Biophysical Impacts of Climate Change on Aquatic Biota in the Columbia Basin

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CB-RAC Webinar, April 21st, 2021

Outline for Talk

- Key results of Climate Change (CC) assessments in the Columbia River Basin (CRB).

- Identify why CC matters for:
  - sustaining existing populations of wild salmonines,
  - restoring threatened populations, or
  - re-establishing extirpated populations.

- Comment on relevance of recent research on Columbia Basin salmon to CC and hydro-system impacts on Upper Columbia aquatic biota.

Columbia River Basin - Climate Change Recap

- **Temperatures** have already warmed about 1.1°C in the CRB since the 1970s, and are expected to warm another 1-3°C by the 2050s, 2-5°C by the 2080s.

  → Snow-pack decline as more winter precipitation falls as rain, especially on the US side of the Columbia Basin.

  → Peak glacier melt by the 2040s, 75-100% glacier loss by 2100.

  → **Summer water temps** up 1.7 - 2.0°C by 2080s (Yearsley 2009; Isaak et al. 2018).

- **Precipitation** trends are less certain, but seasonal differences are appearing.

  → Wet winter/spring months get wetter.
  → Dry summer months get drier.

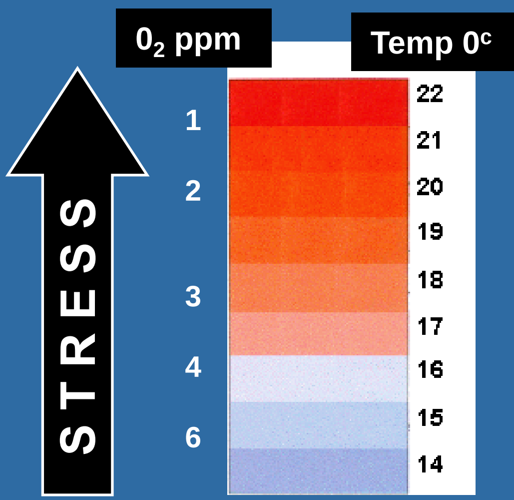
- **Floods and Droughts!**

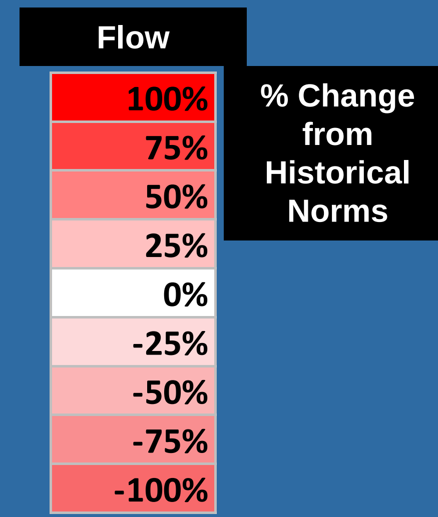
  → Higher winter flows, earlier peak spring runoff, and longer periods of low summer flows more common by the 2030s.

  → Climate change will impact flood risk management, hydroelectric generation patterns, energy consumption, and ecosystems.

How Climate Change Affects Salmonids

Climate change challenges the scope for life history adaptation to variations in thermal and hydrological (physical) regimes and associated ecological (bio-physico-chemical) changes.

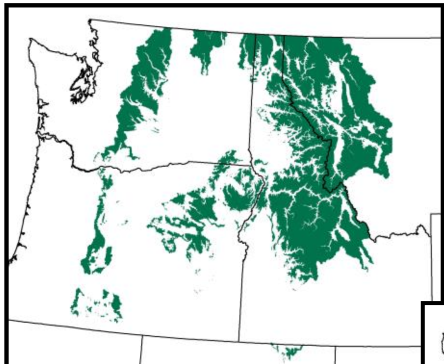


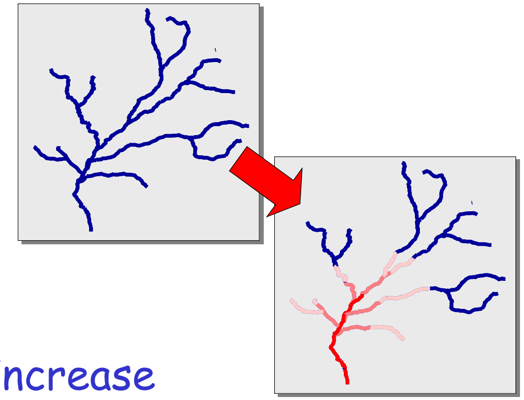


- Behaviour (movement, response), physiology (growth, maturation), and ecology (food-web) are controlled by temperature, oxygen and flow conditions
- Physiological Performance is optimal at 15°C and 6-8 ppm O_2
- Salmonids are stressed at Water Temps > 17°C or O_2 < 4 ppm
  → 25°C is acutely lethal & < 2-3 ppm O_2 is debilitating, leading to mortality
- Extreme flows (high or low) lead to life-stage-specific impacts

Cold-Water Fish Guilds

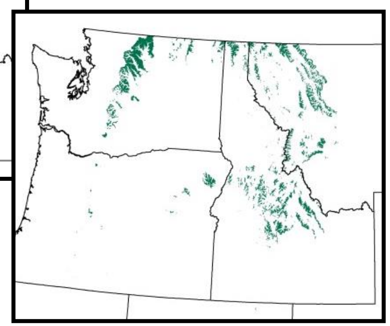
Currently Suitable Habitat for Juvenile Bull Trout



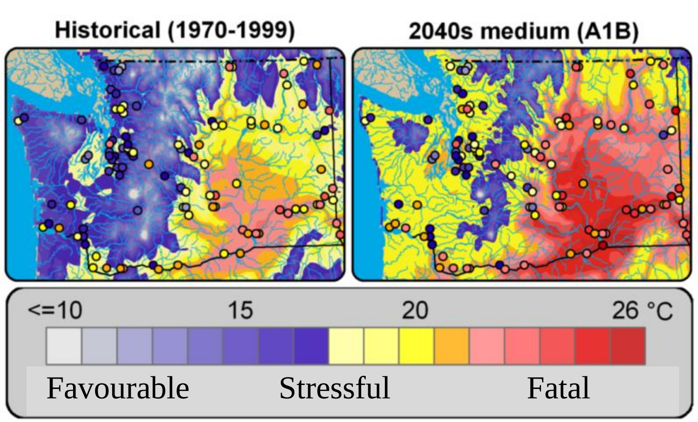


~ 1.6 °C Increase

~ 5.0 °C Increase



Salmon



Climate Change Impacts

- Temperature Increases
  - **Fragmentation** of habitats
  - **Lake effects**
    - Deeper 20C isotherm
    - Shallower 4 ppm O2 isopleth

    → **Temp-Oxy "Squeeze"**
  - **Habitat loss** for cold water species
- Ecosystem Re-Organization
  - Loss of streamside vegetation due to **fire/insects**
  - **Competition** for prey
  - **Invasives**
  - **Pathogens**

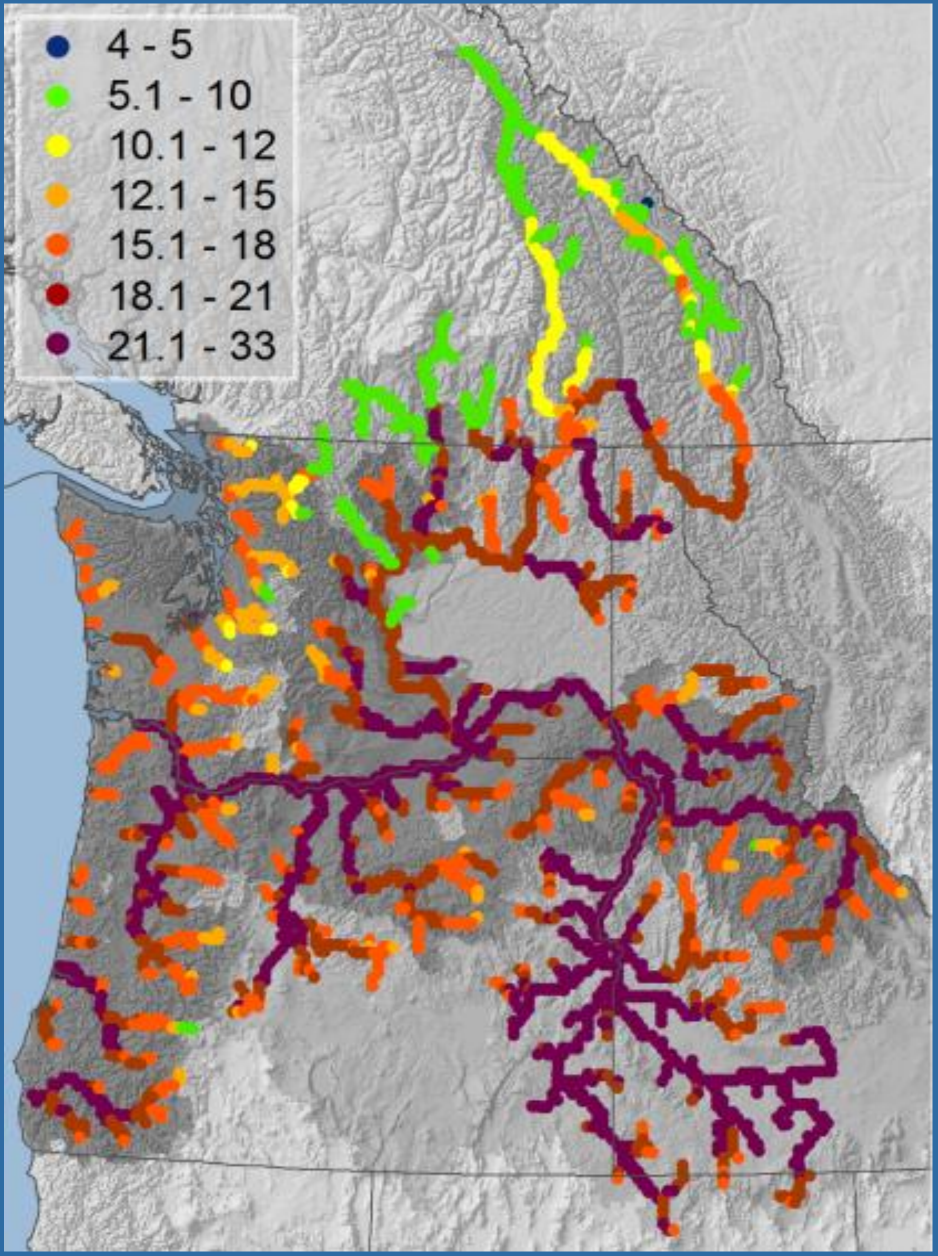
Dan Isaak, USFS, Boise, ID & Peter Tschaplinski, BC MoF

