Regional Climate Model
- Spatial scale sufficient to distinguish mountain ranges
- No regional ocean projections (yet)





Summary of Global to Regional Climate Trends (history) and Projections (future)

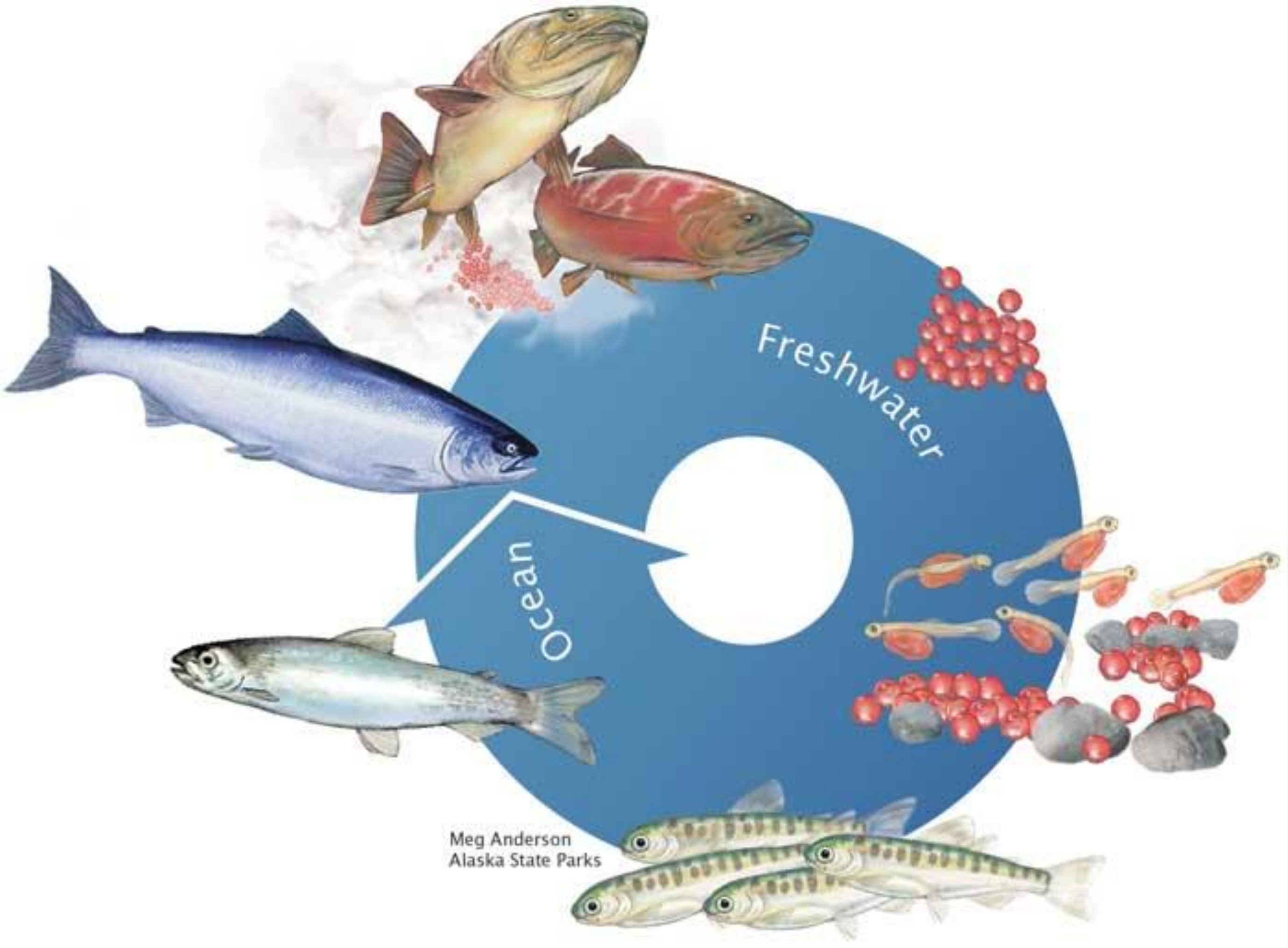
TRENDS:

- Average global temperature increase of roughly 1 degree in the past 100 years.
- Warming is even higher in Canada's portion of the north temperate zone.
- Seasonal air temperature increases in BC's southern interior range from 0.8 (fall) to 1.8 (winter) degrees in the past 100 years.
- On average, BC winters are becoming drier and summers wetter.
- Stream flows are changing to an earlier snow melt and peak freshet combined with extended intervals of lower summer flows and increased fall flows.

Projections:

- Currently planet is "on track" to increase by another 1.5 degrees by 2100.
- Interior BC seasonal air temperatures may increase by 2-4 degrees by 2060.
- Significant changes to stream network event (drought and flood conditions) timing (2-4 week temporal shifts), along with quantity and quality (i.e. temperature, sediment and nutrient delivery) of water delivery throughout BC and western North America.

Climate change matters because of potential for impacts on each life history stage of fish in freshwater and marine ecosystems (i.e. Salmon sustainability depends on many vital ecosystem linkages)

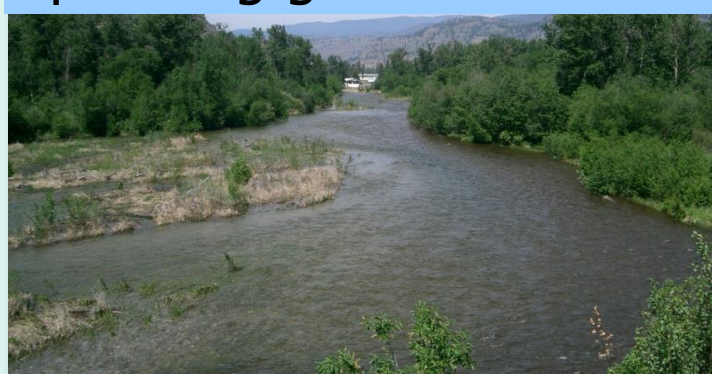


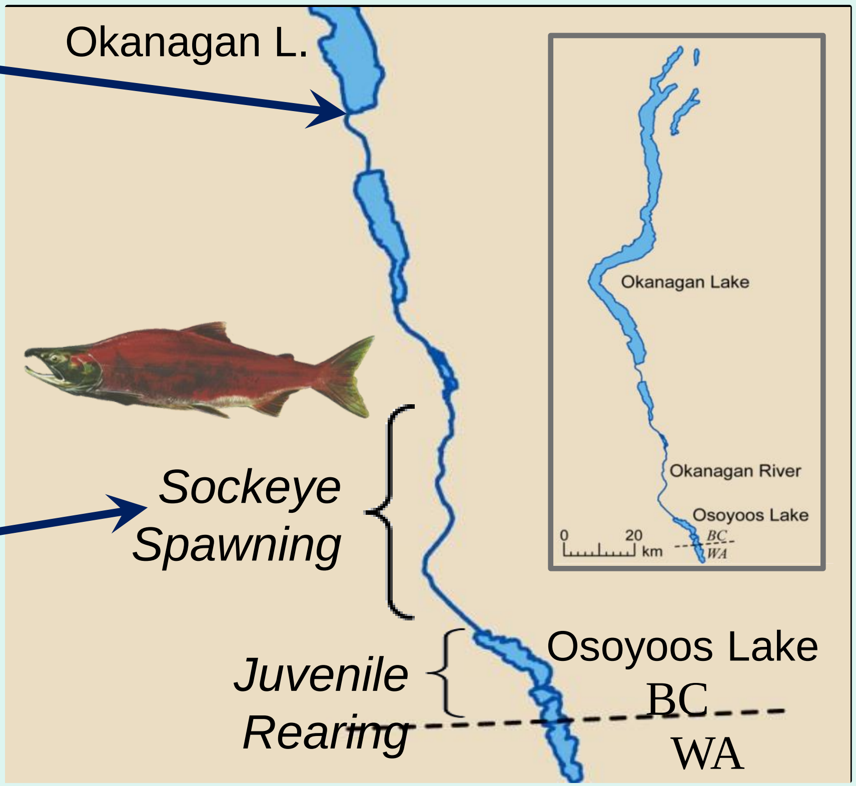
Examples of why climate change matters for EFN's of fish, aquatic ecosystems & associated fisheries in BC's interior

