Impacts of Climate Change on Fish Passage and Reintroduction

Future of Our Salmon Conference

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Outline

Understanding Climate Change

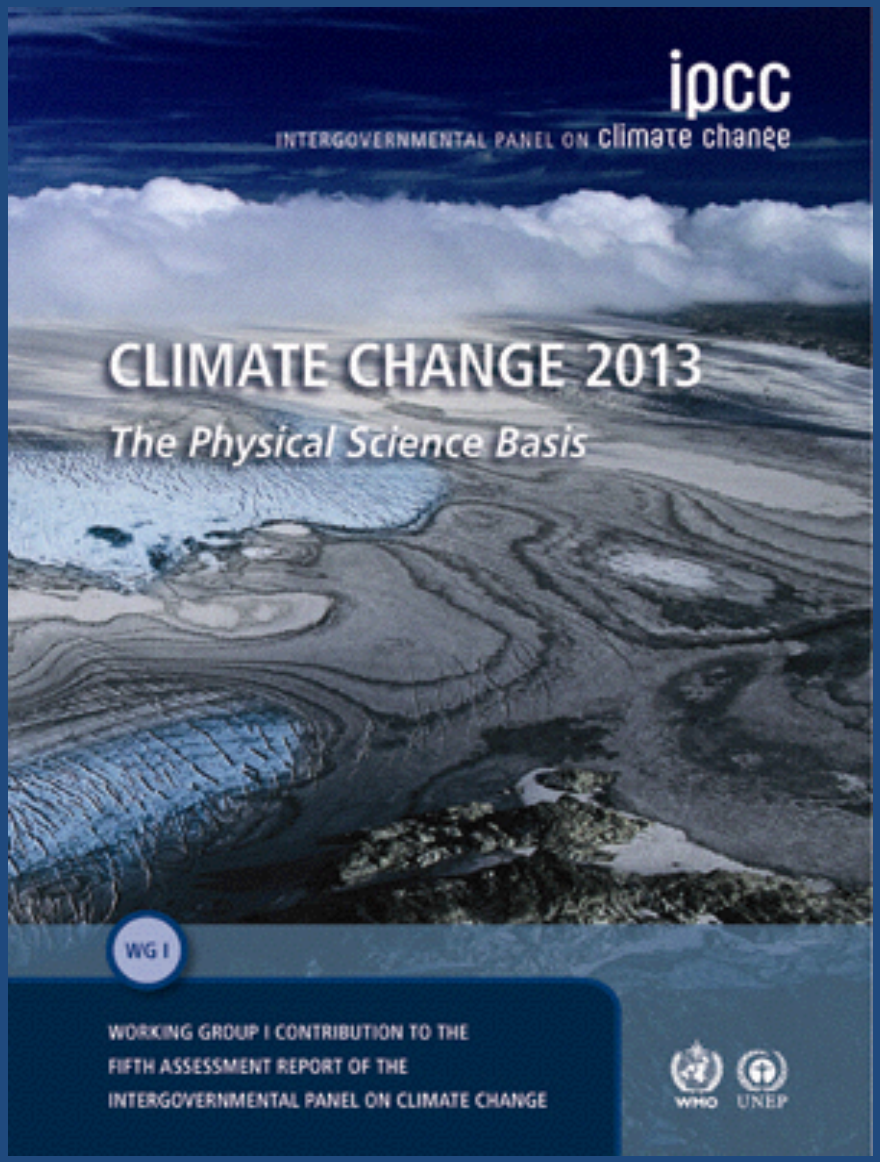
Defining Fish Vulnerability to Climate Change

Potential Adaptive Management Frameworks, Strategies and Tools

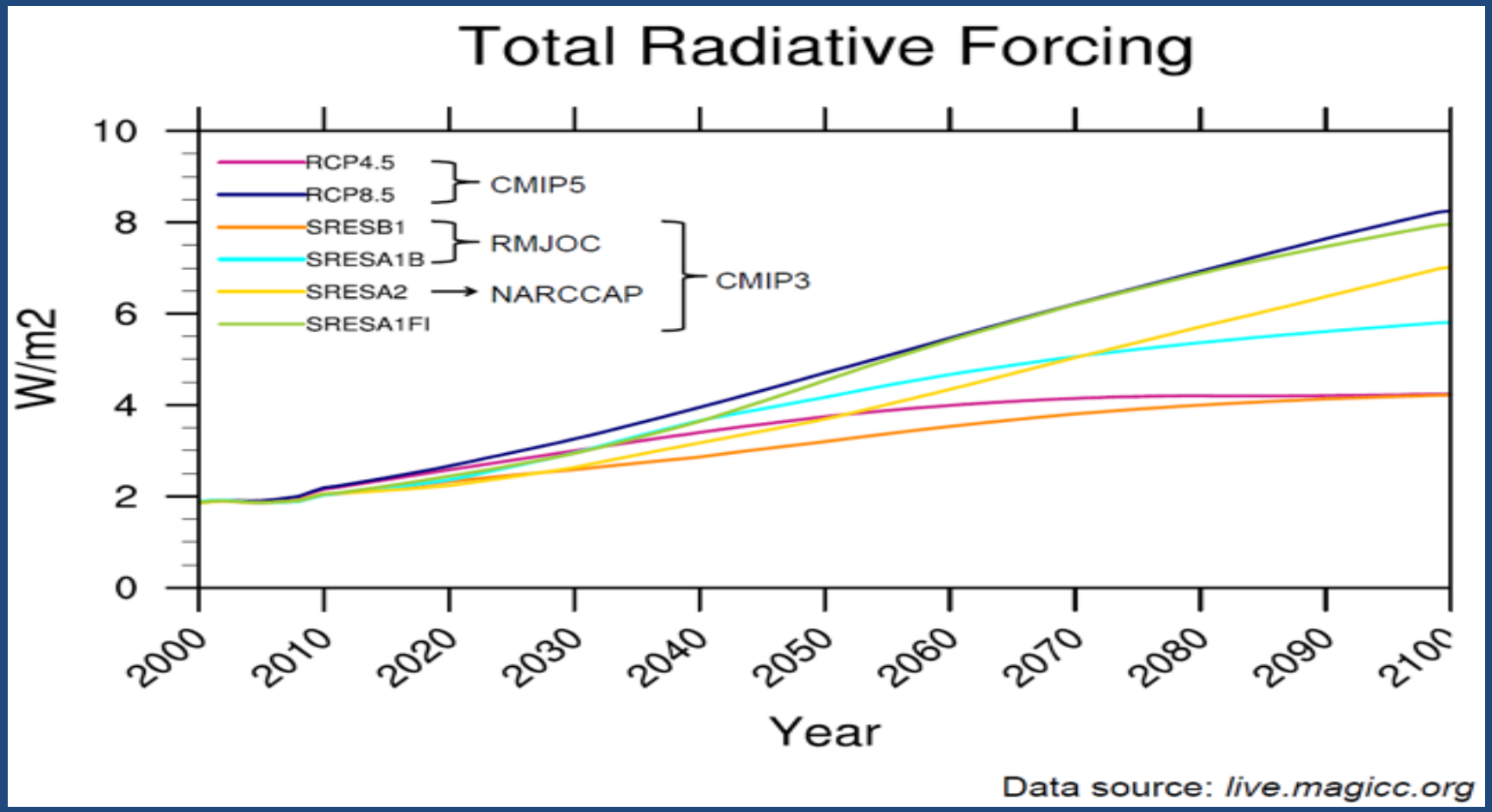
Collaborative Challenges

IPCC: International Panel on Climate Change

- Established by the United Nations: 1988
  - Lead international research body on climate change
  - Reports on State-of-the-Science on climate change and latest/best forecasts every 5-7 years
- Report (IPCC-4) in 2007
  - Used about a dozen Global Climate Models (GCMs) from the Coupled Model Inter-comparison Project (CMIP-3)
- Latest Preliminary Report (IPPC-5) in 2013:
  - Used numerous improved GCMs from t**he** Coupled Model Inter-comparison Project (CMIP-5: i.e. atmospheric,ocean, land models linked, includes effects of other gases)