Pacific Northwest Rivers

Summer temperature projections by 2080

(NCEAS and CIG, USC and UW)

indicate spatial limits for viable salmonid populations

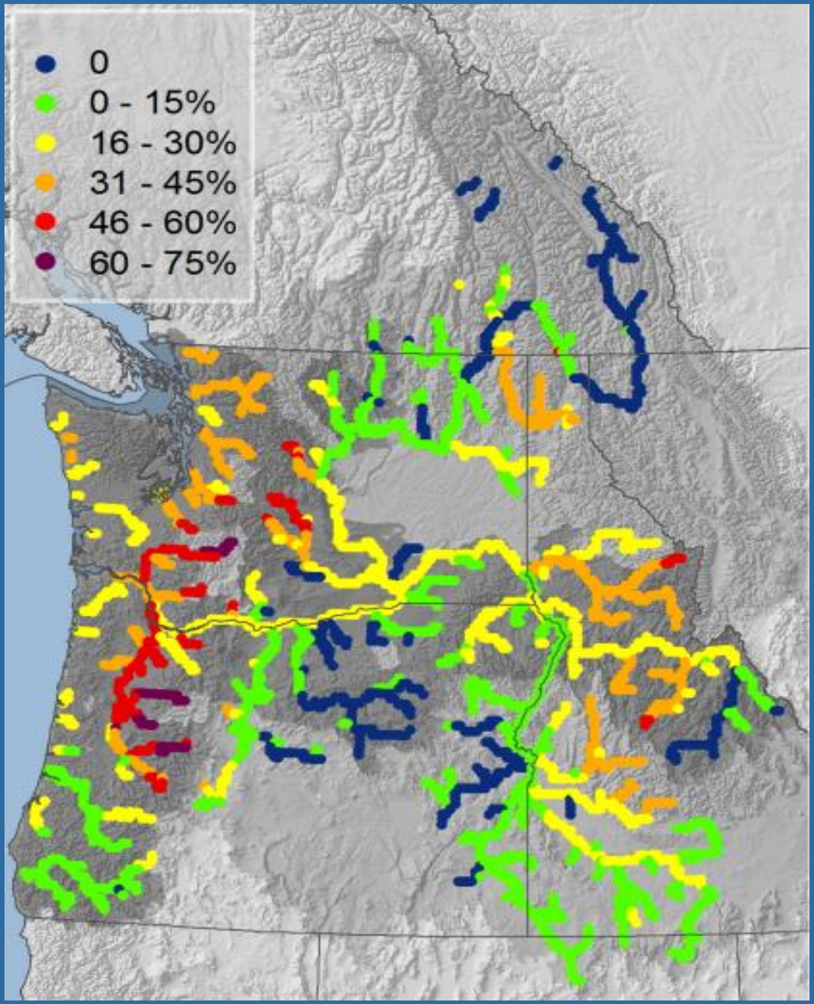


Low latitude and low elevation stream networks will be marginal for sustaining productive salmonine populations

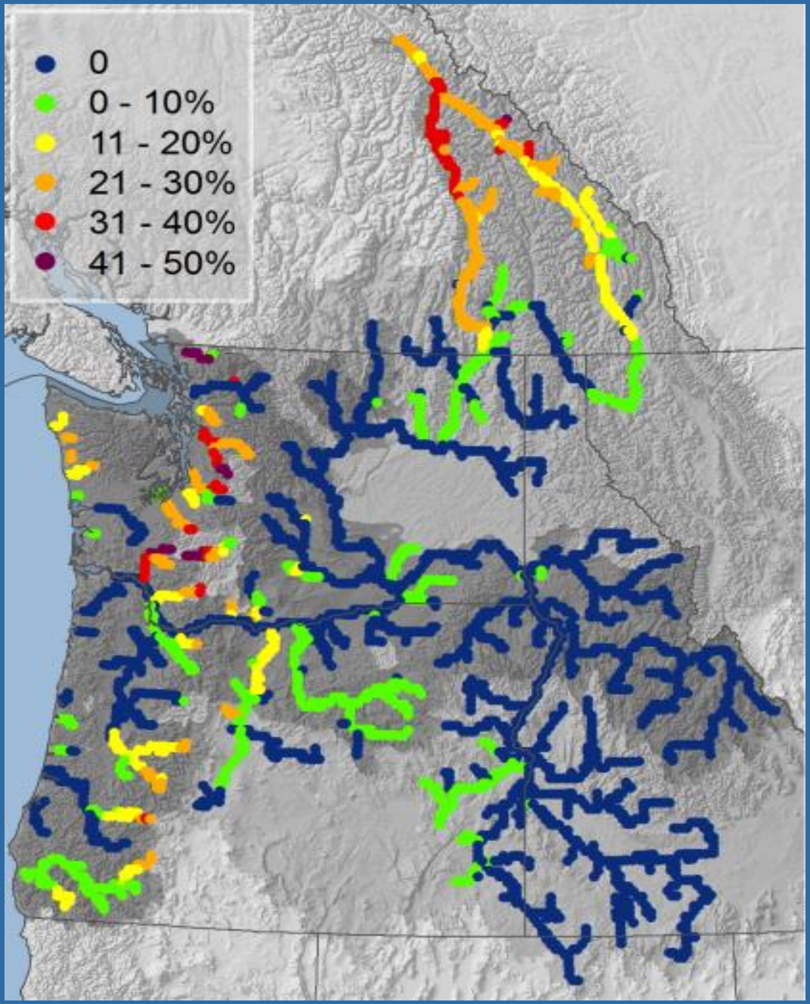
Alisa Wade et al. at NCEAS 2017 Powerpoint

PNW Rivers: % Change in Q by 2080s

% Decrease in Min Flows



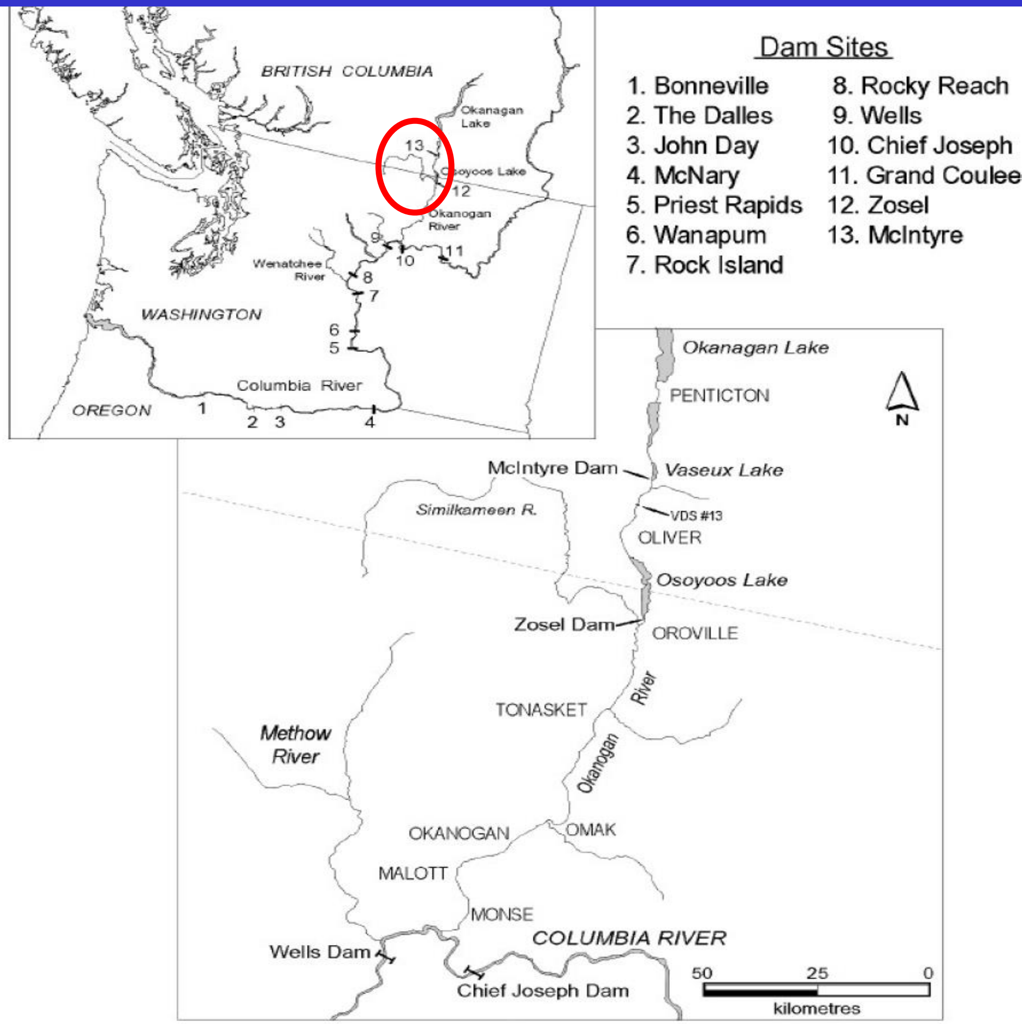
% Increase in Max Flows



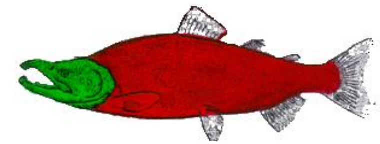
Alisa Wade et al. at NCEAS 2017 Powerpoint

