Impacts of Climate Change on Fish Passage and Reintroduction

Future of Our Salmon Conference

March 20, 2014

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Heinith Consulting
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 the 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 CO₂ 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)

U.S. Average Temperature Projections

- Historical (CMIP3)
- SRES A2
- SRES A1B
- SRES B1
- Historical (CMIP5)
- RCP 8.5
- RCP 6.0
- RCP 4.5
- RCP 2.6
- NCDC Observations

Temperature Change (°F) vs. Year
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

<table>
<thead>
<tr>
<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td>The earth's atmosphere is warming because of increasing greenhouse gases</td>
<td>Unequivocal</td>
<td>Unequivocal (0.89°C since 1900)</td>
</tr>
<tr>
<td>In the Northern Hemisphere, the last 30 years are the warmest than at any time since 600 AD</td>
<td>Not in report</td>
<td>Likely</td>
</tr>
<tr>
<td>Human activity is causing the warming</td>
<td>Very likely</td>
<td>Extremely likely</td>
</tr>
<tr>
<td>Sea level rise is occurring due to global warming</td>
<td>Likely</td>
<td>Very Likely</td>
</tr>
<tr>
<td>The earth’s atmosphere will continue to warm for the rest of the century</td>
<td>Likely in the 2.0-4.5°C range by 2050-2100</td>
<td>Likely in the 0.9-2.6°C range (1.1-4.8°C by 2100)</td>
</tr>
<tr>
<td>Atmospheric sensitivity to increasing greenhouse gases</td>
<td>Very sensitive; rapid warming likely</td>
<td>Sensitive, but warming is likely to be gradual</td>
</tr>
<tr>
<td>Heat waves have increased due to global warming</td>
<td>More likely than not</td>
<td>Very likely</td>
</tr>
<tr>
<td>Droughts (number and intensity) have increased due to global warming</td>
<td>Unsure</td>
<td>Possible</td>
</tr>
<tr>
<td>Sea levels will rise 0.3-0.8m by 2100</td>
<td>Possible</td>
<td>Likely</td>
</tr>
<tr>
<td>Extreme precipitation events will increase and intensify</td>
<td>Likely</td>
<td>Very likely</td>
</tr>
<tr>
<td>Tropical cyclone intensity will increase due to global warming</td>
<td>Unsure</td>
<td>More likely than not</td>
</tr>
<tr>
<td>Temperature forecast level of confidence at <strong>global scales</strong></td>
<td>High</td>
<td>High</td>
</tr>
<tr>
<td>Temperature forecast confidence at <strong>regional scales</strong></td>
<td>Low-moderate</td>
<td>Low-moderate</td>
</tr>
<tr>
<td>Precipitation forecast level of confidence at <strong>global scales</strong></td>
<td>Low</td>
<td>Moderate</td>
</tr>
<tr>
<td>Precipitation forecast level of confidence at <strong>regional scales</strong></td>
<td>Low</td>
<td>Moderate</td>
</tr>
<tr>
<td></td>
<td>Low (moderate in a few areas, but Pac NW isn't one of them)</td>
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</tbody>
</table>
Comparison of 2007 (CMIP 3) and 2013 (CMIP 5) GCMs Downscaled for the Columbia Basin

2040s* Climate Projections for the Columbia River Basin

Temperature

CMIP 5: +1.2 to 3.8°C
CMIP 3: +0.8 to 3.2°C

Precipitation

Rupp et al. 2013; Abatzoglou 2012
Main takeaway: Temperature increases are a key driver in the expected streamflow trends, no matter which precipitation scenario was chosen.
Temperature thresholds (°C) for critical parts of different salmon life stages (Beechie 2012)