EFN's of Sockeye Salmon in the regulated Okanagan River

Penticton Dam is the major flow control point

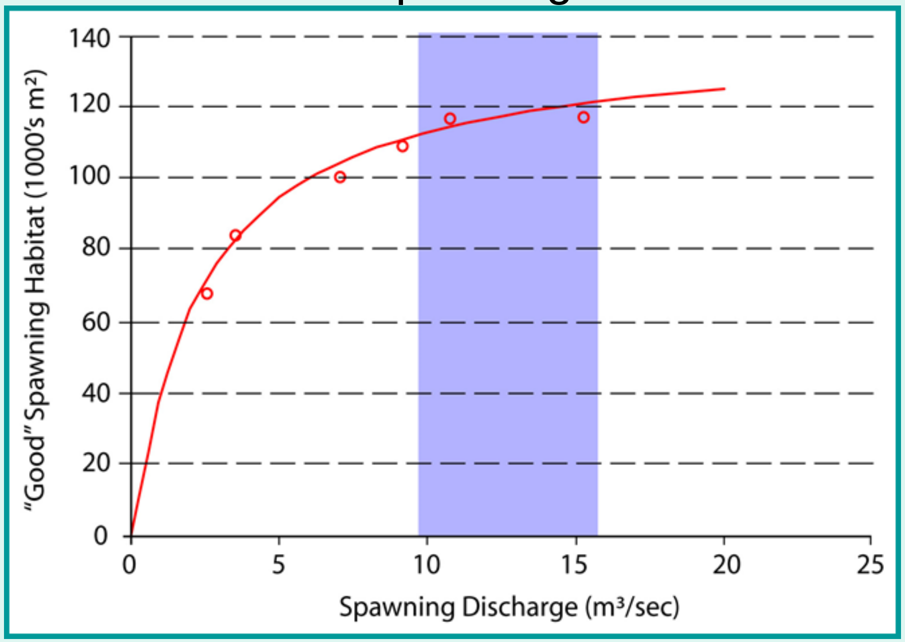
Okanagan River Sockeye spawning grounds



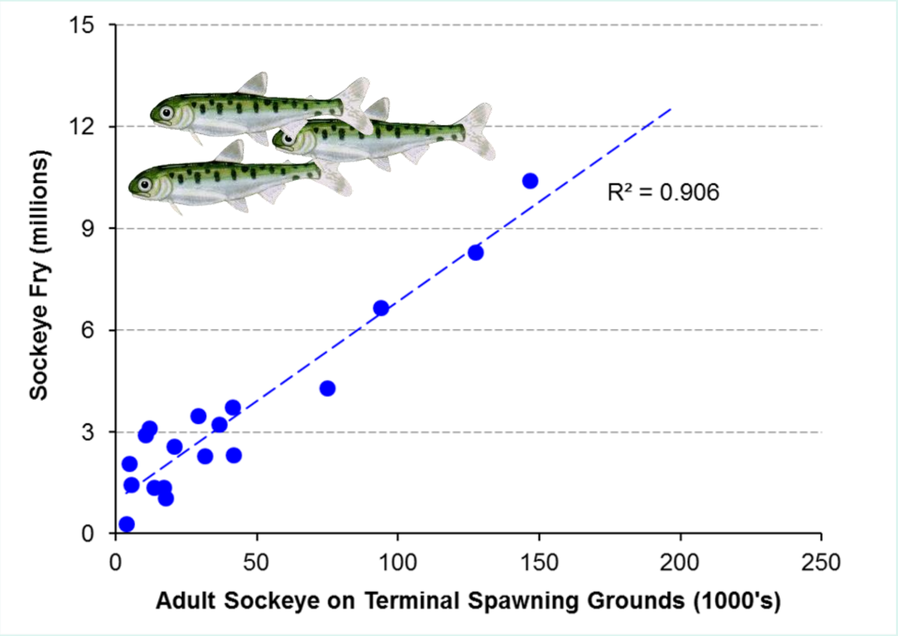


Riverine structure, hydrology and potential climate change linkages to Okanagan Sockeye Salmon