Thermal Regime & Flow Impacts Due to Climate Change

Lessons from Recent Research on Okanagan Salmon



Mid-Columbia Okanagan Sockeye



Spatial and temporal variations in environmental conditions control the frequency, magnitude and duration of life-stage-specific bottlenecks that influence fitness and subsequent population outcomes…

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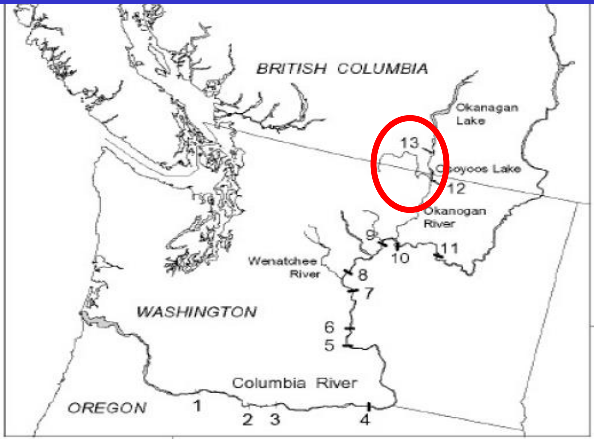

Dam Sites

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3. John Day
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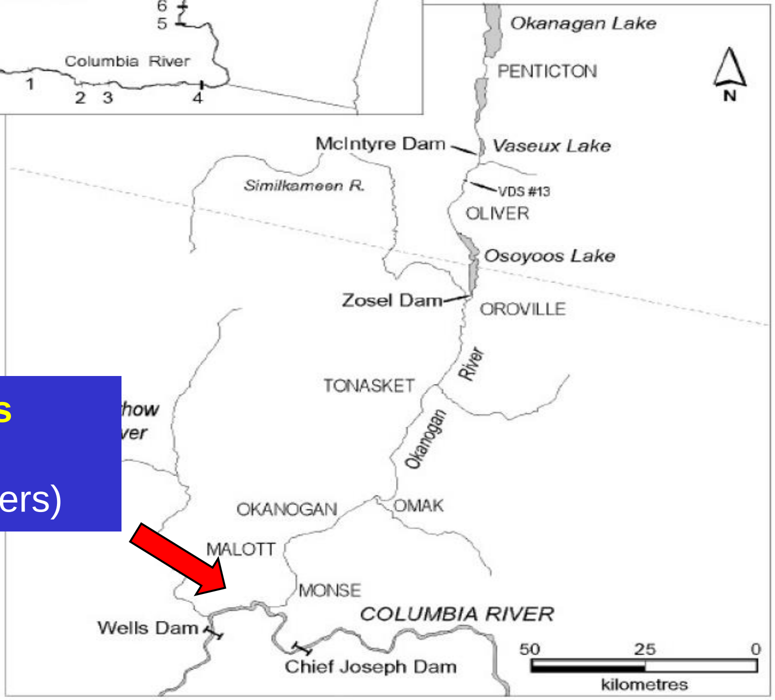

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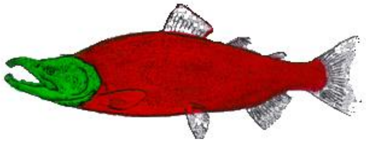

1. **Tributary Access**
   (thermal and/or hydrological barriers)

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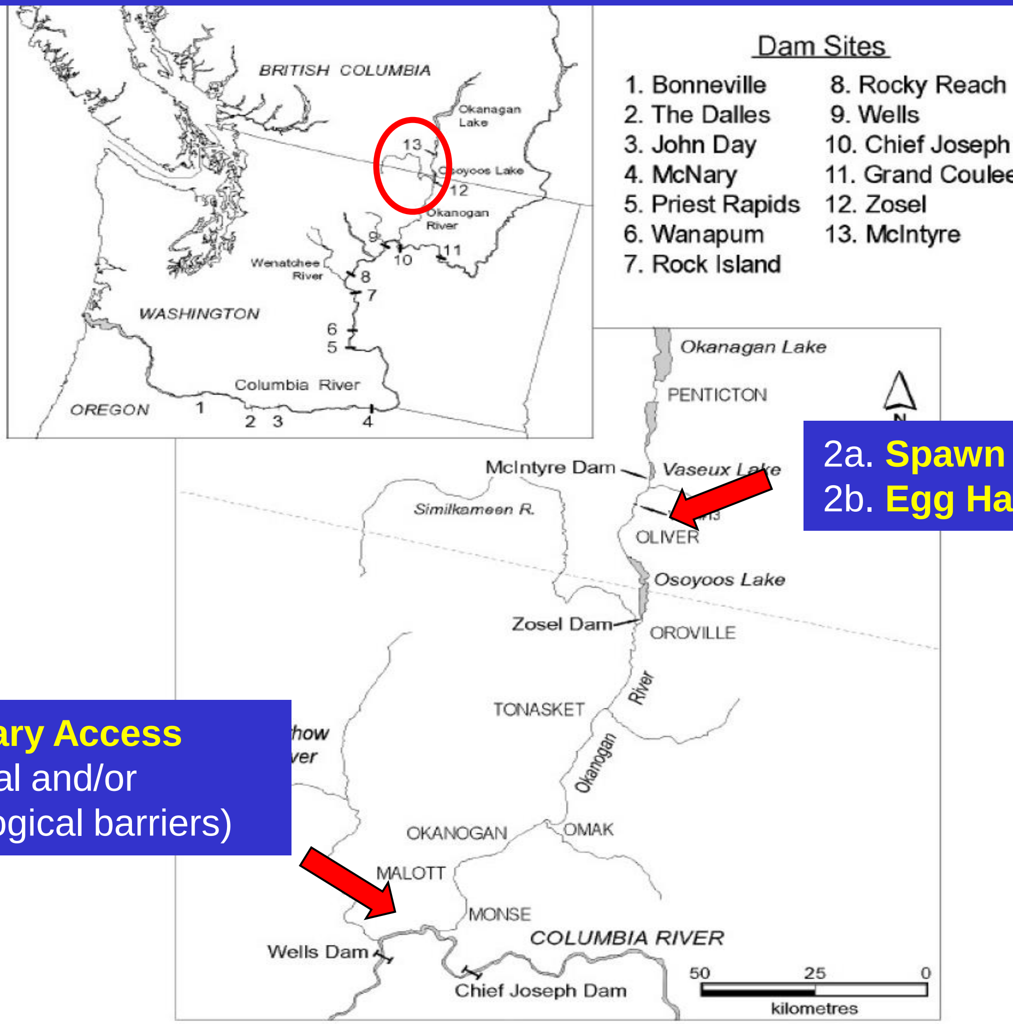

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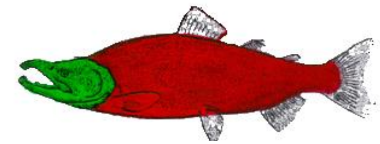

2a. **Spawn Timing**
2b. **Egg Hatch Timing**

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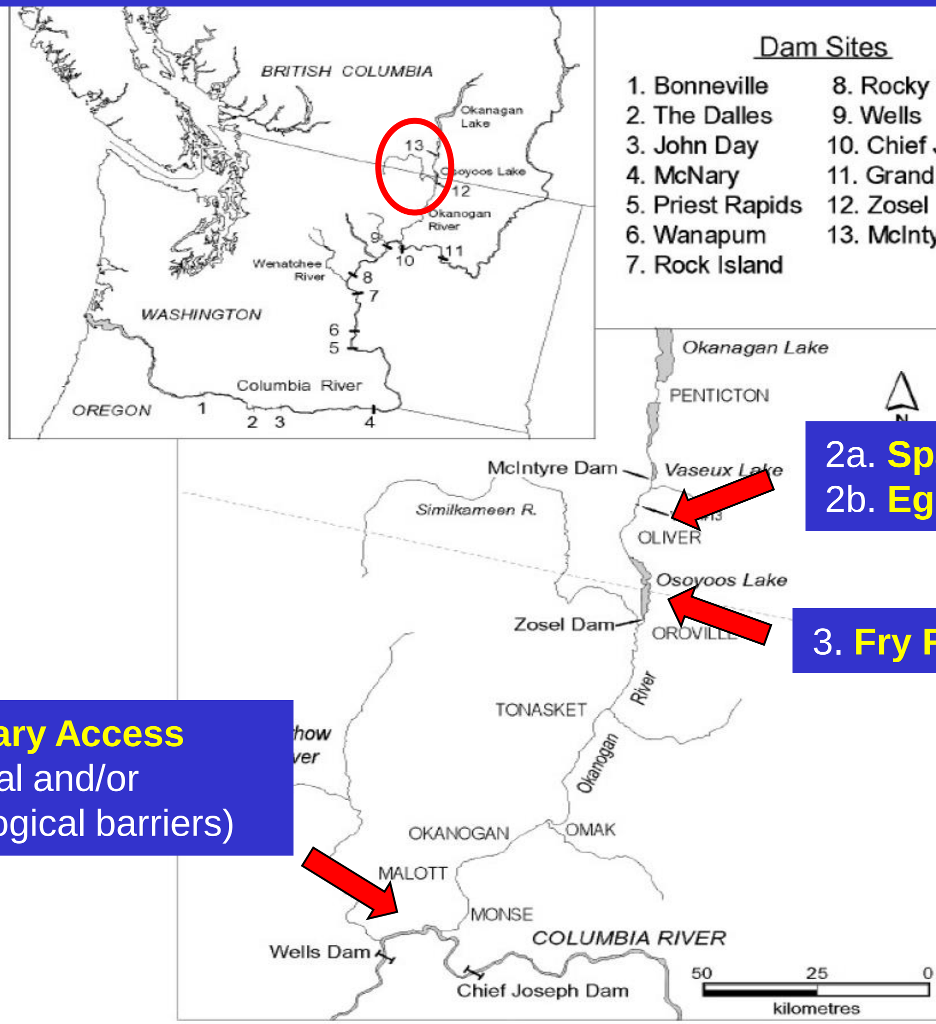