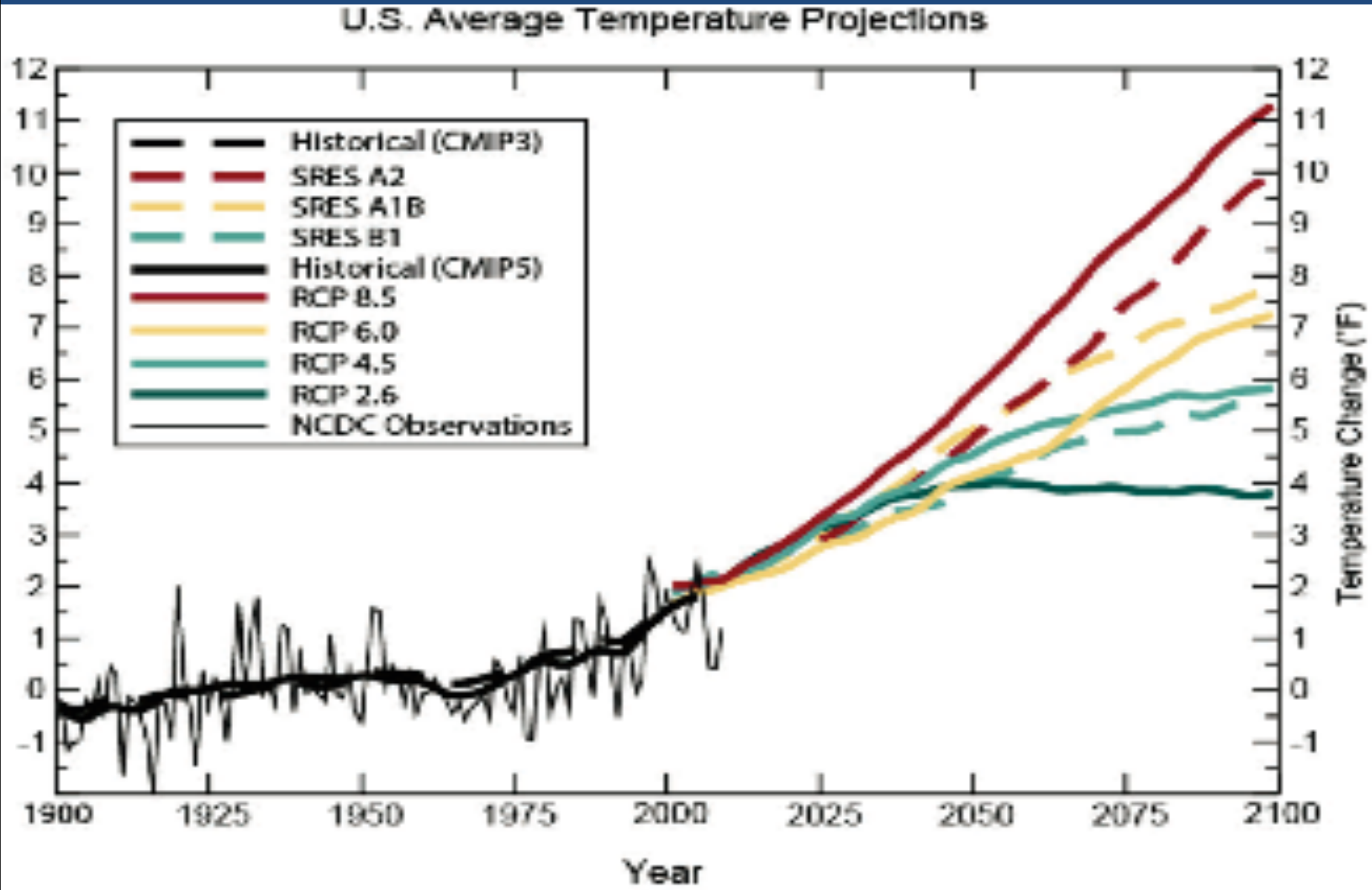
Climate Change- Increase in Radiative Forcing (wave energy reflected to Earth)



Current CO_2 levels: 400 ppm

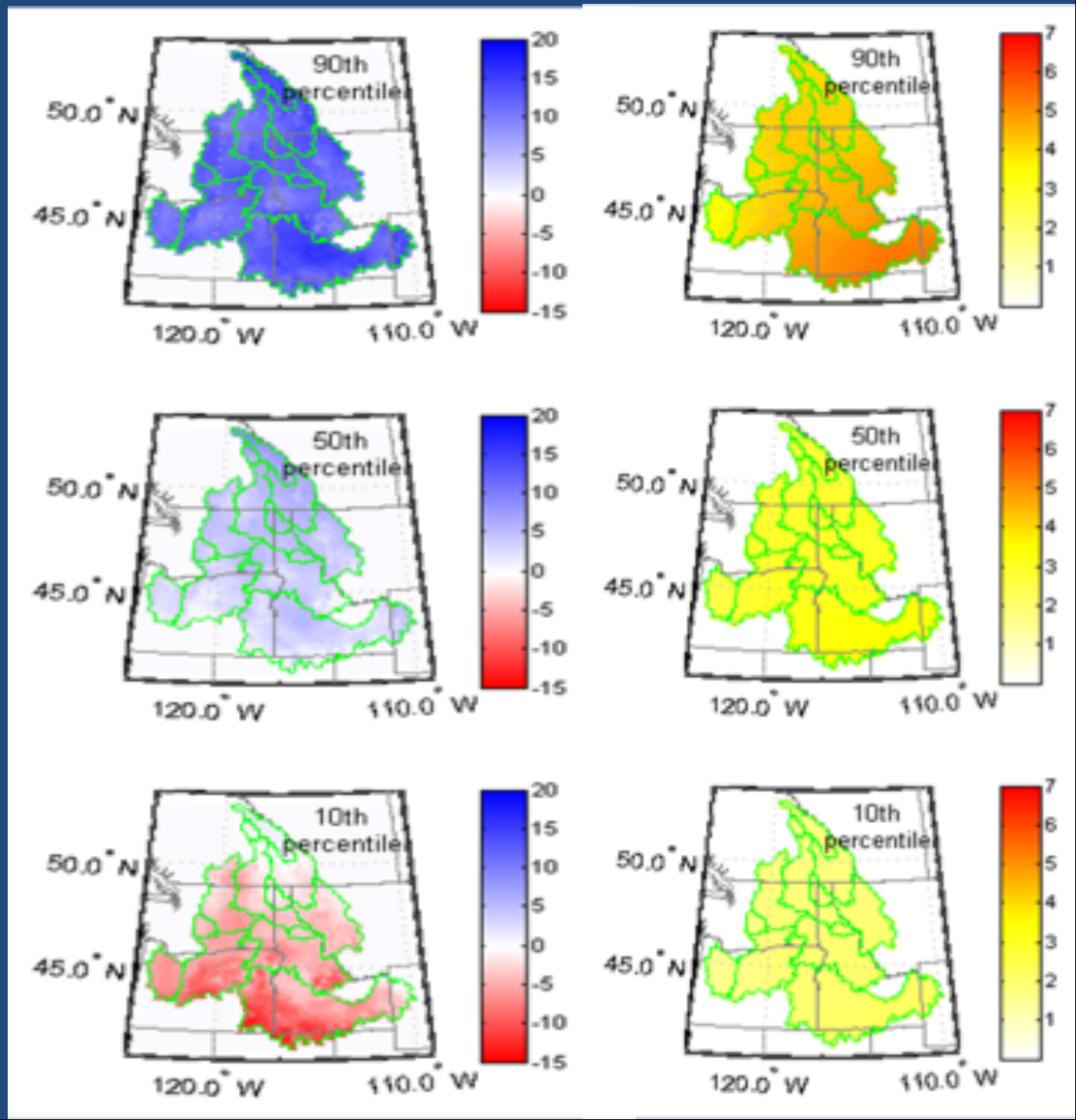
Most likely range by 2040: 480 (RCP4.5) to 550 ppm (RCP8.5)