<table>
<thead>
<tr>
<th>Life stage</th>
<th>Chinook (<em>O. tshawytscha</em>)</th>
<th>Chum (<em>O. keta</em>)</th>
<th>Coho (<em>O. kisutch</em>)</th>
<th>Pink (<em>O. gorbuscha</em>)</th>
<th>Sockeye (<em>O. nerka</em>)</th>
<th>Steelhead (<em>O. mykiss</em>)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adult migration</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Optimal threshold</td>
<td>14.5</td>
<td>12.8</td>
<td>15.6</td>
<td></td>
<td>12.8</td>
<td>12.8</td>
</tr>
<tr>
<td>Lethal threshold</td>
<td></td>
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<tr>
<td>Thermal blockage</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>22</td>
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<tr>
<td>Adult holding and spawning</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Optimal threshold</td>
<td>14.8&lt;sup&gt;a&lt;/sup&gt;</td>
<td>15</td>
<td>17</td>
<td></td>
<td>19</td>
<td></td>
</tr>
<tr>
<td>Detrimental to internally held gametes</td>
<td></td>
<td></td>
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<td></td>
<td></td>
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<tr>
<td>Incubation and early fry development</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Upper threshold</td>
<td>14.5</td>
<td>10</td>
<td>12</td>
<td>12</td>
<td>12.5</td>
<td>12</td>
</tr>
<tr>
<td>Juvenile rearing</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Optimal threshold</td>
<td>14.8&lt;sup&gt;a&lt;/sup&gt;</td>
<td>15</td>
<td>17</td>
<td></td>
<td>19</td>
<td></td>
</tr>
<tr>
<td>Lethal threshold</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>20</td>
</tr>
<tr>
<td>UZNG&lt;sup&gt;b&lt;/sup&gt;</td>
<td></td>
<td>19.8</td>
<td>23.4</td>
<td></td>
<td>21</td>
<td>24</td>
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<tr>
<td>Smoltification</td>
<td></td>
<td></td>
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<tr>
<td>Impairment threshold</td>
<td>12–17</td>
<td>15</td>
<td></td>
<td></td>
<td></td>
<td>13</td>
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</table>

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

<sup>a</sup>Natural rations level.

<sup>b</sup>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
- Climate
  - Temperature
  - Precipitation
  - Storm Tracks
  - Seasonal Shifts
- Non-Climate
  - Land-Use Changes
  - Population Growth
  - Urbanization
  - Social Values

Hazards/Pathways
- Water temperature
- Timing shifts
- Runoff Volumes
- Transitional basins (snow vs. rain)
- Etc.

Consequences/Vulnerabilities
- Ecosystem Function
- Navigation
- Hydropower
- Flood Control
- Recreation
- Water Supply

Adaptive Strategies
- 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).
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
THE DALLES DAM

Wettest outflows under two 2040's climate scenarios

The Dalles: Regulated Outflows (wyr H20)

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Data</th>
<th>Oct</th>
<th>Nov</th>
<th>Dec</th>
<th>Jan</th>
<th>Feb</th>
<th>Mar</th>
<th>Apr1</th>
<th>Apr2</th>
<th>May</th>
<th>Jun</th>
<th>Jul</th>
<th>Aug1</th>
<th>Aug2</th>
<th>Sep</th>
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<tbody>
<tr>
<td>2RC-CC</td>
<td>QOUT</td>
<td>108.3</td>
<td>129.5</td>
<td>184.4</td>
<td>244.9</td>
<td>231.4</td>
<td>252.5</td>
<td>264.7</td>
<td>317.1</td>
<td>359.8</td>
<td>395.6</td>
<td>259.1</td>
<td>200.4</td>
<td>167.3</td>
<td>119.2</td>
</tr>
<tr>
<td>CC_2A-TC_Base</td>
<td>QOUT</td>
<td>97.7</td>
<td>127.1</td>
<td>188.1</td>
<td>242.8</td>
<td>238.5</td>
<td>245.5</td>
<td>280.2</td>
<td>330.5</td>
<td>365.0</td>
<td>389.0</td>
<td>254.7</td>
<td>195.5</td>
<td>171.3</td>
<td>119.5</td>
</tr>
<tr>
<td>CC_2A-TC_Dry</td>
<td>QOUT</td>
<td>76.2</td>
<td>113.6</td>
<td>140.0</td>
<td>191.2</td>
<td>195.4</td>
<td>199.3</td>
<td>206.0</td>
<td>275.8</td>
<td>300.8</td>
<td>320.0</td>
<td>186.0</td>
<td>163.5</td>
<td>140.1</td>
<td>100.4</td>
</tr>
<tr>
<td>CC_2A-TC_Wet</td>
<td>QOUT</td>
<td>85.9</td>
<td>141.5</td>
<td>284.3</td>
<td>348.4</td>
<td>349.0</td>
<td>349.1</td>
<td>324.7</td>
<td>448.2</td>
<td>426.6</td>
<td>370.9</td>
<td>193.0</td>
<td>165.2</td>
<td>139.4</td>
<td>103.4</td>
</tr>
</tbody>
</table>
THE DALLES DAM

Driest outflows under two 2040’s climate scenarios
April 10 – June 20 = 260/220 kcf at McNary Dam

- 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

June 20-August 31 = 200 kcf at McNary Dam

- 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 Operation: What is working

Survival

Fish Travel Time

Steelhead*

Yearling Chinook*

Survival (Steelhead*)

Fish Travel Time (Steelhead*)

Survival (Yearling Chinook*)

Fish Travel Time (Yearling Chinook*)

* Statistically significant at $\alpha=0.05$ 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