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3. **Fry Rearing** (In-Lake)

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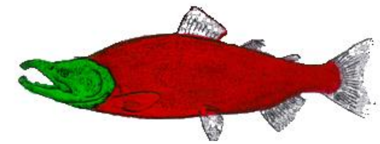

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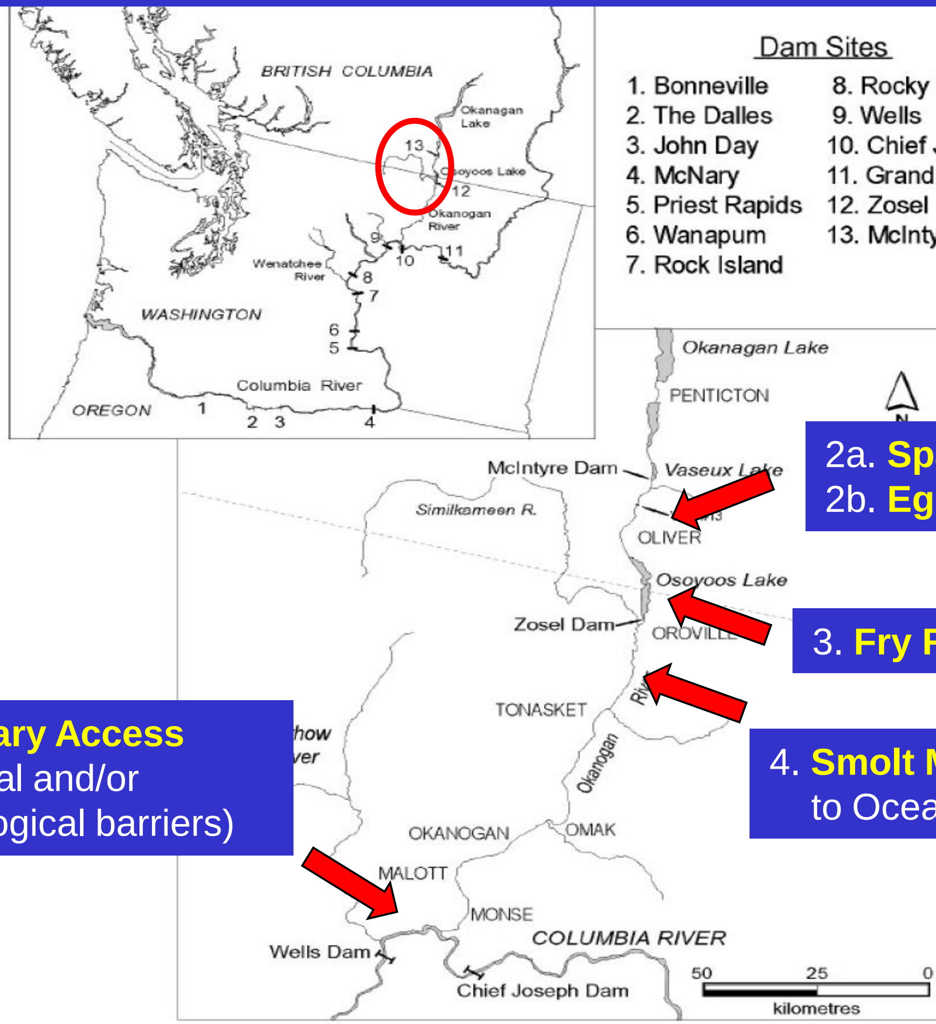

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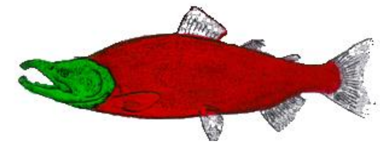

2a. **Spawn Timing**
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4. **Smolt Migration Timing** to Ocean

1. **Tributary Access** (thermal and/or hydrological barriers)

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Tributary Access

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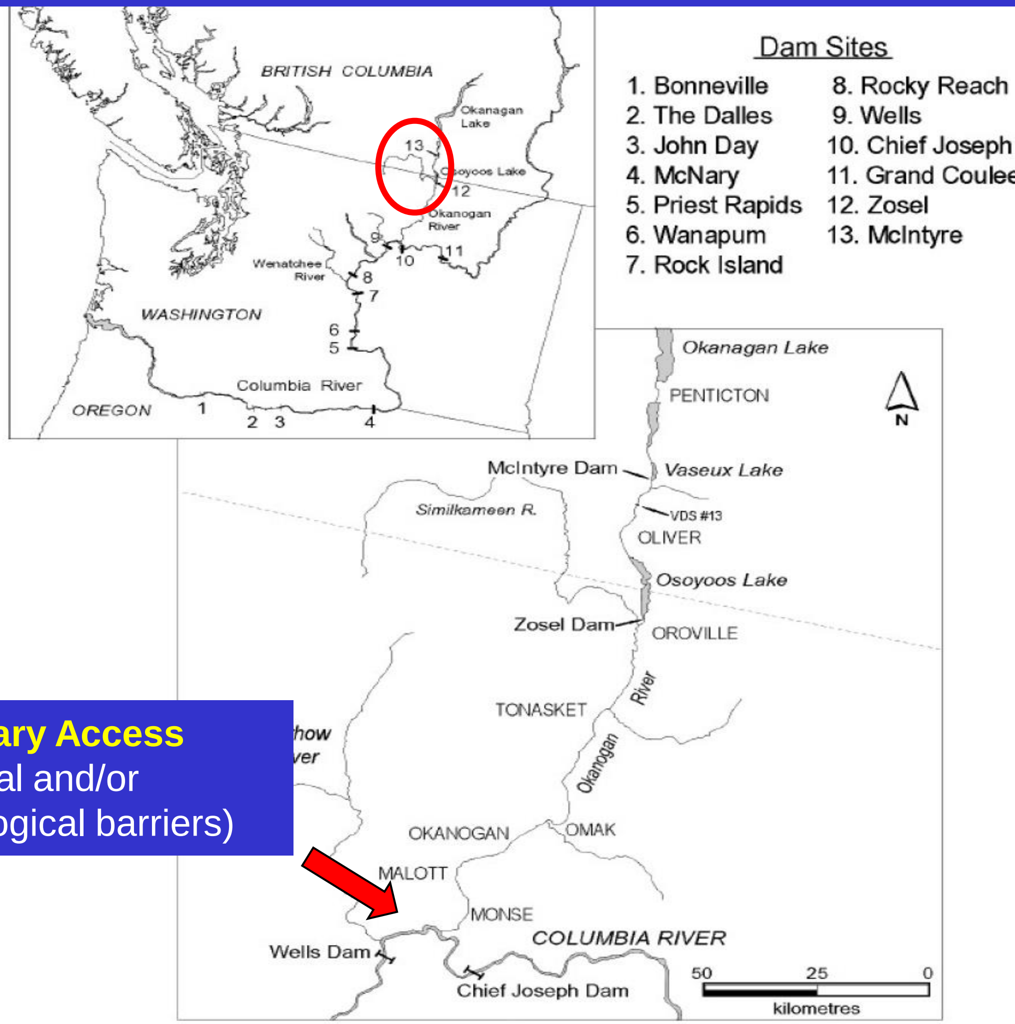

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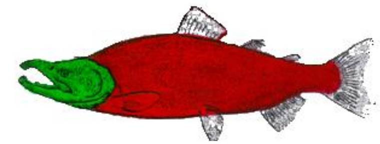
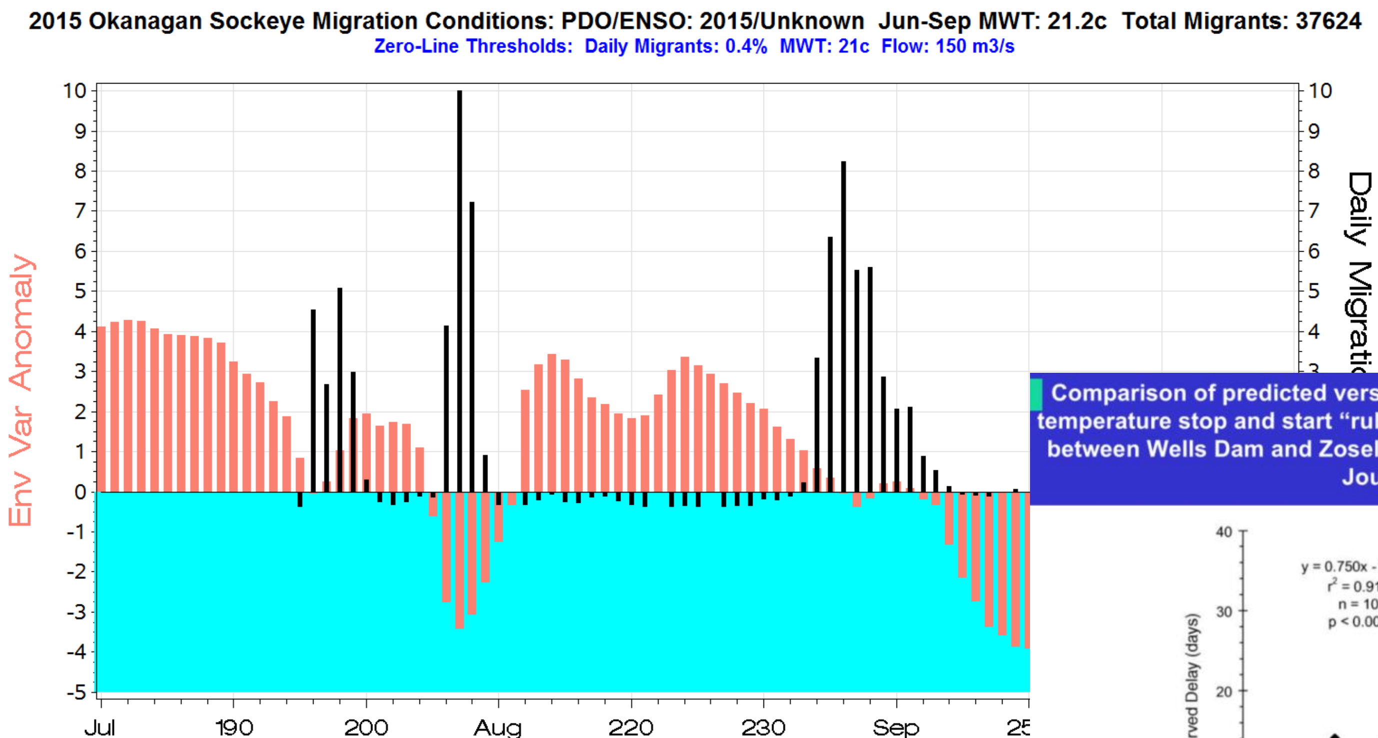