Climate Change Induced Temperature Changes (National Climate Assessment 2013)



Global Climate Model Results For CRB from 2007 IPPC-4 (Coupled Model Intercomparison Study:CMIP3)

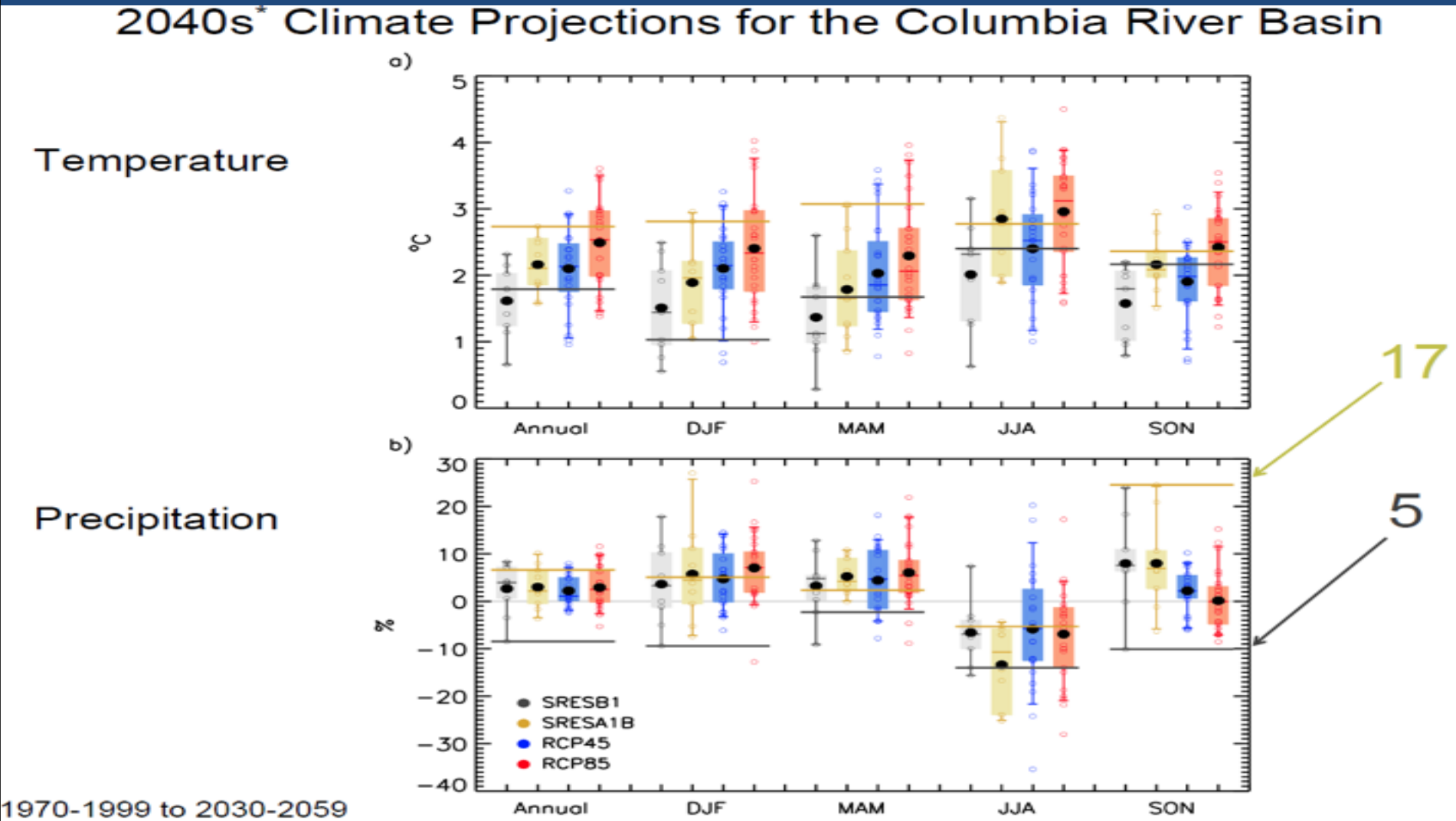
- Annual 2-6°F (1.5-4°C) warming by the 2040s
  - Warmer in the interior than the coast, particularly in summer
- Annual precipitation range from 20% decrease to 15% increase by the 2040s
  - Drier conditions in Snake River Basin and increased precipitation in BC



IPCC-5 *Preliminary* "Findings" Statements

Scientific Consensus	**IPCC-4 (2007)**	**IPCC-5 (2013)**
The earth's atmosphere is warming because of increasing greenhouse gases	Unequivocal	Unequivocal (0.89°C since 1900)
In the Northern Hemisphere, the last 30 years are the warmest than at any time since 600 AD.	Not in report	**Likely**
Human activity is causing the warming	Very likely	**Extremely likely**
Sea level rise is occurring due to global warming	Likely	**Very Likely**
The earth's atmosphere will continue to warm for the rest of the century	Likely in the 2.0-4.5°C range by 2050-2100	**Likely in the 0.9-2.6°C range** (1.1-4.8°C by 2100)
Atmospheric sensitivity to increasing greenhouse gases	Very sensitive; rapid warming likely	Sensitive, but **warming is likely to be gradual**
Heat waves have increased due to global warming	More likely than not	**Very likely**
Droughts (number and intensity) have increased due to global warming	Unsure	Possible
Sea levels will rise 0.3-0.8m by 2100	Possible	**Likely**
Extreme precipitation events will increase and intensify	Likely	**Very likely**
Tropical cyclone intensity will increase due to global warming	Unsure	**More likely than not**
Temperature forecast level of confidence at ***global scales***	High	High
Temperature forecast confidence at ***regional scales***	Low-moderate	Low-moderate
Precipitation forecast level of confidence at ***global scales***	Low	Moderate
		Low (moderate in a few areas, but Pac NW isn't

Comparison of 2007 (CMIP 3) and 2013 (CMIP 5) GCMs Downscaled for the Columbia Basin