Available Spawning Habitat

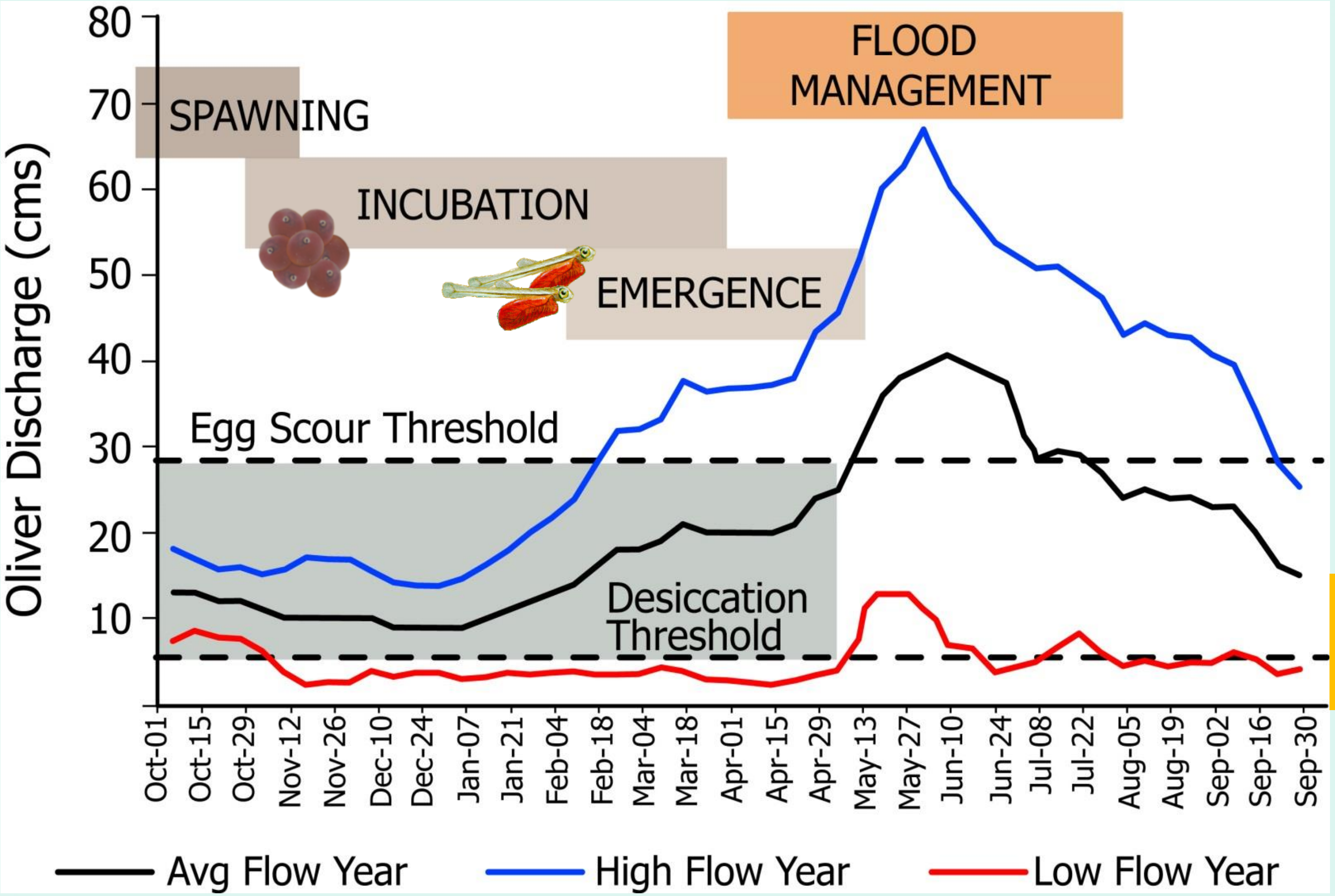


Fry Abundance



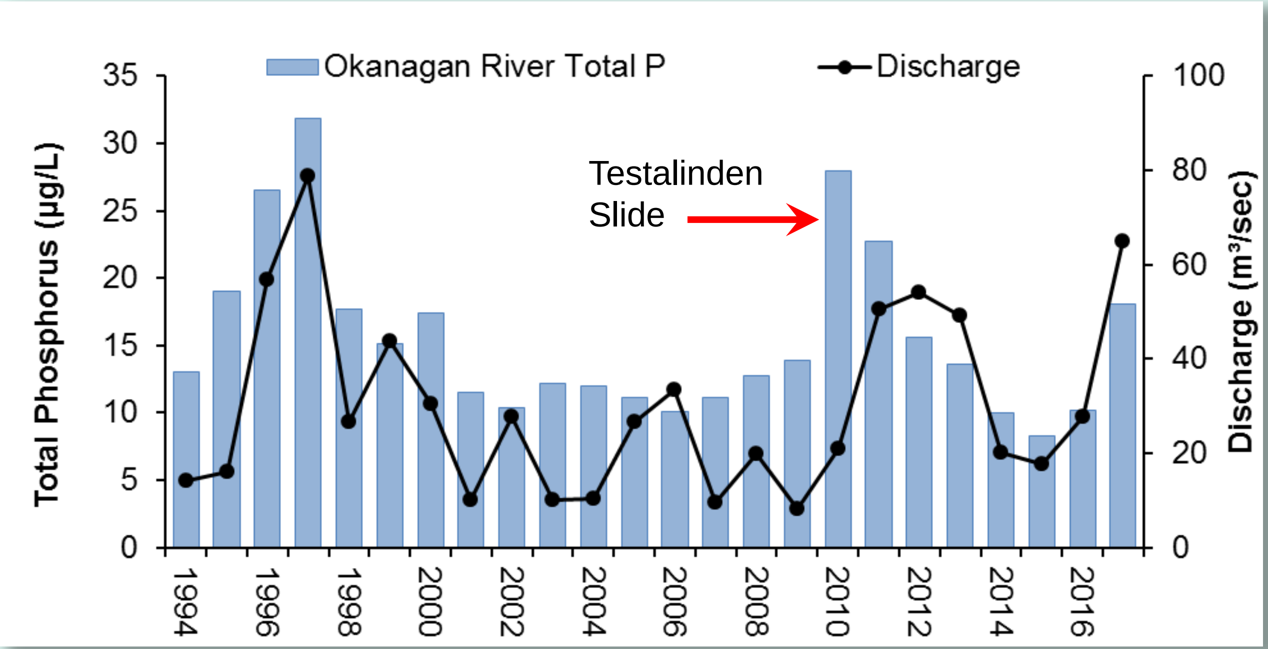
- River morphology & fish behaviour define spawner EFNs
- Spawning area constrains number of adults
- Adult abundance determines subsequent fry recruitment (Hyatt & Stockwell, 2018)
- Late summer drought may pit EFN against irrigation needs.

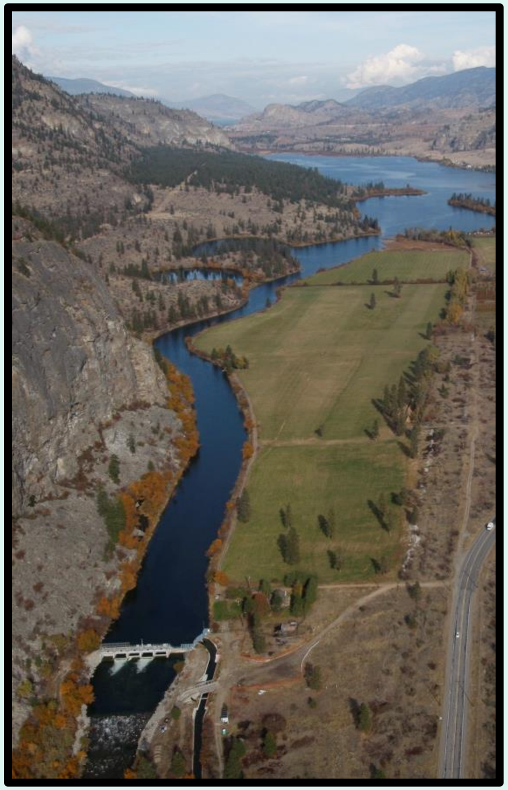
Climate-induced changes to frequency/magnitude of flood & drought events complicate water regulation to meet EFNs of spawners, eggs, alevins (i.e. flows to maximize spawning area, minimize flood-scour, drought-desiccation loss, Hyatt et al, 2015)



Manage Drought

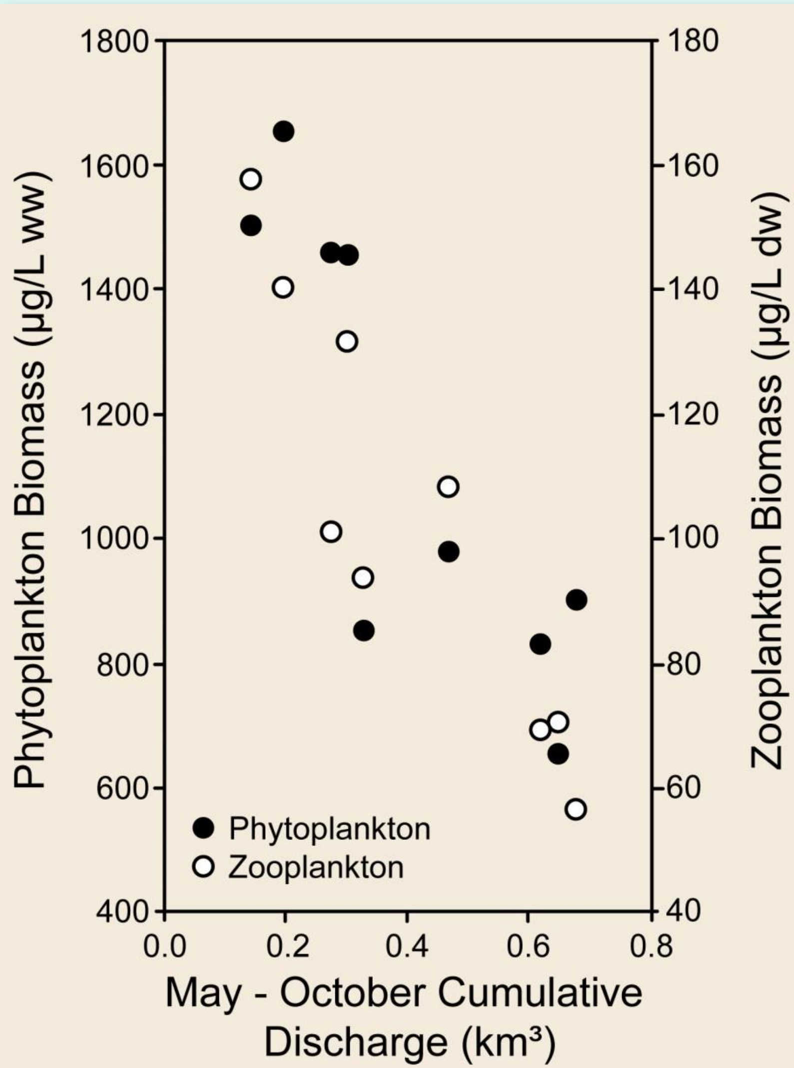
Ecosystems are linked e.g. river discharge influences nutrient delivery to Okanagan lakes used for rearing by salmon & other resident fish





Phosphorus concentrations in Okanagan R. and in Osoyoos L. (as well as other lakes) change with variations in mean summer discharge. Quantity/timing of nutrient delivery affects production of plankton

River flows control phytoplankton & zooplankton biomass of lake food-webs (i.e. EFN's may need to account for potential linkages & downstream influences).