1. **Tributary Access** (thermal and/or hydrological barriers)

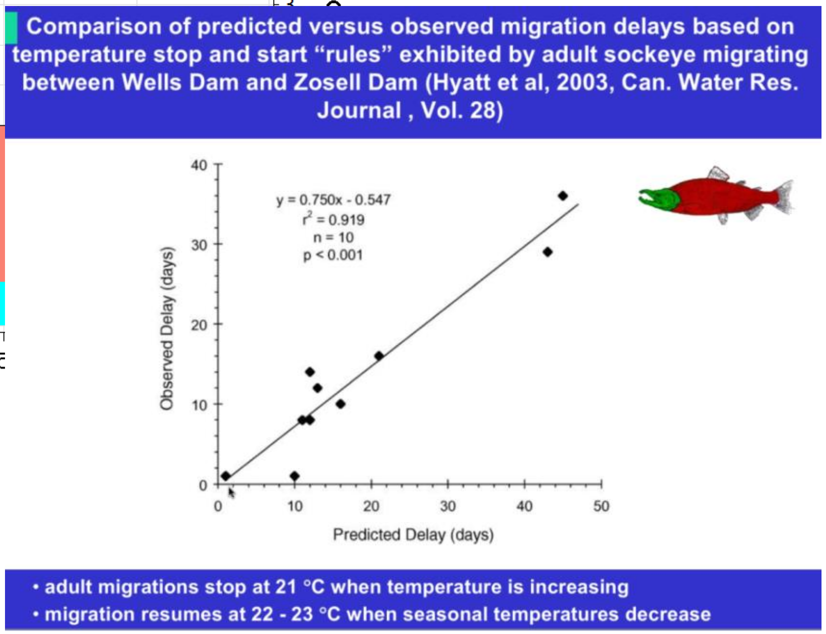
1. Tributary Access: Thermal Barriers

Zosel Dam Counts vs Okanogan Water Temp

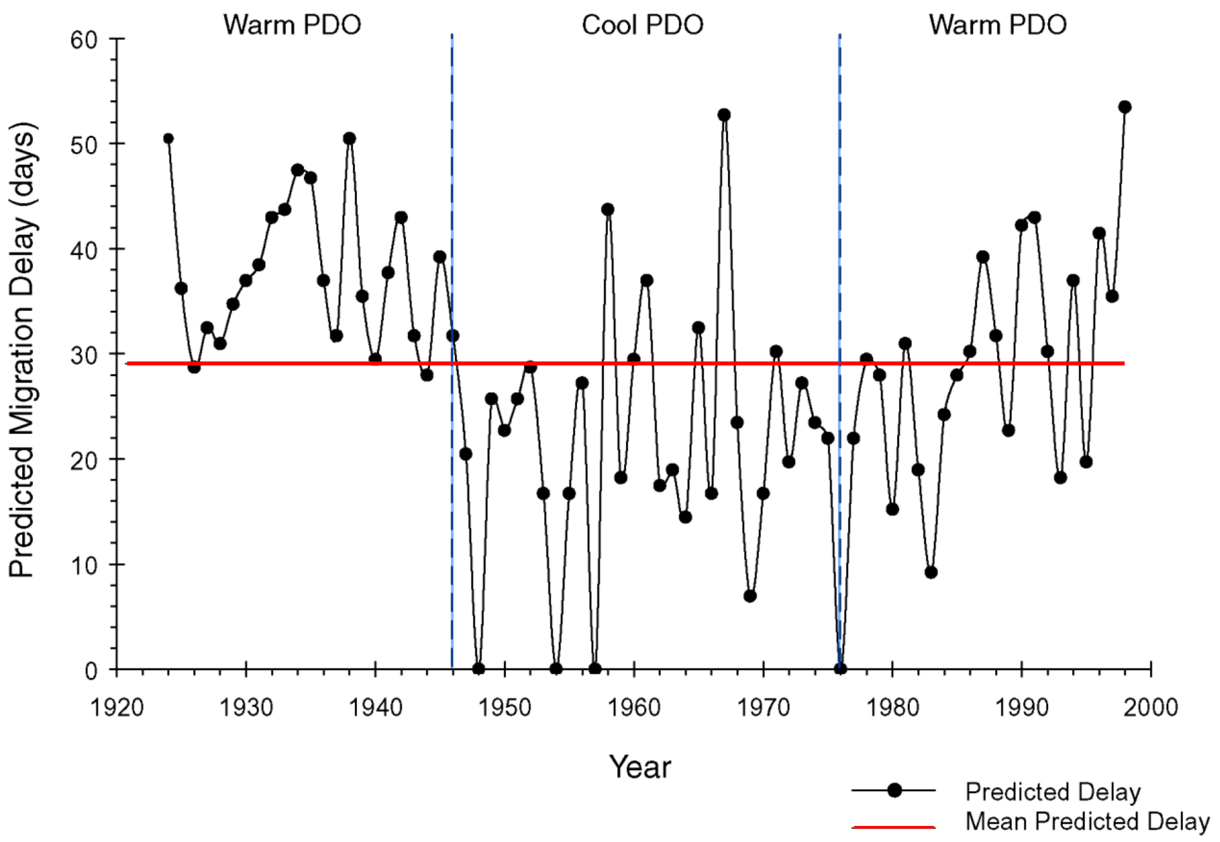


Red bars represent Okanogan daily mean water temperature anomaly in degrees above 21°C. Black bars represent daily migration rate anomaly relative to median daily rate. (Hyatt et al. 2020 - https://waves-vagues.dfo-mpo.gc.ca/Library/40898829.pdf)

Migration delays (#days) at the Okanogan/Columbia junction can be predicted based on Okanogan water temperatures >= 20-21°C.



Tributary Access: Thermal Barriers

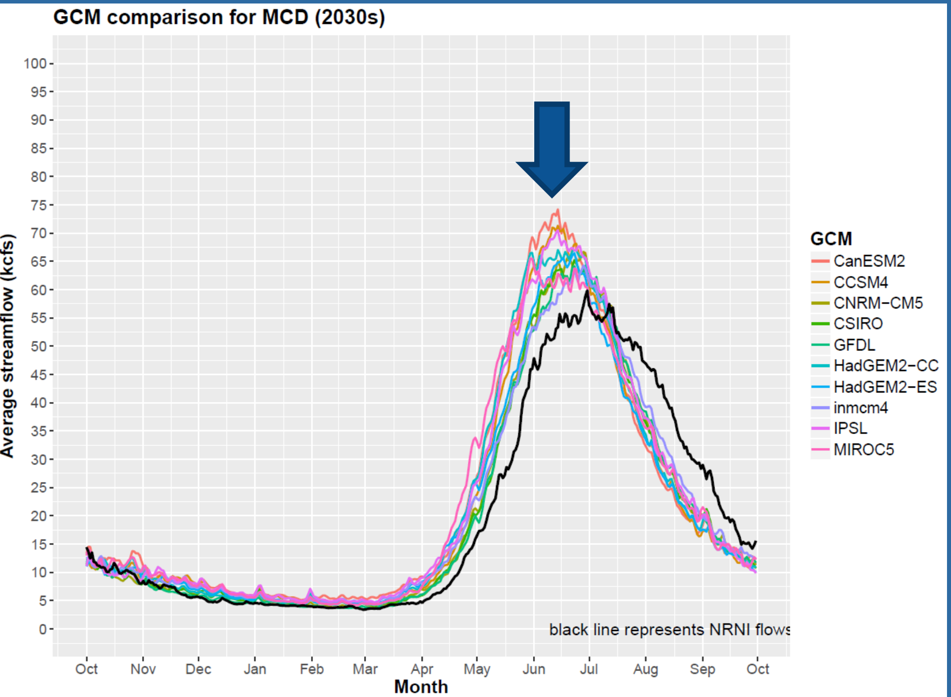


Temperature-based estimates of adult Sockeye migration delays 1924-1998

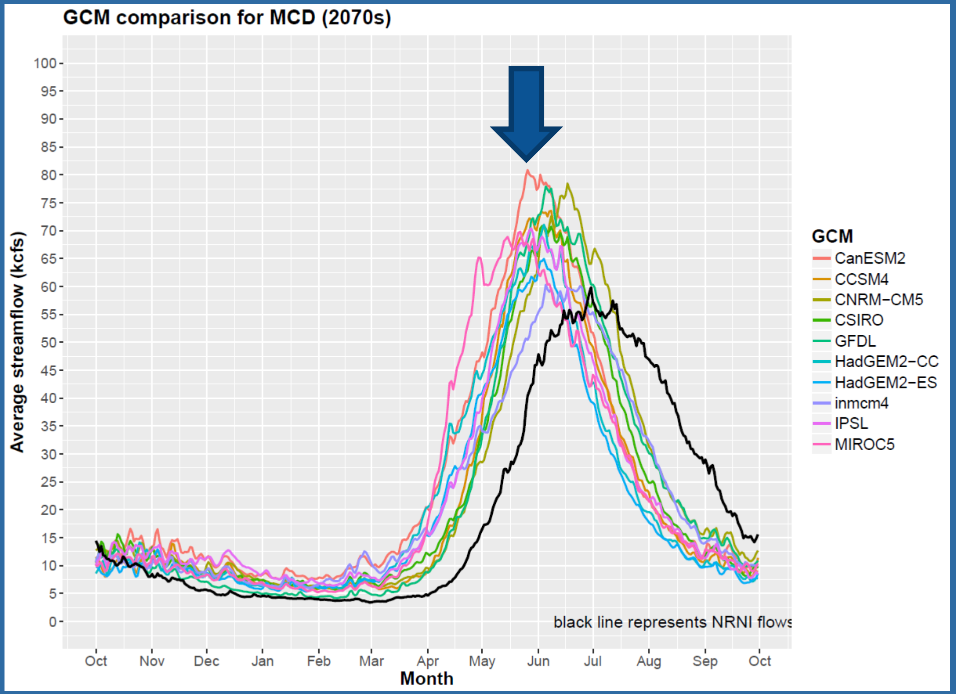
(Hyatt et al. 2003)