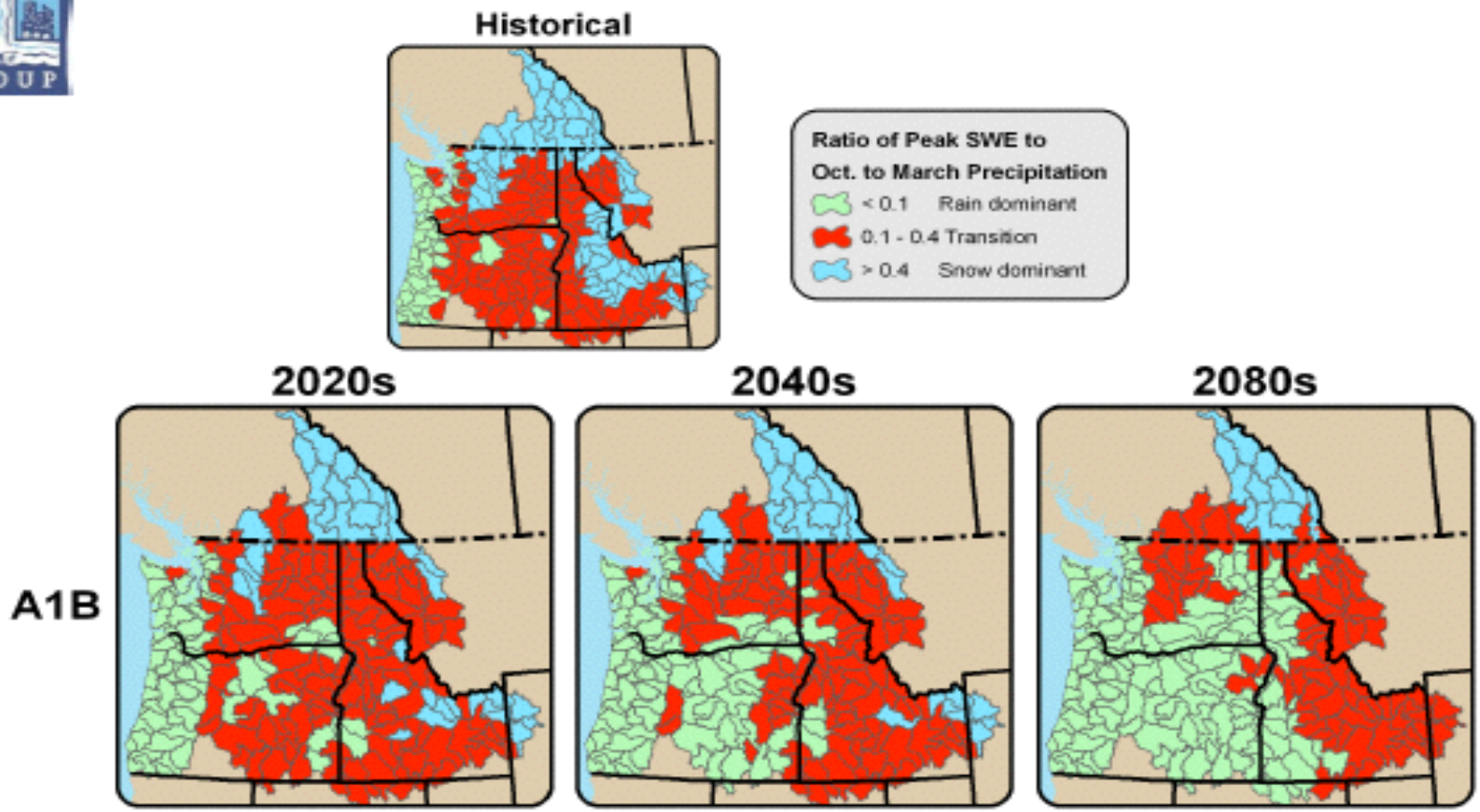


CMIP 5: +1.2 to 3.8°C

CMIP 3: +0.8 to 3.2°C

Rupp et al. 2013; Abatzoglou 2012

Changing Watershed Classifications

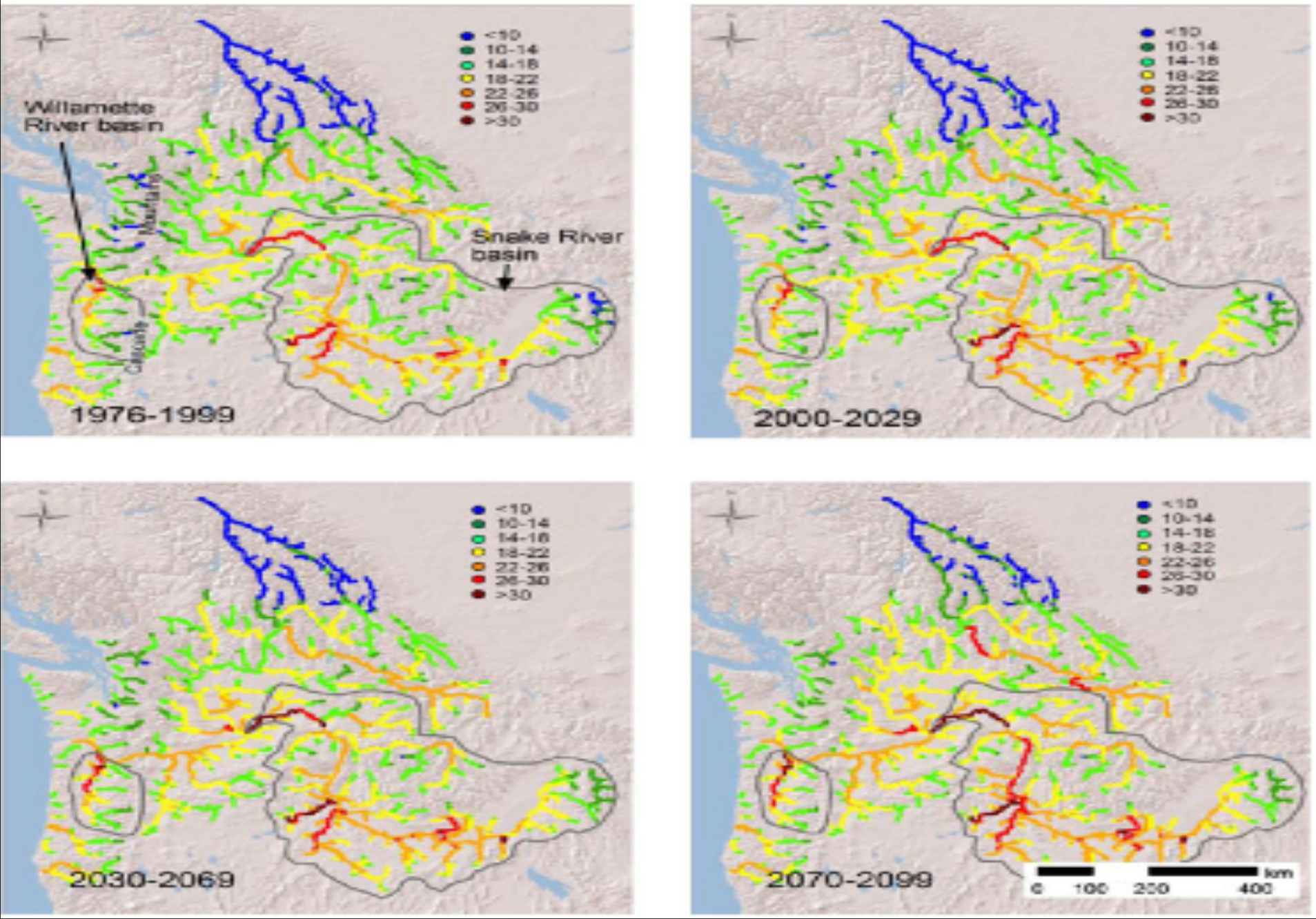


- Based on Composite Delta Method scenarios (multimodel average change in T & P)
- Historical period includes 1916-2006 water years (Oct-Sep)

Map: Rob Norheim

Main takeaway: Temperature increases are a key driver in the expected streamflow trends, no matter which precipitation scenario was chosen

Modeled Maximum Weekly Temperatures (Beechie et al. 2012)



Temperature thresholds (C) for critical parts of different salmon life stages (Beechie 2012)

Life stage	Chinook (*O. tshawytscha*)	Chum (*O. keta*)	Coho (*O. kisutch*)	Pink (*O. gorbuscha*)	Sockeye (*O. nerka*)	Steelhead (*O. mykiss*)
Adult migration						
Optimal threshold			15.6			
Lethal threshold	22	21	21			
Thermal blockage						22
Adult holding and spawning						
Optimal threshold	14.5	12.8	15.6			12.8
Detrimental to internally held gametes			20			
Incubation and early fry development						
Upper threshold	14.5	10	12	12	12.5	12
Juvenile rearing						
Optimal threshold	14.8[a]	15	17			19
Lethal threshold		21	23		20	
UZNG[b]	24	19.8	23.4	21		24
Smoltification						
Impairment threshold	12–17		15			13

Temperatures cited are for constant exposure, unless otherwise noted. Data compiled from Bjornn and Reiser (1991), Eaton and Scheller (1996), McCullough *et al.* (2001), and Richter and Kolmes (2005).

[a]Natural rations level.