Physical Drivers of Biota

- Phytoplankton and zooplankton biomass in Osoyoos and Skaha lakes are controlled by Okanagan River discharge (Hyatt et al. 2018).
- Discharge drives high contrast (roughly 3-fold) changes in annual levels of food potentially available to fish in lakes !

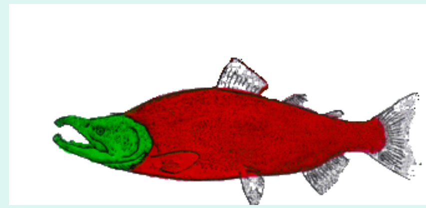
Summary of Interactions Among Climate Change, Freshwater Ecosystem Change and EFNs of Fish and Associated Ecosystems

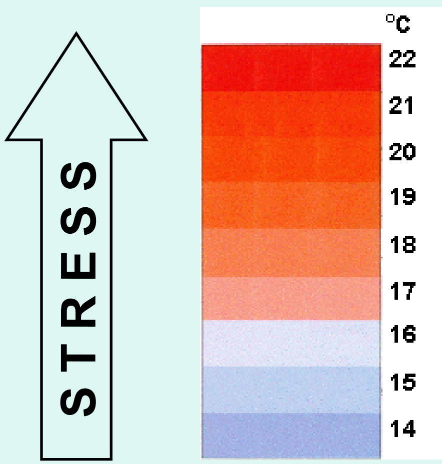
Key Observations:

- The complexity and importance of linkages among terrestrial and aquatic ecosystems (e.g. upland streams, river-main-stem, associated lakes etc.) recommends assessment of both local and downstream flow-functions when setting EFNs.
- Climate change induced impacts on the frequency, magnitude and timing of flow events (e.g. seasonal floods, drought) will exert widespread influences on life history outcomes for salmon and resident fish in lake and stream environments.
- Climate change, water, fish, ecosystems and associated EFNs are all intimately linked and make cumulative impact future prediction of interaction outcomes difficult and less certain than at present.
- Although climate change impacts on flow needs of fish are likely to be significant, impacts on thermal requirements may be greater (dealt with next!)

Climate Change & Freshwater Thermal Regimes

Climate change will challenge the scope for life history adaptation by fish to variations in seasonal thermal regimes and associated changes to aquatic ecosystems.





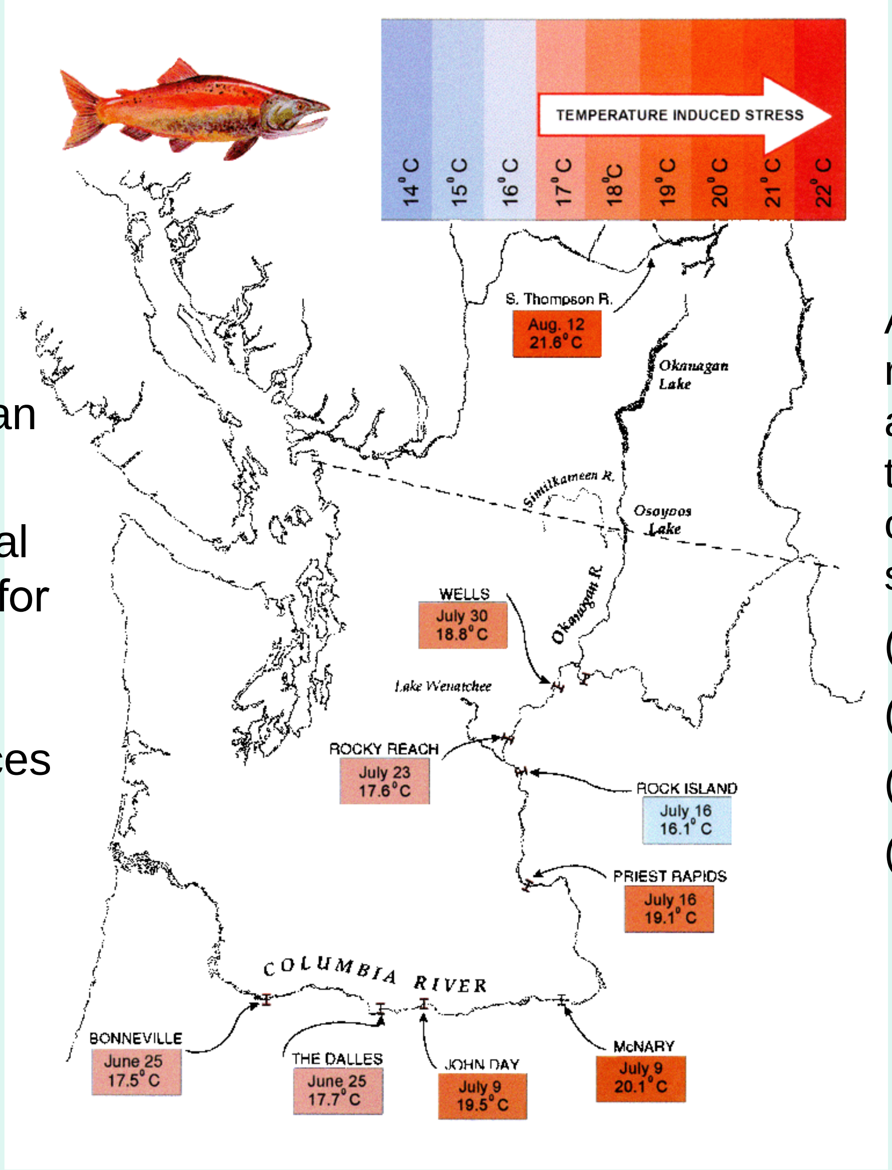
- many elements of behaviour, physiology, & ecology of salmon are controlled by temperature
- physiological performance is optimal at 15 °C
- salmonids are increasingly stressed between 17 and 24 °C
- 25 °C is lethal

Results presented here first for Okanagan sockeye are part of a general approach to developing: (1) analysis of salmon population responses to historic variations in climate, (2) inferences about global warming impacts on salmonids and (3) identification of potential options for effective stock management, conservation and/or restoration.

Changes to Aquatic Thermal Regimes in Southern Watersheds Pose Threats Salmon & Resident Fish at Several Life Stages

General procedure developed on Okanagan sockeye is to:

(1) identify a biophysical model or "set of rules" for a given life history response and then
(2) predict consequences of climate change



Analysis of sockeye responses to seasonal & annual variations in thermal regimes are now complete for life history stages involving:

(1) adult migration

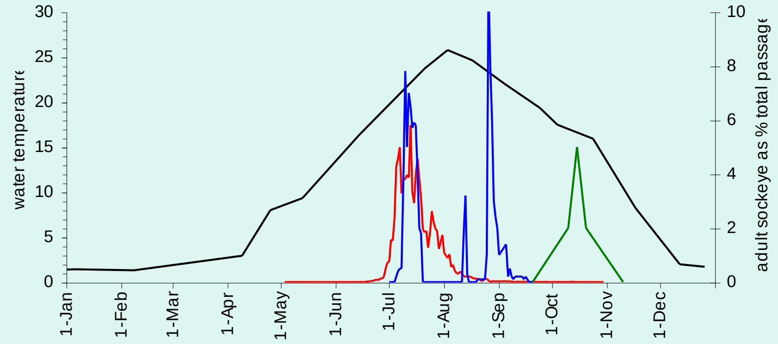
(2) adult spawn timing

(3) egg-fry incubation

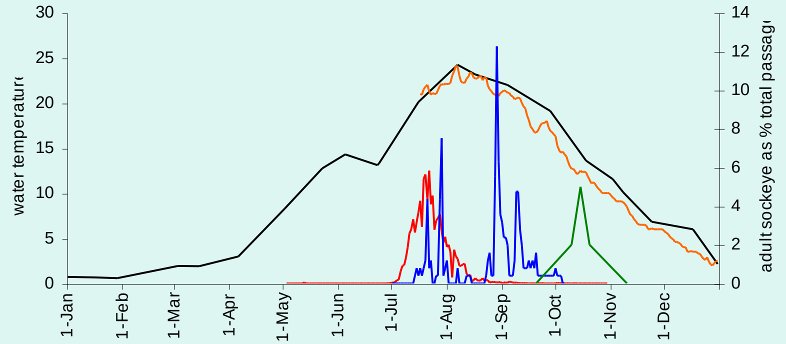
(4) juvenile rearing

Derivation of Temperature "Rules" for Adult Migration

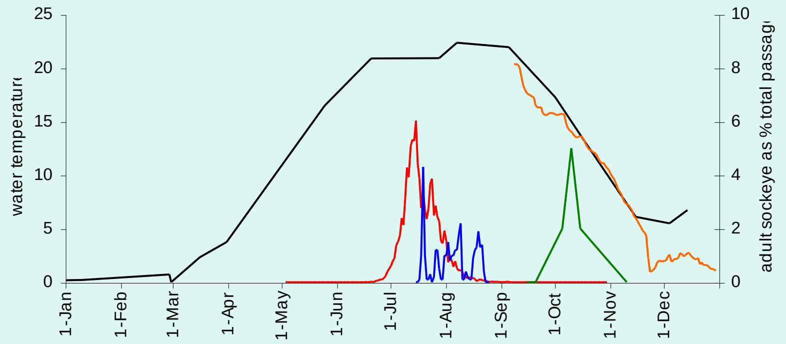
(Hyatt et al. 2003. Can. Wat. Res. J. 28: 689-713)



- Adult Sockeye migration through Wells Dam on the Columbia mainstem is generally "unimodal" ( )



- Sockeye migration through Zosel Dam on the Okanagan River is often "polymodal" ( )



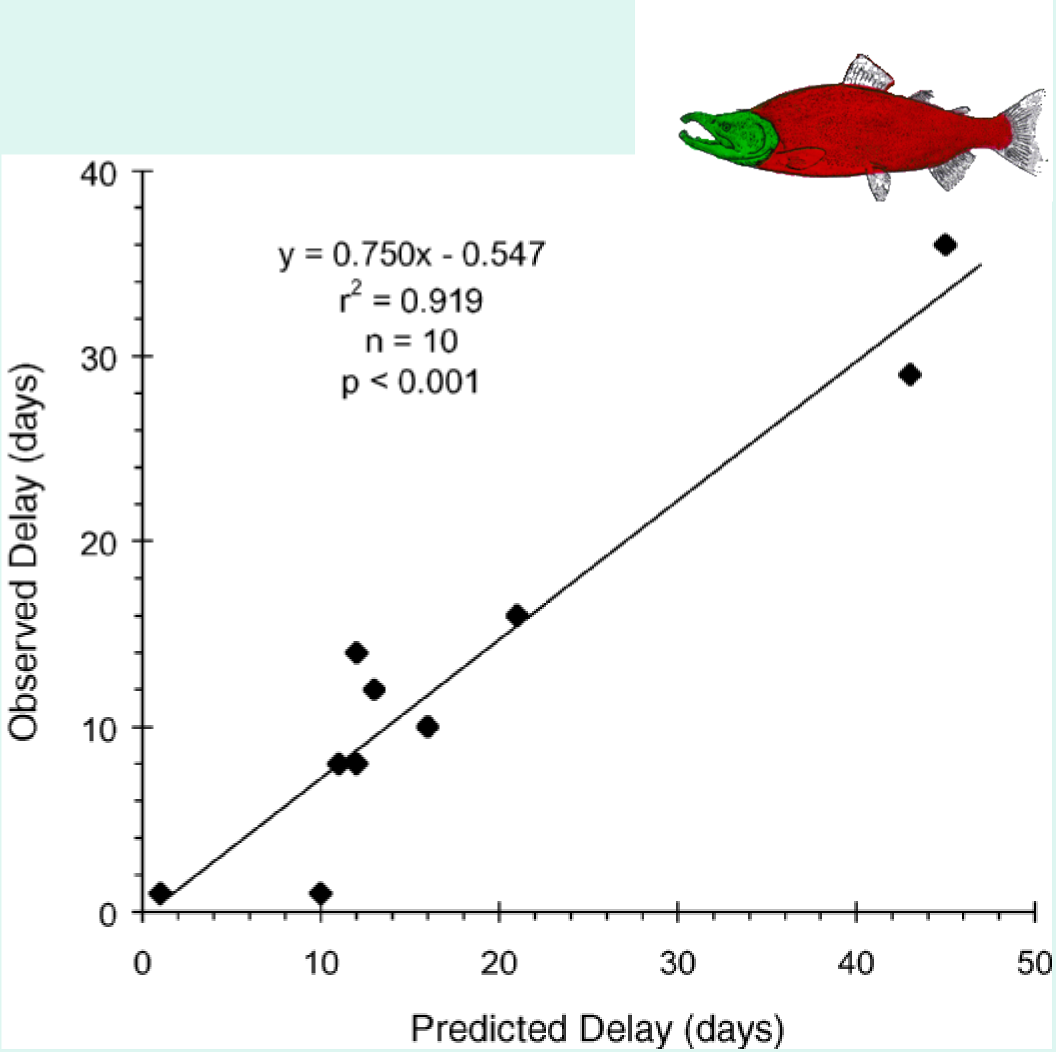
- Disruptions & delays to adult entry into the Okanagan R. coincide with extremes of seasonal temperature variation ( )

true water temp

spawners

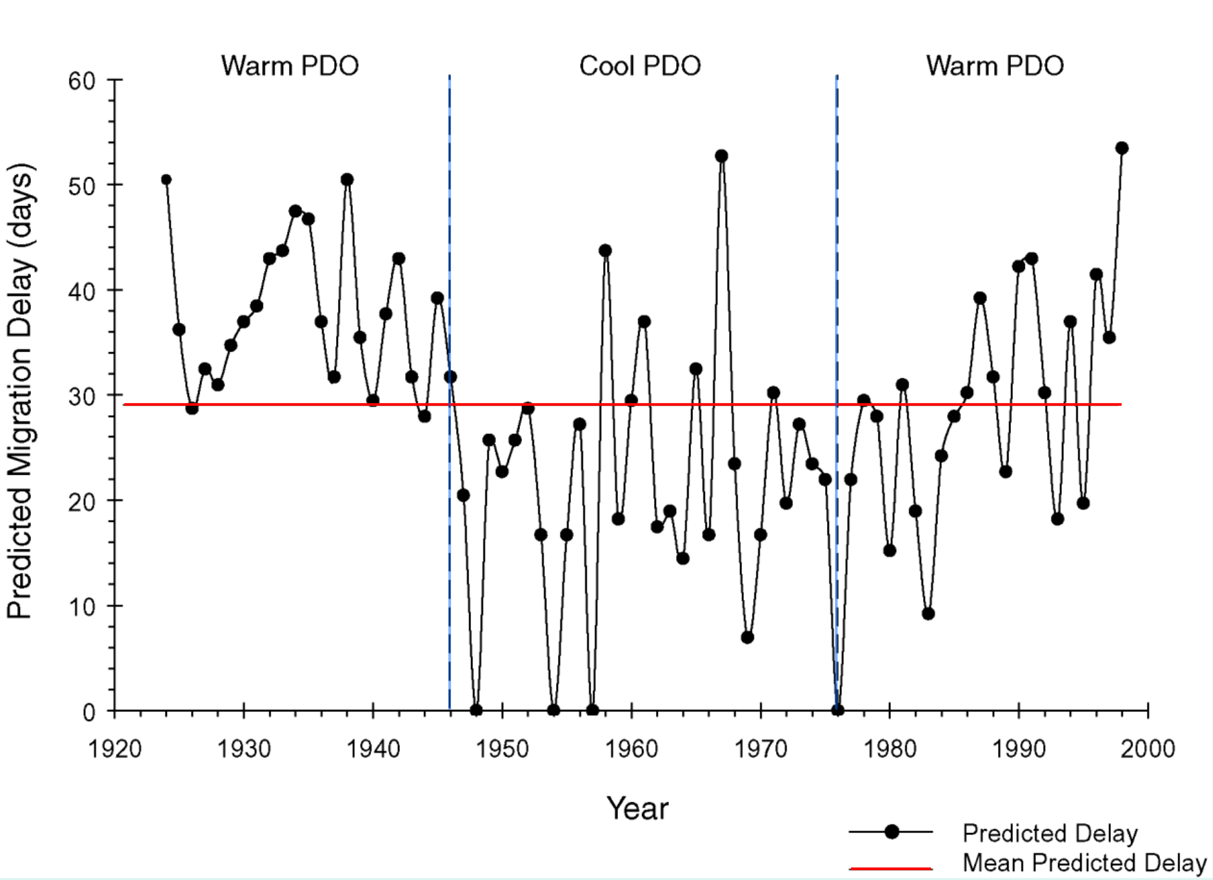
- **Adult migrations stop at 21 °C when temperature is increasing**
- **Migration resumes at 21 - 22 °C when seasonal temperatures decrease**