Average Mica Inflows: 2030s and 2070s (All Hydro Models)

2030s



2070s



- By 2070s, average higher March-May flows indicated, with more significant June-August decreases
- **Peak spring runoff 1-2 weeks earlier by the 2030s, and about 2-4 weeks earlier by the 2070s**
- **Higher spring peaks** as winter/spring precipitation increases
- 10-20% increase in the frequency and magnitude of **Intense Wet Days**
- **Lower Jul-Aug flows by 2030s** as snowpack diminishes and glaciers deplete

Flood and Scour Events

Spring 2017-2018 in Southeastern BC

Okanagan's Mission Creek
May 2017 at 100 m3/s

Kettle River
May 2018

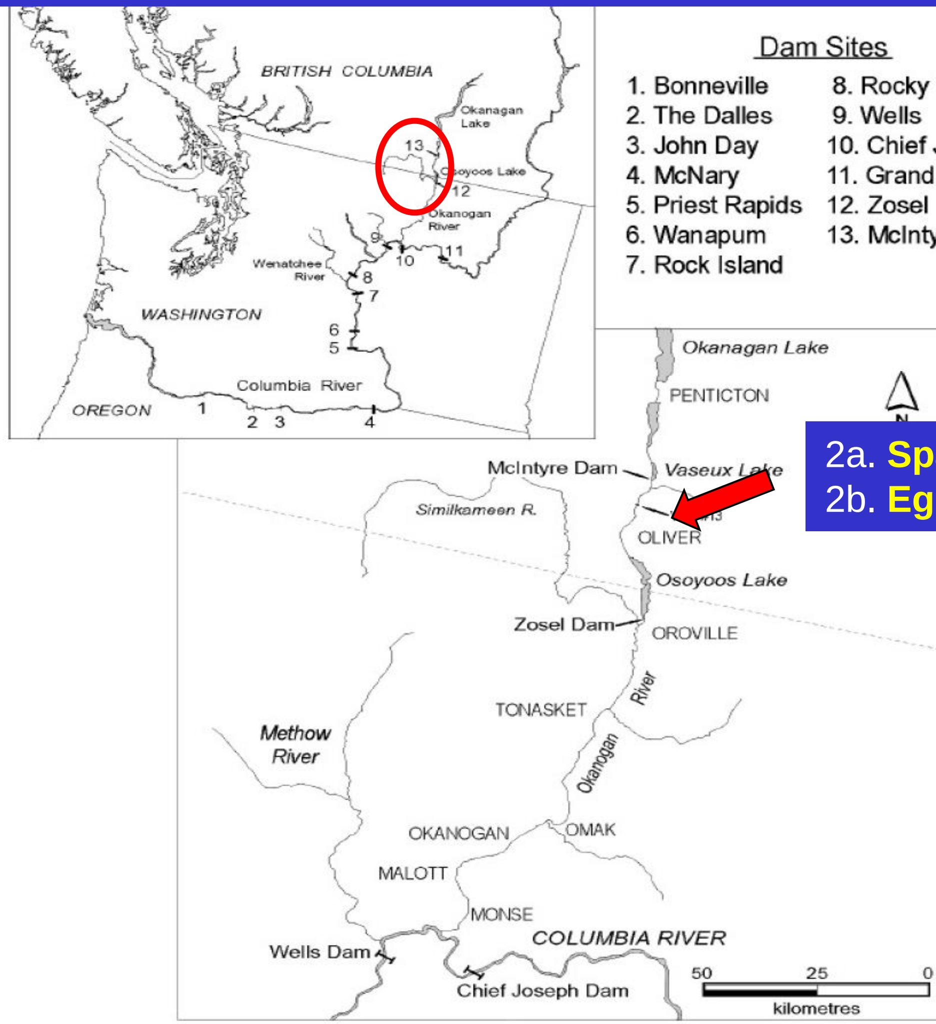
Anomalous flow events induced by climate change will alter habitat for aquatic biota with increased frequency…

1. Tributary Access: Sediment Barriers

Tributaries blocked to fish passage

2. Spawn Timing and Egg-Hatch Timing

Lessons from Recent Research on Okanagan Salmon



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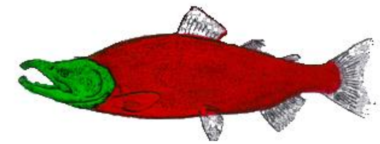
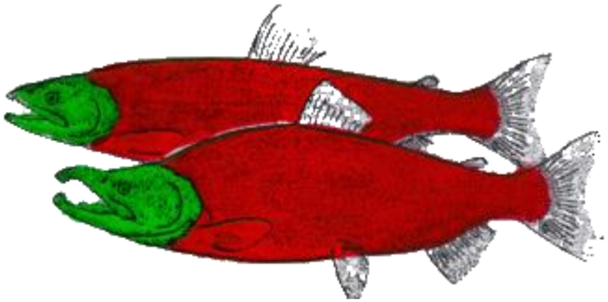
2a. **Spawn Timing**
2b. **Egg Hatch Timing**

Mid-Columbia Okanagan Sockeye



2a. Spawn Timing Impacts

Thermal Warming Delays Date of Peak Spawn

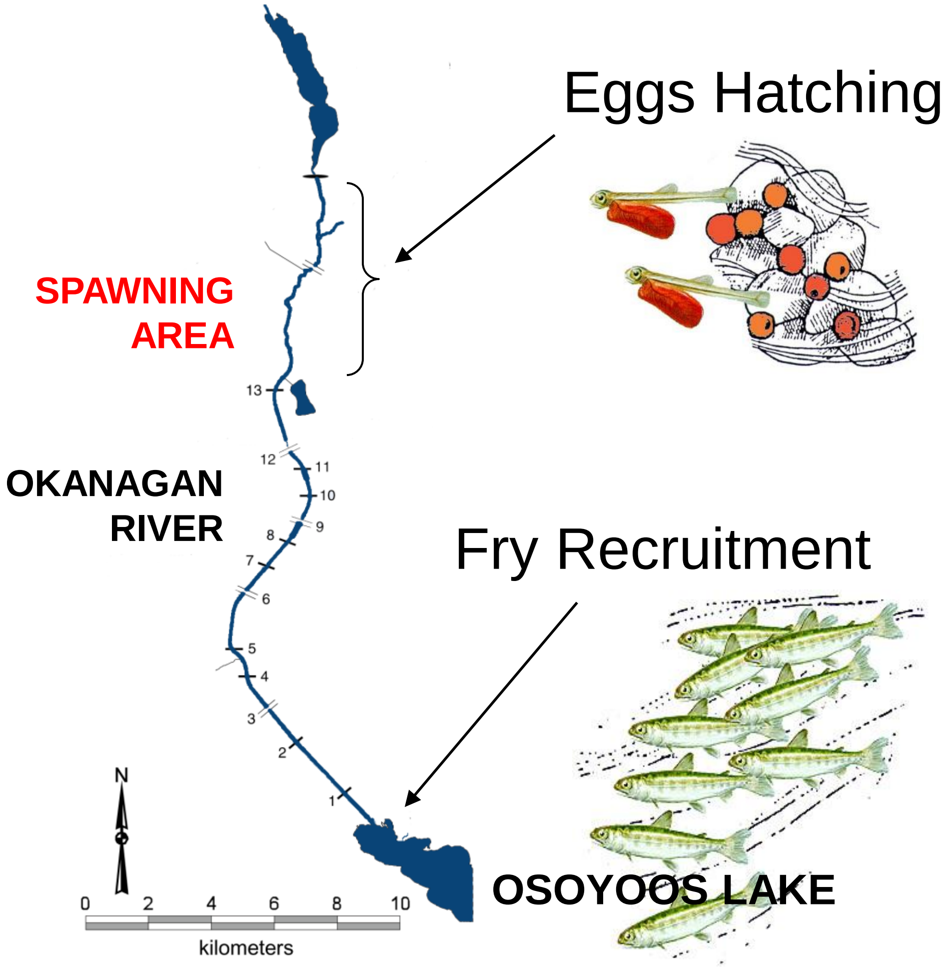


"Cool" Period 1947 - 1985	"Warm" Period 1985 - 2000
October 11th (Oct. 3 - Oct. 19) n = 11	**October 19th** (Oct. 10 - Oct. 24) n = 12

Peak spawning by Sockeye **delayed 9 days**, on average, during recent "warm" interval (Hyatt et al. 2003)