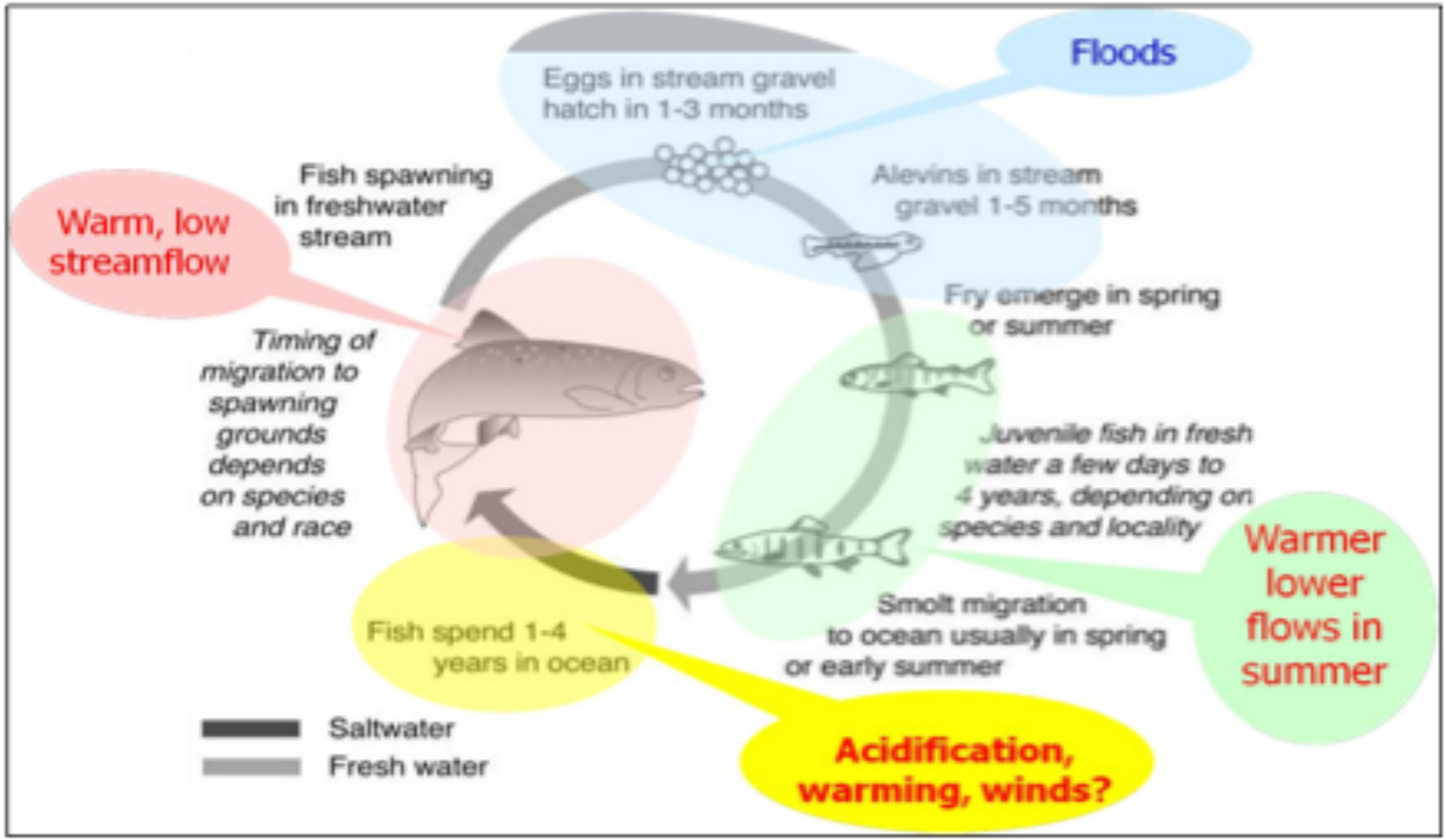
[b]Upper zero net growth (UZNG) temperature: maximum weekly temperature at which fish can live for several days but at which they do not ingest enough food to gain weight.

Physical/Chemical Climate Change Impacts Affecting Anadromous Fish Life Histories

- Ocean acidification
- Increased global sea, estuary and freshwater temperatures and hypoxia
- Increased wind changes, precipitation patterns, reduced snowpack and glaciers, altered sea currents and sea level rise

Physical/Chemical/Biological Climate Change Impacts on Salmon Lifecycle

(from N. Mantua)



Pathways of Climate and Non-Climate Impacts likely to affect Future Fish Passage

Impact Drivers	Hazards / Pathways	Consequences/ Vulnerabilities	Adaptive Strategies
•Climate •Temperature •Precipitation •Storm Tracks •Seasonal Shifts •Non-Climate •Land-Use Changes •Poplulation Growth •Urbanization •Social Values	•Water temperature •Timing shifts •Runoff Volumes •Transitional basins (snow vs. rain) •Etc.	•Ecosystem Function •Navigation •Hydropower •Flood Control •Recreation •Water Supply	•Operations •Rule Curves •Structural Changes •Forecasting •Biological Opinions

Climate impact and non-impact pathways linking drivers and adaptation solutions
(From Brown et al. 2010 "A New Angle on Adaptive Management - Reducing Plausible Vulnerability in the Upper Great Lakes")

Bottom Up and Top Down Frameworks to Assess Climate and Non-Climate Impacts to Future Fish Passage