Predicted vs observed delays for Okanagan Sockeye adult entry into Okanagan R. based on temperature stop & start migration model (Hyatt et al. 2003, CWRJ)



Temperature-based estimates of adult sockeye delays 1924-1998

Adult sockeye migration delay based on seasonal changes in water temperature of the Okanagan River



• Applying temperature-migration model suggests delays range from 0 - 72 days & average 40 days per annum. The magnitude of delays alternate with PDO cycles & have been increasing steadily in association with climate warming during 1985 - 2015 compared with lesser delays in the "cool" 1947-1985 interval.

Temperature-induced Migration Delays for Salmon Have Serious Biological & Economic Impacts.

- 30 day delay given "warm" PDO equals time to migrate the entire 1000 km from the coast to upriver spawning areas for Okanagan sockeye. Migration delays reduce salmon "fitness" (MacDonald et al 2001).
- Migration delays eliminate ready access to fish by First Nation's subsistence, ceremonial and economic opportunity fisheries (Hyatt et al 2003).
- Cooke et al. (2004, Fisheries 29: 22-33) suggested that migration deviations of between 28-42 days by major stocks of Fraser R. sockeye salmon were associated with mortalities representing up to **$72 million CDN in fishing industry losses during 2002 alone and 2004 was probably worse**.
- In 2015, stress inducing temperature (>23 degrees C) delays in the Columbia main-stem (below Mc Nary Dam at the Okanagan R mouth) were accompanied by a >97% mortality of all returning adult Sockeye!
- **Thermal conditions due to exceptional climate variations in 2015 are anticipated to resemble average conditions due to climate change by the year 2070 !**

Importance of Adaptation as Human System Response

Increased levels of long-lived, greenhouse gases make a 0.5-1.0 degree increase in global temperature by 2100 very likely (IPCC) !

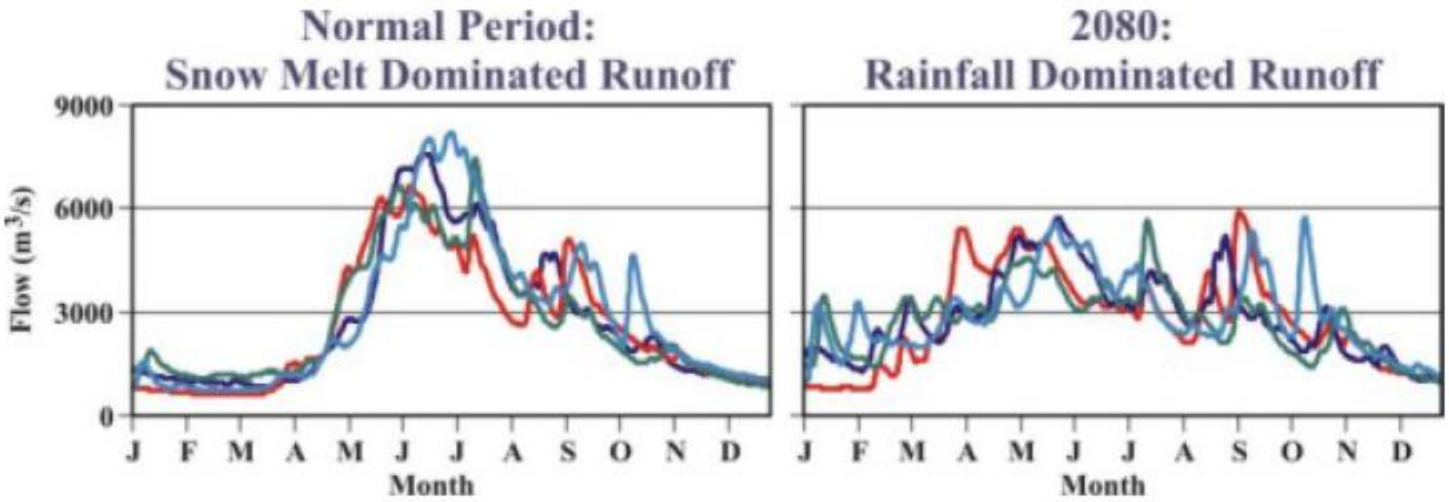
Developing effective adaptation responses to minimize harm from climate change will be increasingly important in the coming decades.

Objectives of DFO's 2013-2018 Aquatic Climate Change Adaptation Services Program (ACCASP)

1. **Develop eco-region risk assessments to identify key vulnerabilities to climate change (e.g. our Okanagan work)**
2. **Execute research projects to increase understanding of impacts**
3. **Develop "tools" for adaptation**

Example 1, Fraser R: aquatic climate projections (IAR-1)

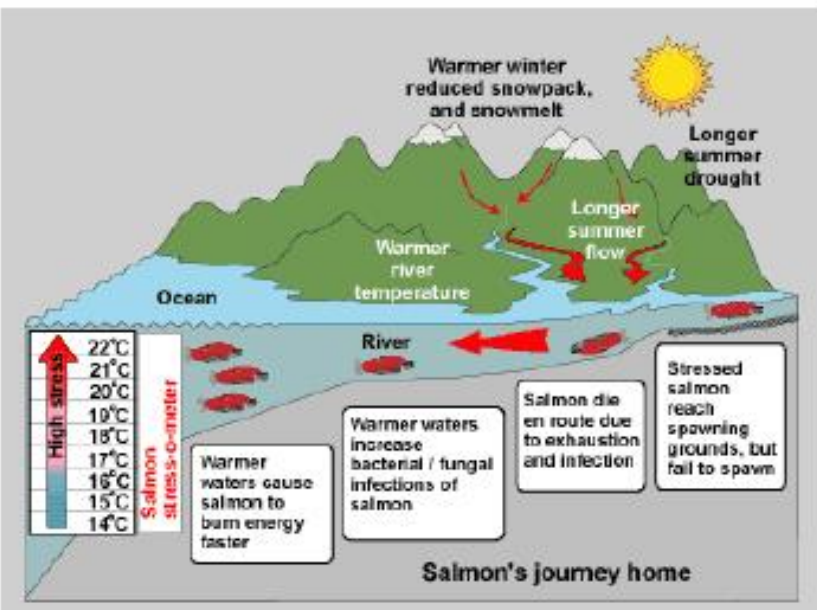
Changes in freshwater runoff – the Fraser River