2b. Egg-Hatch Timing Impacts

Delayed

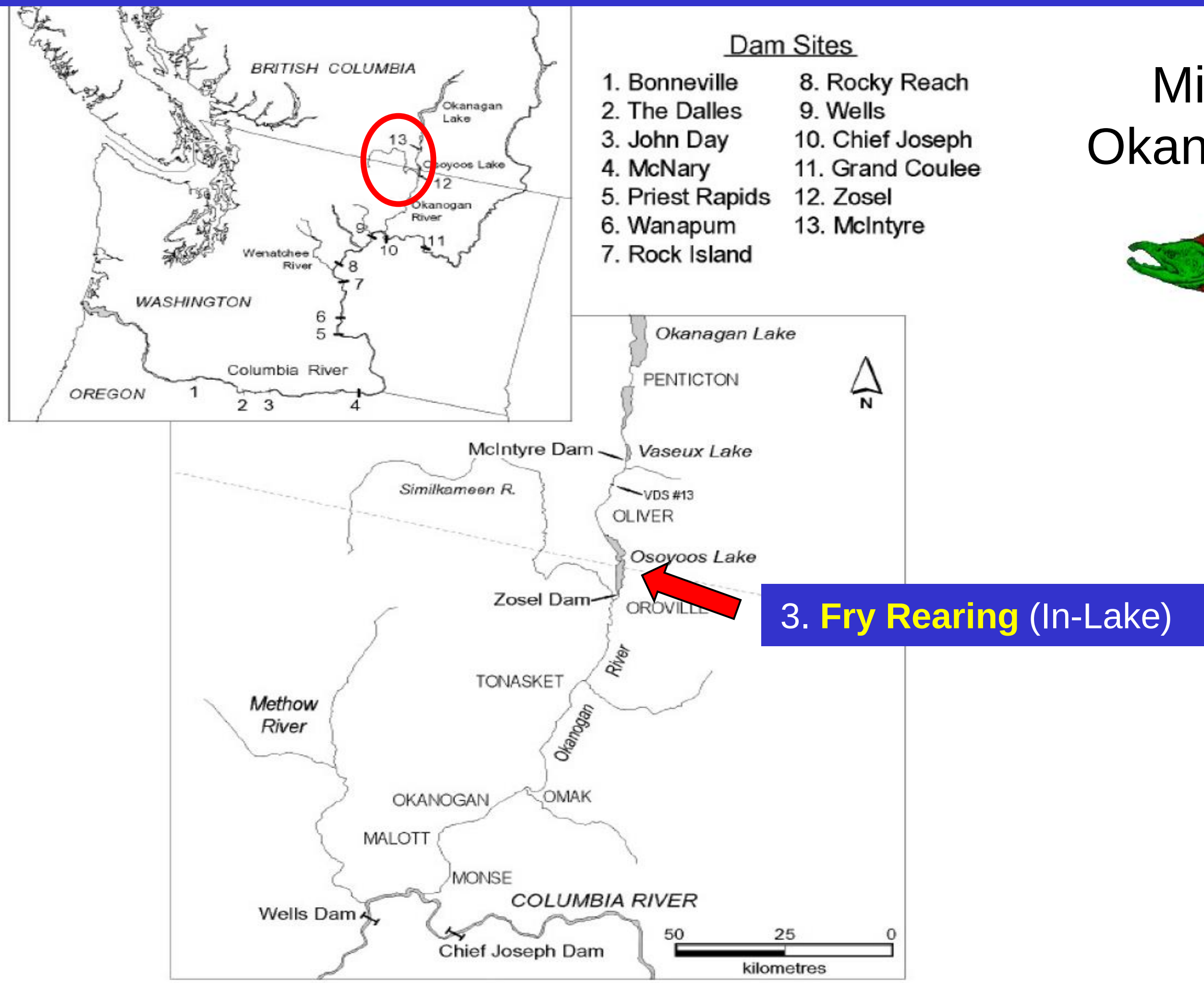


"Cool Period" 1947-1985	"Warm" Period 1985-2001
Peak Hatching Dates	
Feb. 16 Dec. 03 – Apr. 09 n = 10*	Mar. 03 Feb. 05 – Mar. 26 n = 11*

Counter-intuitively, **Peak Hatch Date** was **delayed by ~15 days during warm intervals**.

3. Fry Rearing (In-Lake)

Lessons from Recent Research on Okanagan Salmon



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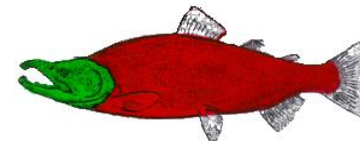
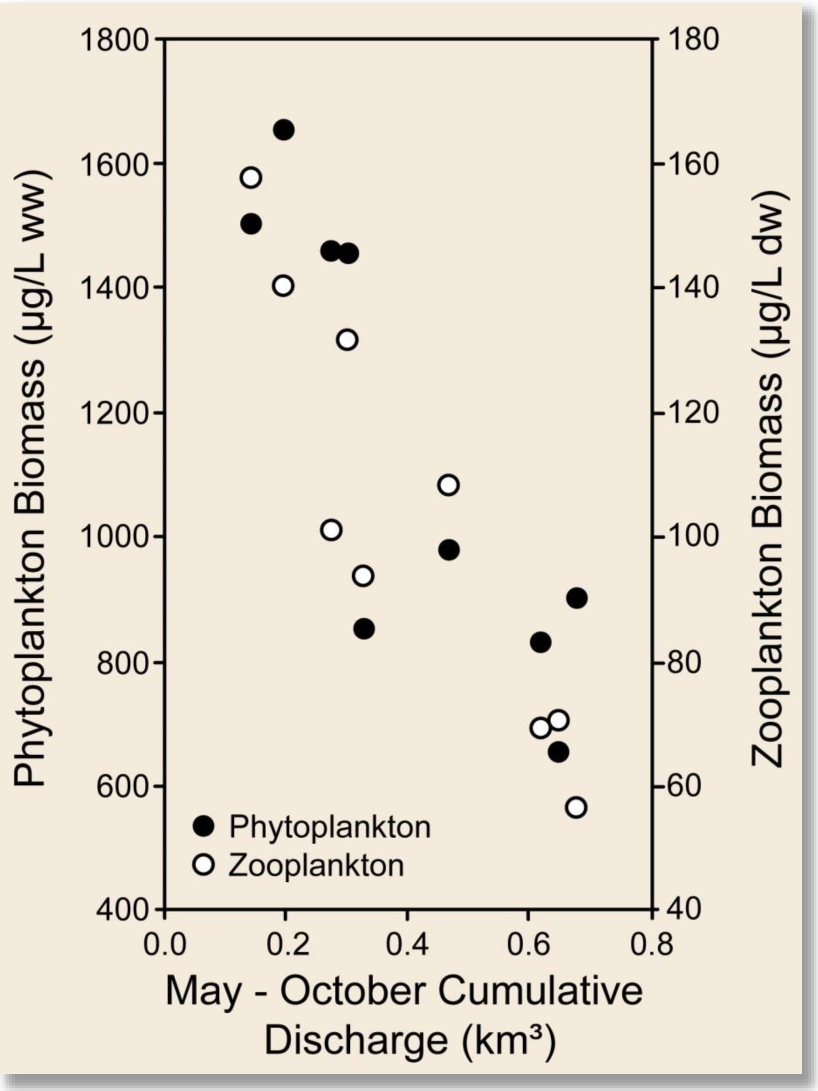
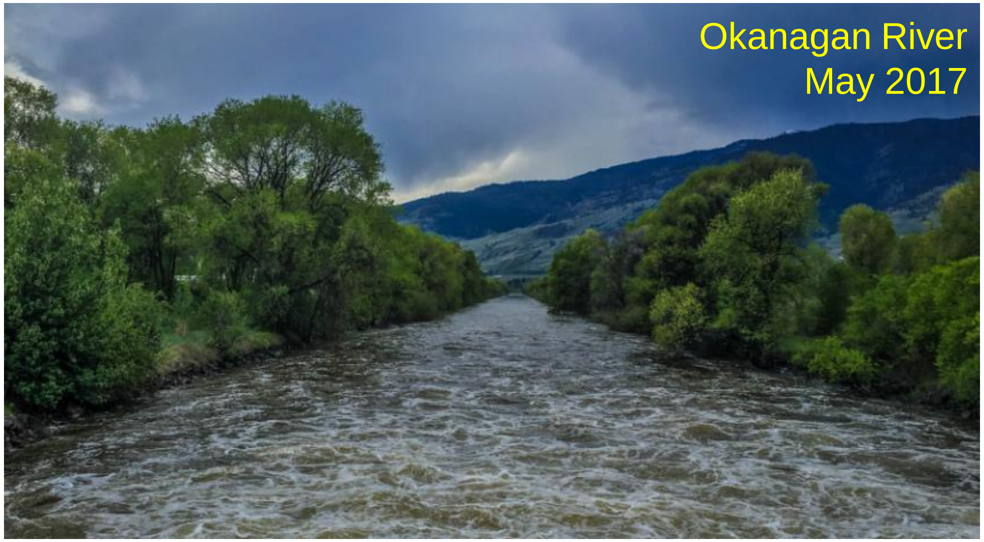


3. Fry Rearing (In-Lake)

River flows control phytoplankton & zooplankton biomass of lake food-webs





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 changes in annual levels of food available to fish in rearing lakes