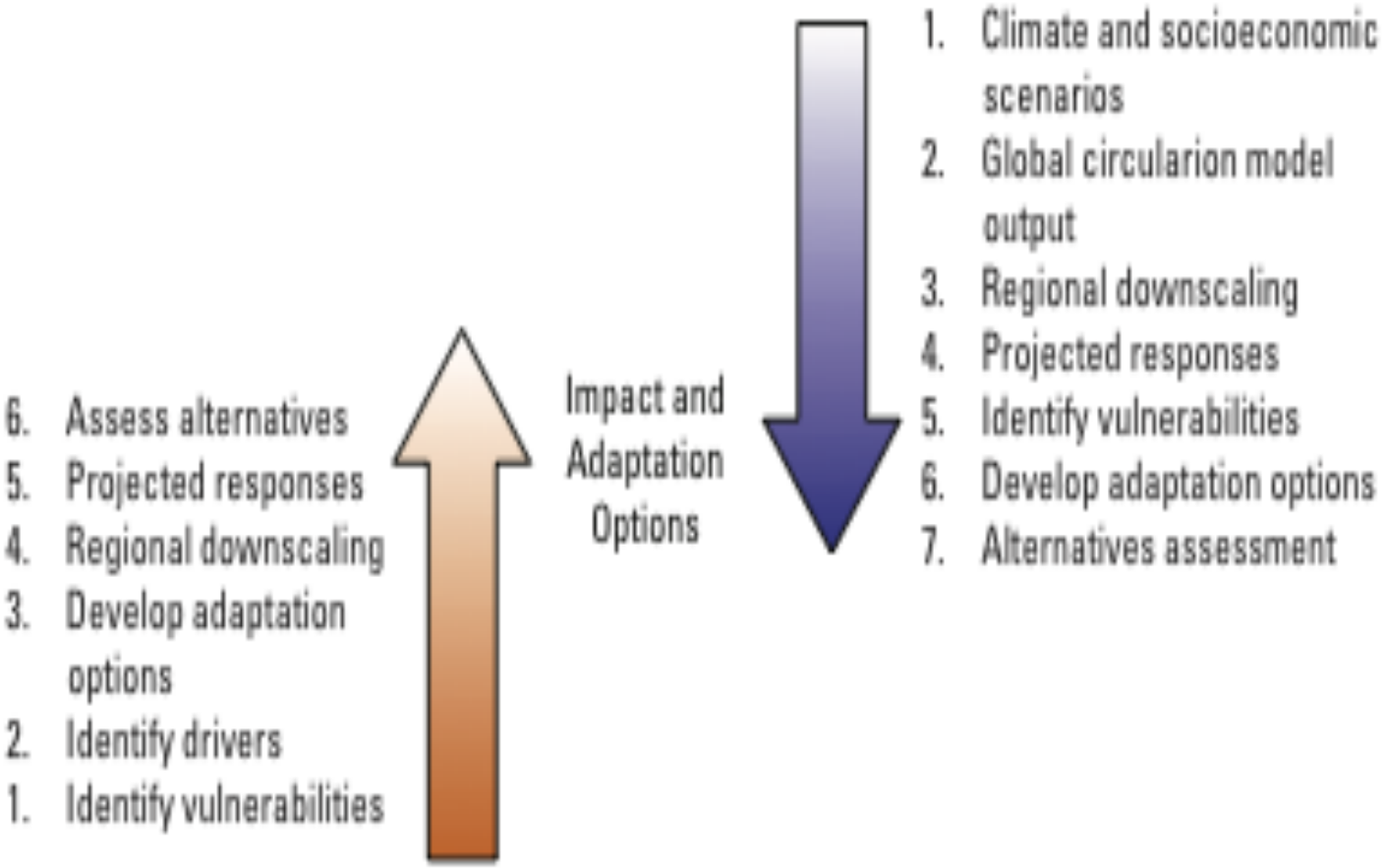


Figure 9. Bottom-up and top-down scenario definitions in climate change assessments (after Colorado Water Conservation Board, 2008).

A Top Down Climate Framework for Fish

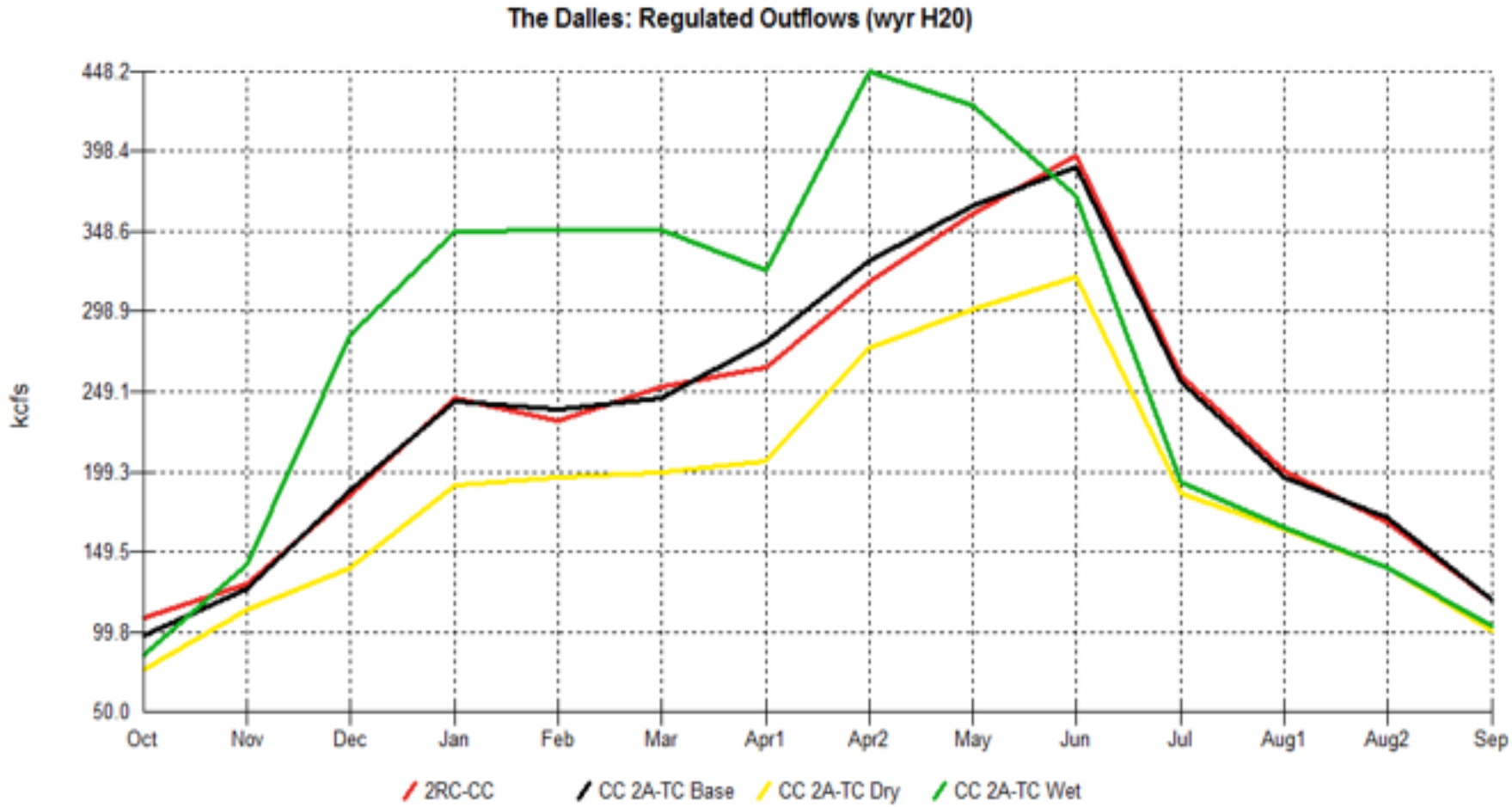
Regional Collaboration on:

1. **Recent global climate models (GCMS/CMIP5)**
2. **Downscaling GCMS for Columbia River Basin**
3. **Create hydrologic model data sets (unregulated flows) w/ bias correction ***
4. **Flood Risk Management (RESSIM-changes to reservoir rule curves and hydro regulation (HYDSIM) modeling of hydrologic data sets (flows, reservoir elevations, spill)**
5. **Secondary water quality modeling (i.e. temperature, SNTEMP; CE-QUAL-2; CMOP)**
6. **Secondary biological and habitat modeling (i.e. CMOP estuary; Comparative Survival Study, NOAA Compass; sediment transport modeling)**
7. **Synthesize water quality, flow and habitat model outputs with ocean models for impacts on individual stock life histories and productivity**

Improvements to hydrological modeling methods through Trans-boundary climate science collaboration, River Management Joint Operational Committee process and national forum inputs (e.g. National Drought Information Center; National Atmospheric Research Center)