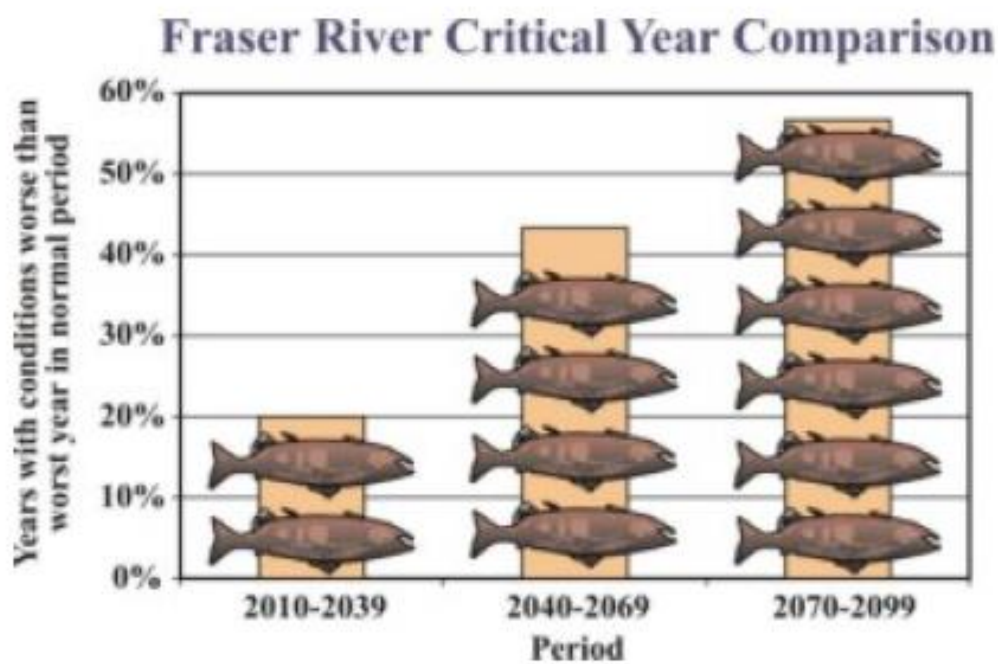


- Less snowmelt, more rainfall runoff
- Peak flows from heavy rainfall, rather than spring "flood"

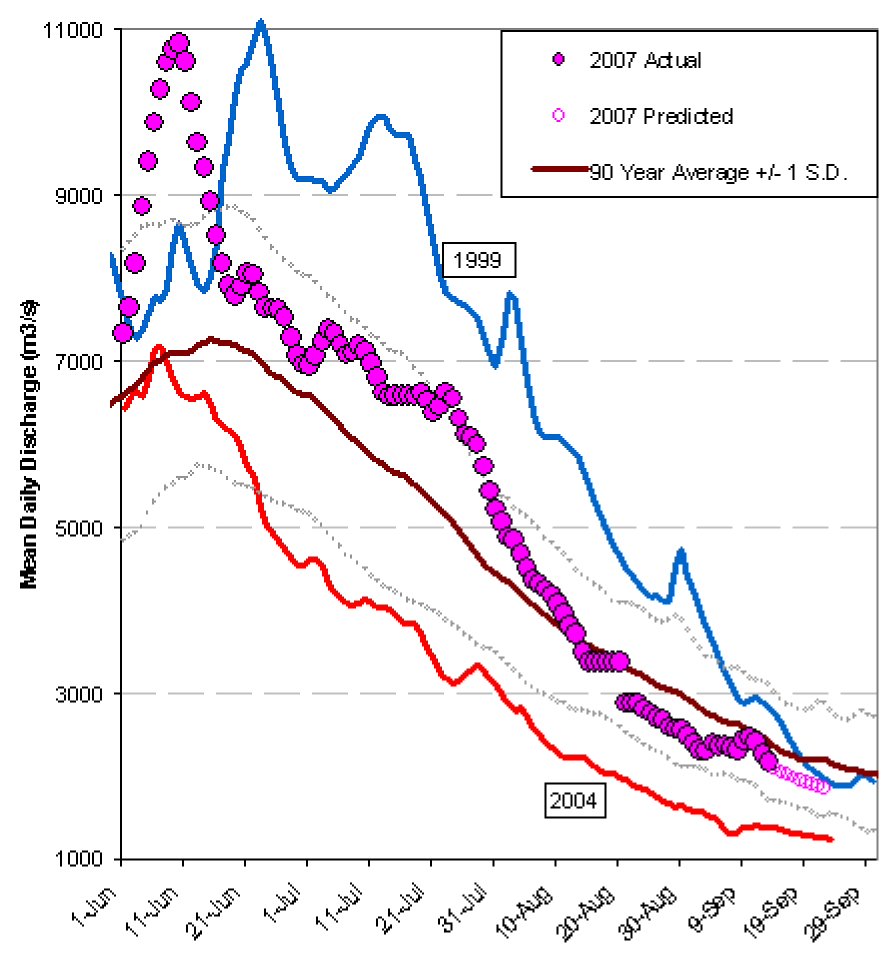
Example 1, Fraser R: projected consequences for salmon (IAR-1)

Impacts on adult salmon: Increased temperature in streams, lakes and rivers



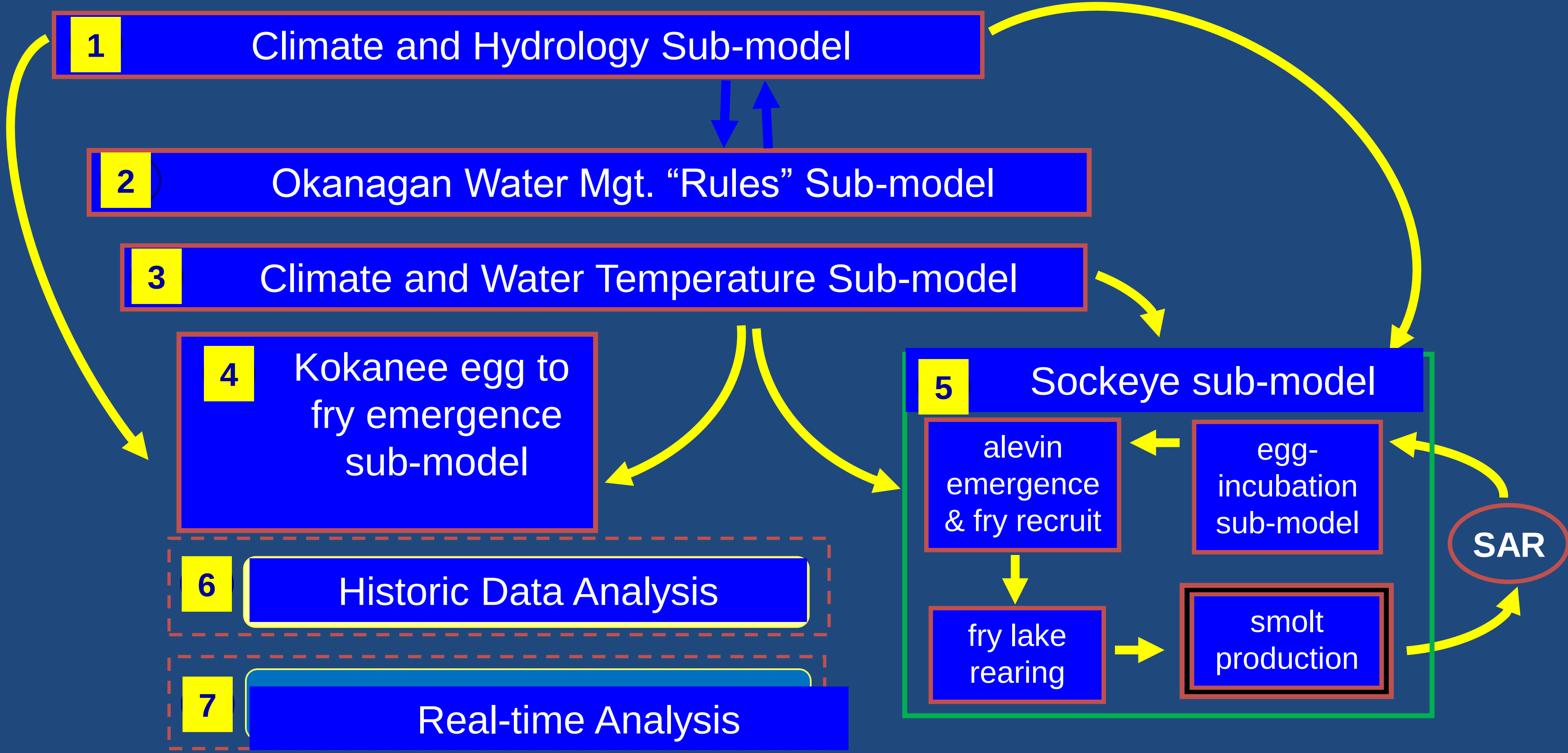


Example 1, Fraser R: operational models represent an adaptation "tool" to provide guidance for in-season decision-making



- A numerical IAR-1 model predicts flow and temperature conditions
- These predictions drive a biological effects model to estimate in-river mortality
- If required, harvest levels are reduced to compensate for excessive predicted in-river mortality (IAR-2)
- IAR-3 would require social science studies of fleet and stakeholder options.