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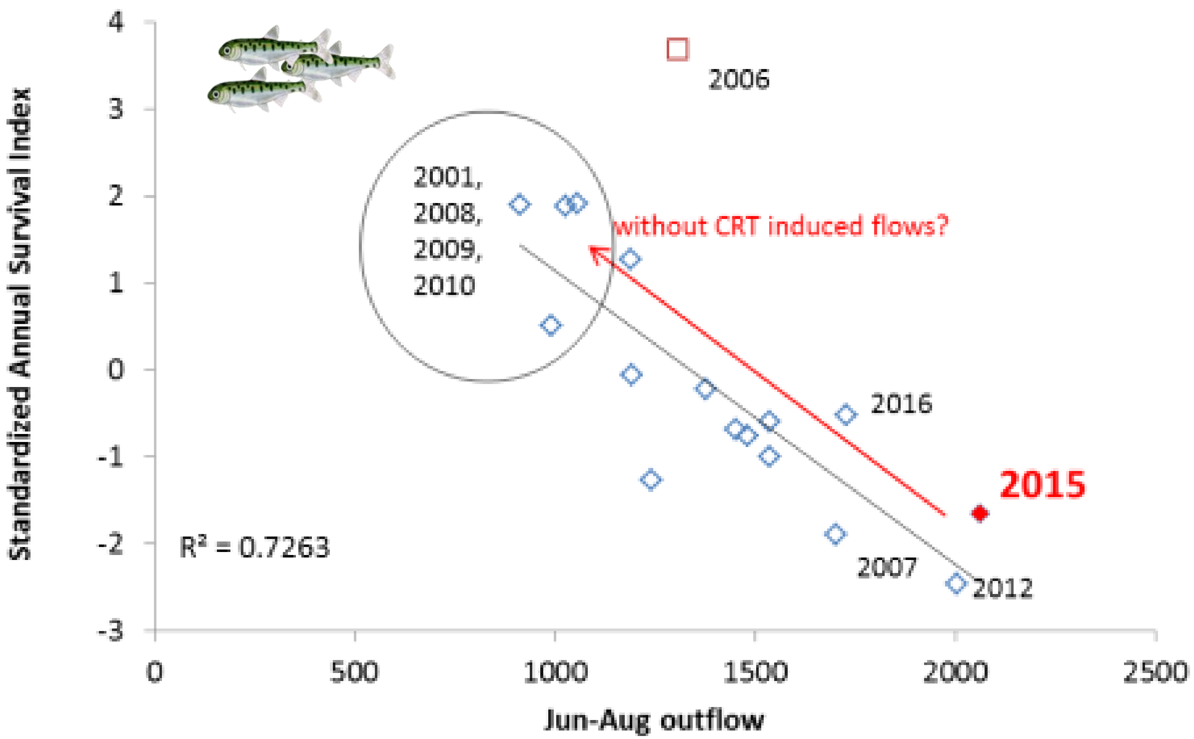
Arrow Lakes Kokanee Survival



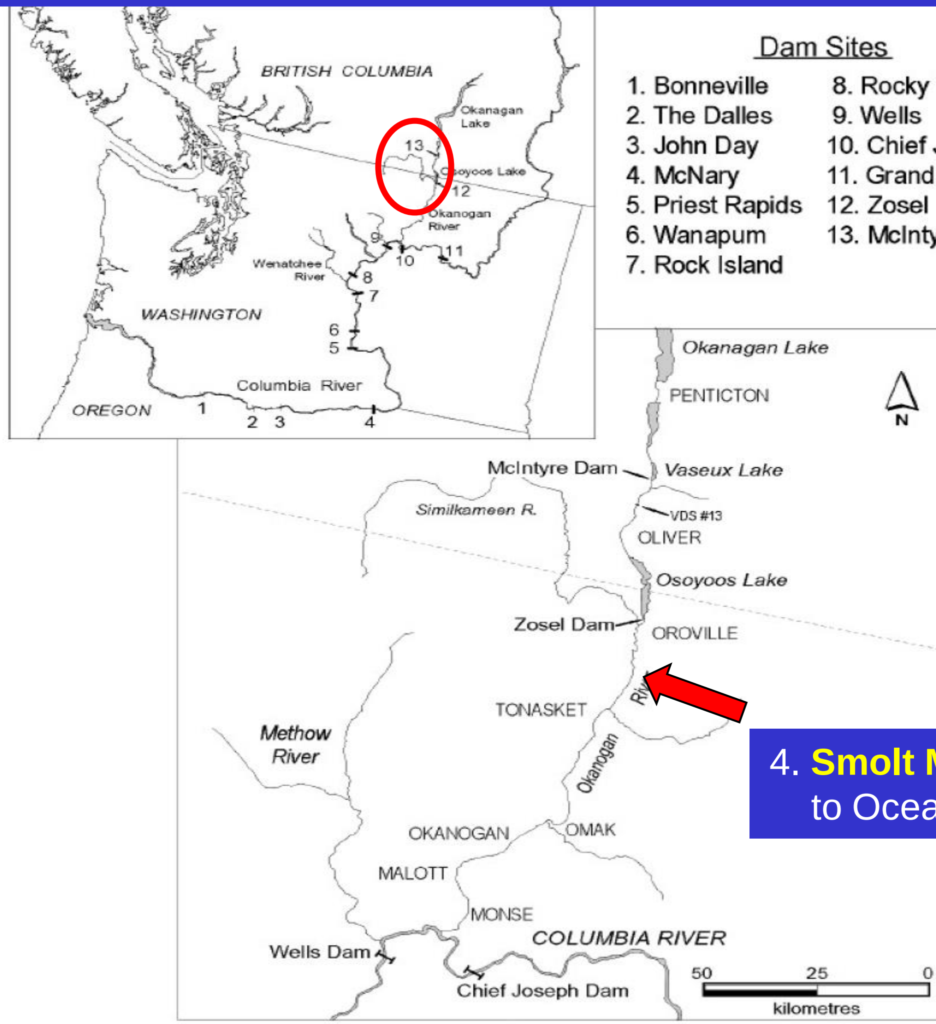
W. Warnock (BC FLNRORD)

Physical Drivers of Biota

- Discharge (dam spill) levels on food available to fish in rearing lakes drive survival of planktivores

4. Smolt Out-Migration to Sea

Lessons from Recent Research on Okanagan Salmon



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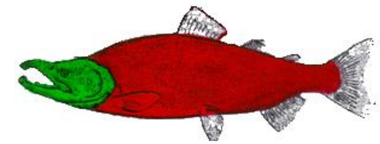


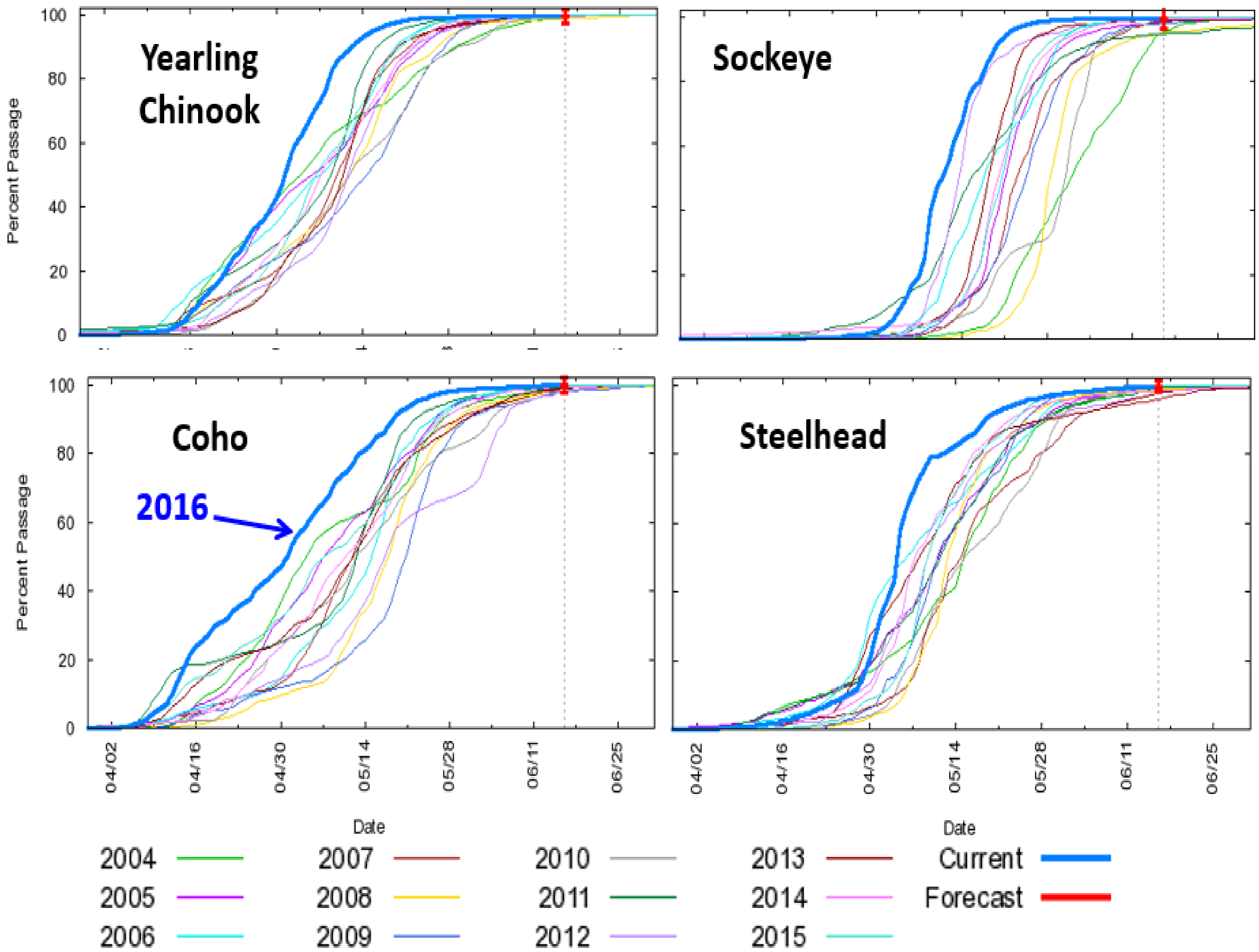
4. **Smolt Migration Timing** to Ocean

4. Smolt Seaward Migration

1-2 Weeks Earlier in Warm Years

Spring Smolt Migrations

Match-mismatch consequences at ocean entry?



In 2016 >50% of salmon smolts migrated seaward more than a week earlier than the all-year average (i.e. May 12th vs May 23rd)

Conclusions

- Discharge and thermal regimes in the Columbia River are influenced by climate change as well as by hydro-system management.
- Sustainability of sensitive aquatic biota and restoration of threatened or extirpated populations constitute a challenging central socio-ecological issue to current and future management of the Columbia River.
- For example, success in sustaining or restoring wild salmon populations over 50 years in the Columbia Basin has been limited and climate change will likely complicate the task going forward.
- Narrowly focused performance metric models will provide insight into hydro-system management and climate interaction outcomes for a few well-studied, ecosystem components of high value.

Thank-you! Questions?