THE DALLES DAM

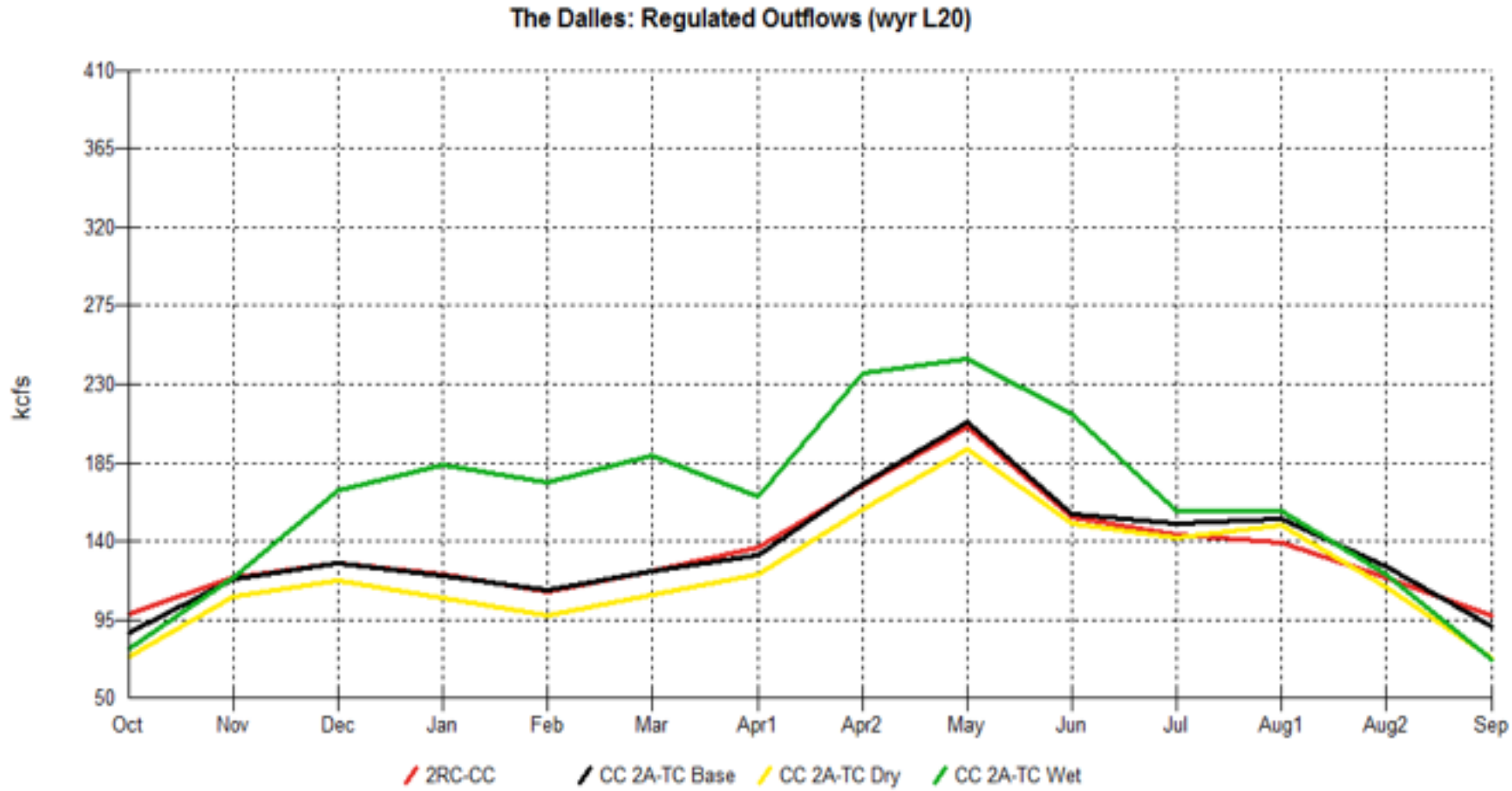
Wettest outflows under two 2040's climate scenarios



Scenario	Data	Oct	Nov	Dec	Jan	Feb	Mar	Apr1	Apr2	May	Jun	Jul	Aug1	Aug2	Sep
2RC-CC	QOUT	108.3	129.5	184.4	244.9	231.4	252.5	264.7	317.1	359.8	395.6	259.1	200.4	167.3	119.2
CC_2A-TC_Base	QOUT	97.7	127.1	188.1	242.8	238.5	245.5	280.2	330.5	365.0	389.0	254.7	195.5	171.3	119.5
CC_2A-TC_Dry	QOUT	76.2	113.6	140.0	191.2	195.4	199.3	206.0	275.8	300.8	320.0	186.0	163.5	140.1	100.4
CC_2A-TC_Wet	QOUT	85.9	141.5	284.3	348.4	349.0	349.1	324.7	448.2	426.6	370.9	193.0	165.2	139.4	103.2

THE DALLES DAM

Driest outflows under two 2040's climate scenarios



Scenario	Data	Oct	Nov	Dec	Jan	Feb	Mar	Apr1	Apr2	May	Jun	Jul	Aug1	Aug2	Sep
2RC-CC	QOUT	98.0	119.6	127.1	121.2	111.4	122.9	137.0	171.6	205.7	153.8	144.3	139.4	119.1	97.5
CC_2A-TC_Base	QOUT	87.2	118.2	127.7	120.5	112.0	122.7	131.7	173.0	208.3	155.8	150.4	153.2	125.5	91.6
CC_2A-TC_Dry	QOUT	73.9	108.7	117.5	107.3	97.2	109.6	121.4	158.6	193.1	149.8	142.1	149.6	114.0	73.6
CC_2A-TC_Wet	QOUT	78.1	119.3	169.3	183.4	173.7	189.6	165.6	236.8	244.8	212.5	157.9	158.0	121.3	72.3

McNARY DAM

FCRPS Salmon BiOp Flow Objectives under two 2040's Climate Scenarios

<u>April 10 – June 20 = 260/220 kcfs at McNary Dam</u>

- **Current Condition meets objective 7% of 14 low water years**
- **Wet Climate Scenario meets objective 43% of 14 water years**
- **Dry Climate Scenario meets objective 0% of 14 low water years**

<u>June 20-August 31 = 200 kcfs at McNary Dam</u>

- **No alternative meets summer flow objective in 14 low water years**

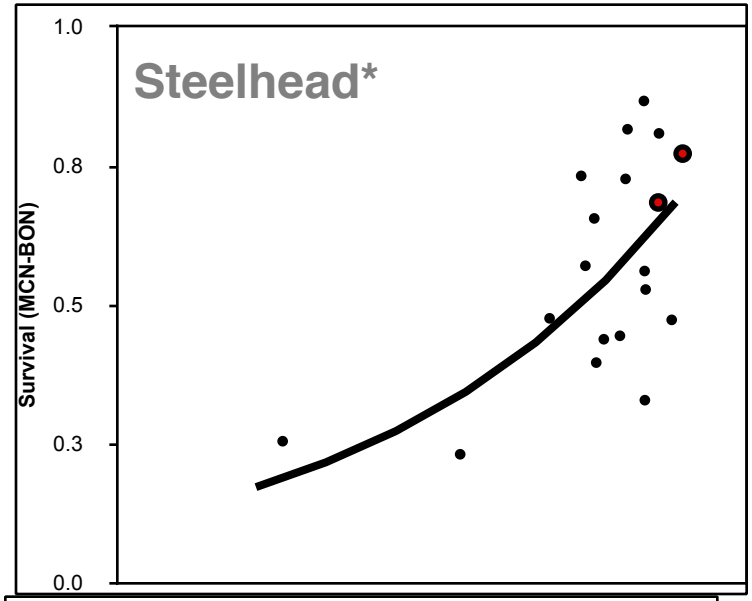
Potential Adaptive Management Strategies/Tools (Operational)

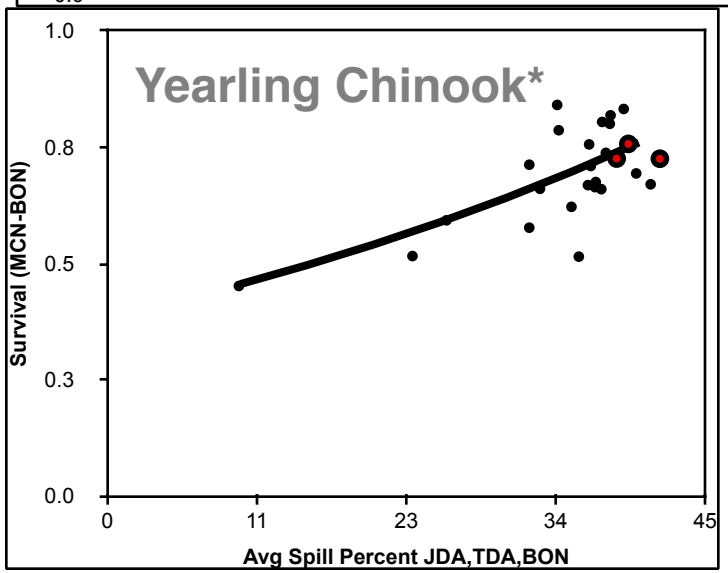
- Increase spring, early summer and late summer flows in river and estuary to reduce temperatures to improve floodplain and groundwater connectivity and reduce adult fish travel time to upstream areas (50% of mainstem summer flow comes from Canada)
- Restore/enhance habitat refugia and connectivity
- Reduce winter reservoir drafting by improving flood risk management via better forecasting methods and modifying rule curves for climate change hydrology
- Reduce juvenile fish travel time by increasing flows and spill
- Reduce daily power peaking to improve spawning and rearing habitat (seek alternative peaking sources)