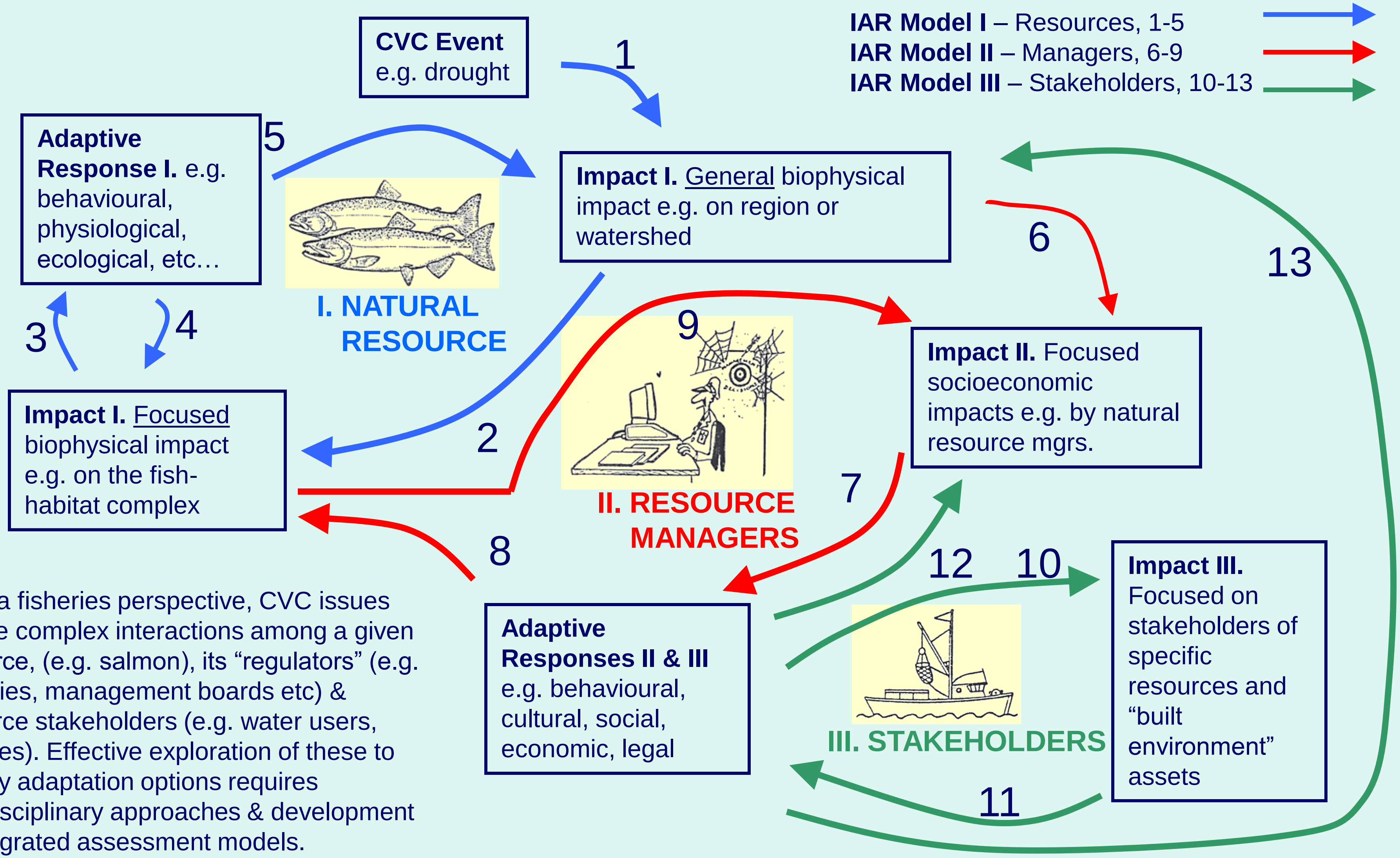
Example 2: Fish-and-Water Management Tools (FWMT) Okanagan (Alexander et al 2008, Hyatt & Stockwell 2010, Hyatt & Stockwell 2015)



The FWMT System is a coupled set of biophysical models of key relationships (among climate, water, fish & property) used to predict the consequences of water mgt. decisions for fish & other water users.

FWMT may be used to explore water management decision impacts in an operational mode employing real-time data, a prospective-mode going forward or in a retrospective-mode looking back on historic water supply, climate & fish years. The FWMT decision support system is an advanced adaptation tool!

Integrated Assessment Models of Impact & Adaptation Responses (IAR) to Climate Variation & Change (CVC) Events Deal with More than just Biophysical Information: Identification of Adaptation Options Requires Interdisciplinary Studies to Create new Knowledge and Tools for Adaptation



From a fisheries perspective, CVC issues involve complex interactions among a given resource, (e.g. salmon), its "regulators" (e.g. agencies, management boards etc) & resource stakeholders (e.g. water users, fisheries). Effective exploration of these to identify adaptation options requires interdisciplinary approaches & development of integrated assessment models.

Adaptation involves many sectors and government departments

- Adaptation is a process with multiple components, such as impact and vulnerability assessments, awareness-raising, capacity building, stakeholder participation and mainstreaming.

  OECD Global Forum on Sustainable Development (November 2004)

- "The task of devising and implementing strategies to adapt … will require worldwide collaborative inputs from a wide range of experts, including physical and natural scientists, engineers, social scientists, medical scientists, those in the humanities, and business leaders and economists."

  Joint science academies' statement (June 2005)

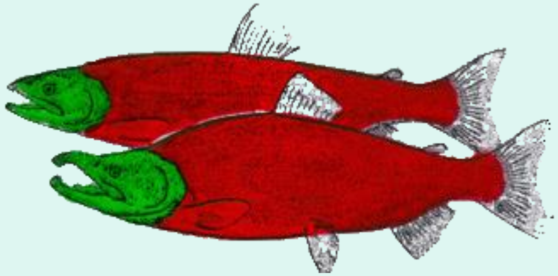
Final Thoughts

• Life history events & production variations of salmon and resident fish do co-vary with short (ENSO) & longer term (PDO) climate regime changes.

• Research into causal mechanisms provides new information tools and models to improve fisheries management (e.g. Okanagan sockeye migration delay and/or mortality predictions; refinement of decision support systems to improve fish friendly water management and harvest management), but the pace of innovation may not match the pace of climate change effects.

• Need exists for research, policy and institutional reform to build “fisheries” and resource management systems that are robust enough to work in an era of increasing uncertainties created by climate change effects !

• Given complex life histories, generalizations about when, where and to what extent environmental flow needs of salmon and resident fish populations will respond to variations in climate regimes will be slow to emerge but in many cases knowledge is already sufficient to initiate some adaptation actions (e.g. water management objectives should be responsive to both seasonal flow & thermal regime objectives).



Thank You !