* If not complete, use 2010 Modified Flows

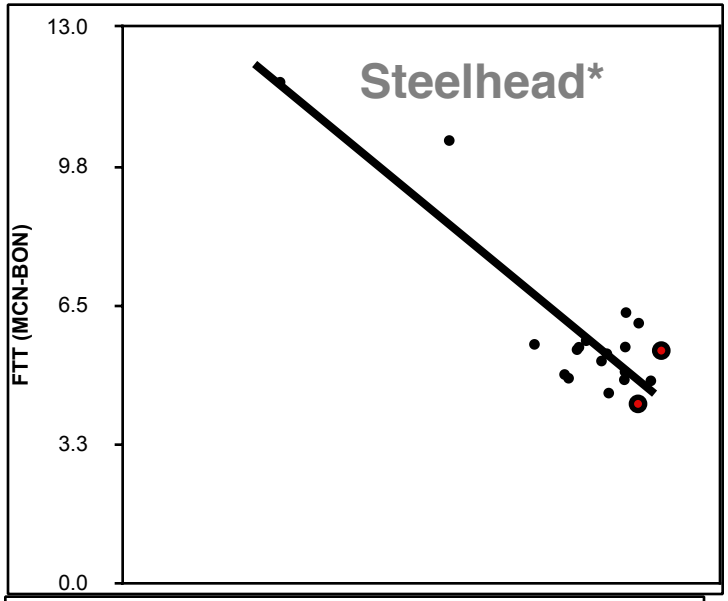
Fish Passage 0peration: What is working

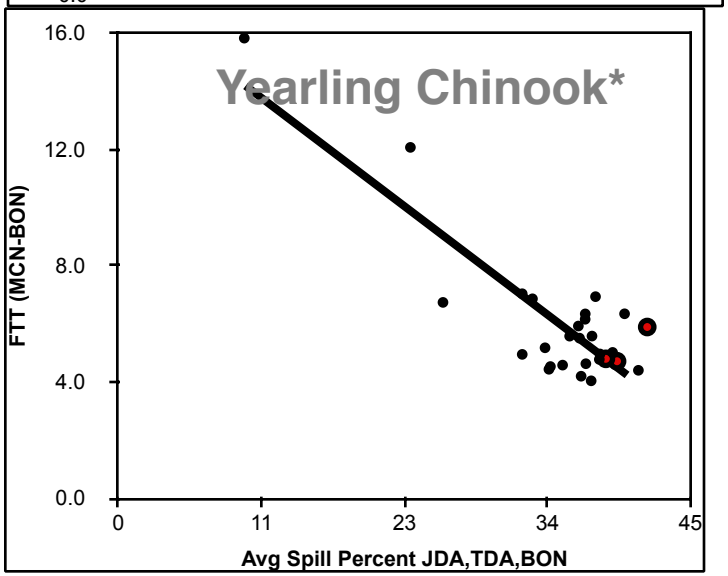
Survival





Fish Travel Time



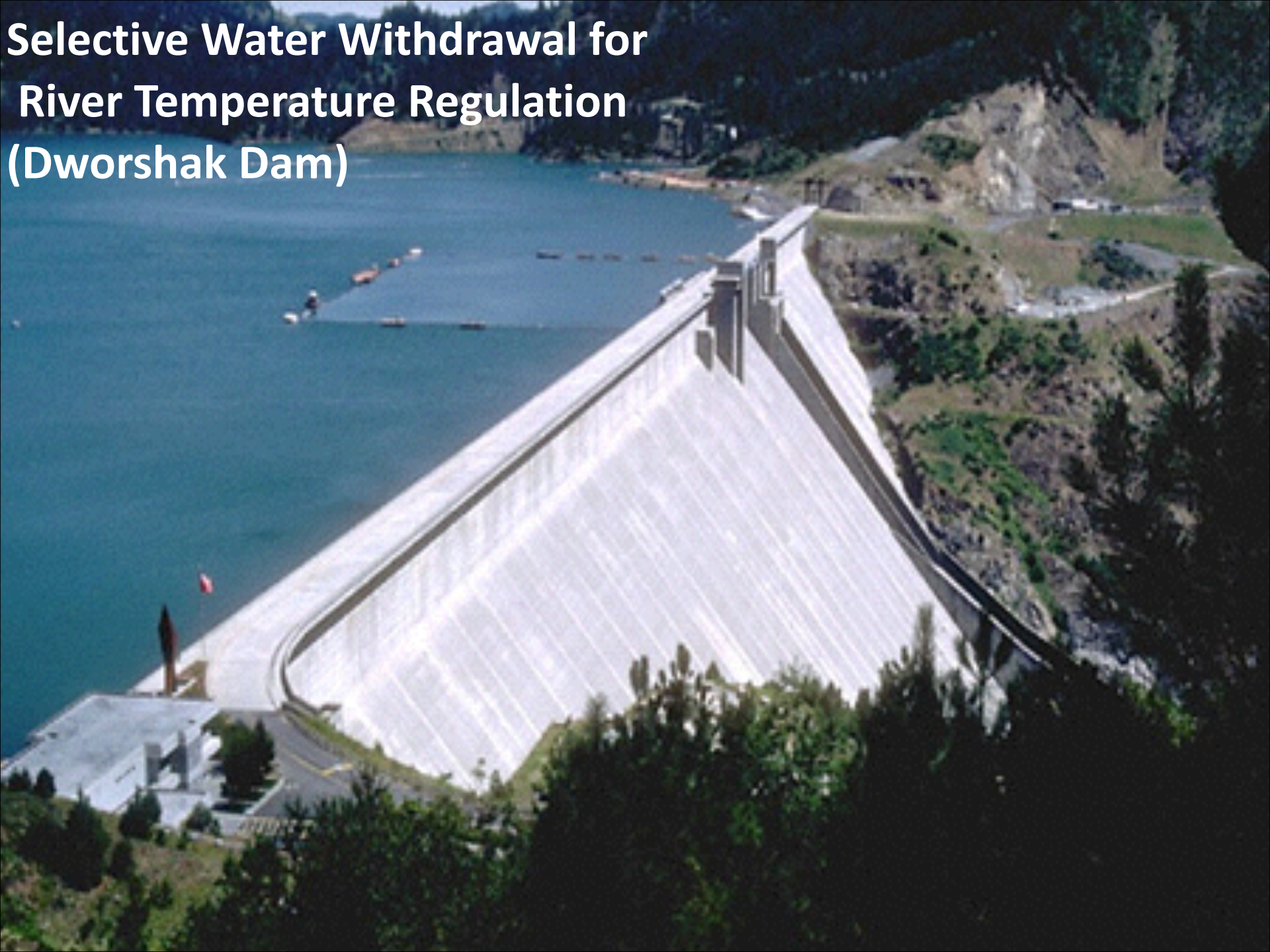


*** Statistically significant at α=0.05 level**

Potential Adaptive Management Strategies/Tools (Structural)

- Restore fish access to cooler water habitats
- Install/implement selective withdrawal at dams to regulate river temperature
- Implement temperature control modifications in existing dam fishways
- Proceed with new fishway designs that reduce adult and juvenile energy expenditure
- Implement water conservation strategies for agriculture and municipal supplies
- Remove levees

Selective Water Withdrawal for River Temperature Regulation (Dworshak Dam)



Collaborative Challenges

- International efforts to reduce global climate change forcings (reducing CO2 emissions)
- Columbia Basin trans-boundary fish passage and governance (Columbia River Treaty)
- Competing water demands particularly in low flow years

Collaborative Challenges

- Climate change uncertainties (more elements of "surprise"- unexpected events that have no historical basis)

- Uncertainty of actions-results
- Funding and resolve to take corrective actions to promote ecosystem resiliency