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Overview of fish-related sensitivities to projected changes in climate and hydrology

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Workshop on climate change, fish and fish habitat in the North Cascadia Ecosystem July 27-28, 2011



21st Century PNW Temperature and Precipitation Change Scenarios



Projected changes in temperature are large compared to historic variability

Changes in annual
precipitation are generally
small compared to past
variations, but some models
show large seasonal
changes (*wetter autumns and winters* and *drier summers*)



21st century PNW climate scenarios relative to past variability





A robust impact of climate warming: less snow

4100 ft (Future) } for a 3000 ft (Present) ~ 2 °C

warming

Snoqualmie Pass 3022 ft



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Hydrologic Climate Change Scenarios for the Pacific Northwest Columbia River Basin and Coastal Drainages

Climate change is projected to have substantial impacts on Pacific Northwest water resources and ecosystems. Recognizing this, resource managers have expressed growing interest in incorporating climate change information into long-range planning. The availability of hydrologic scenarios to support climate change adaptation and long-range planning, however, has been limited until very recently to a relatively small number of selected case studies. More comprehensive resources needed to support regional planning have been lacking. Furthermore, ecosystem studies at the landscape scale need consistent climate change information and databases over large geographic areas. Products using a common set of methods that would support such studies have not been readily available.

To address these needs, the <u>Climate Impacts Group</u> worked with several prominent water management agencies in the Pacific Northwest to develop hydrologic climate change scenarios for approximately 300 streamflow locations in the Columbia River basin and selected coastal drainages west of the Cascades. Study partners are listed below. The scenarios, provided to the public for free via this website, allow planners to consider how hydrologic changes may affect water resources management objectives ind ecosystems.

Access to the data and summary products is available from the menu to the left. The hydrologic data produced by the study are based on <u>climate change scenarios</u> produced for the IPCC Fourth Assessment effort. Information on the methods and modeling tools used in the study is provided in the <u>summary report</u>. For new users of the site, a <u>guide to the website</u> and the data resources contained within it is also

Hydrologic Products

e Impacts Group was funded by the following research partners to develop ia River Basin and coastal drainages climate change scenarios:

itate Department of Ecology eville Power Administration

- Northwest Power and Conservation Council
- Oregon Department of Water Resources
- British Columbia Ministry of Environment

http://www.hydro.washington.edu/2860/



Available PNW Scenarios (80!)

Downscaling Approach			A1B Emissions Scenario	B1 Emissions Scenario
Hybrid Delta	hadcm cnrm_cm ccsm3	2020s	10	10
	echam5 echo_g cgcm3.1_t4 7 pcm1 miroc_3.2 ipsI_cm4 hadgem1	2040s	10	10
		2080s	10	10
Transient BCSD	hadcm cnrm_cm ccsm3 echam5 echo_g cgcm3.1_t4 7 pcm1	1950- 2098+	7	7
Delta Method	composite of 10	2020s	1	1
		2040s	1	1
		2080s	1	1

2020s – mean 2010-2039; 2040s – mean 2030-2059; 2080s – mean 2070-2099



3 basic streamflow patterns

1. rain-dominated

2. *"transient"* basins with an early winter peak from rainfall, and a spring peak from snowmelt

3. *snowmelt-dominated* basins, where streamflow peaks in late spring and early summer



Summer base flows are projected to drop substantially (5 to 50%) for most streams in western WA and the Cascades

> The duration of the summer low flow season is also projected to increase in snowmelt and transient runoff rivers, and this reduces rearing habitat

Ratio of Low Flow (7Q2) Statistics (21st Century ÷ 20th Century)

•	< 0.55	•	0.75 - 0.85
•	0.55- 0.65	\bigcirc	0.85 - 0.95
•	0.65 - 0.75	\bigcirc	0.95 - 1.05

2080s



A1B



2040s

Mantua et al. 2009: Impacts of climate change on key aspects of freshwater salmon habitat for in Washington State (in review)

A warmer climate and flooding

- At mid-elevations, more precipitation will fall as rain and less as snow
- a warmer atmosphere holds more moisture: theory and climate models suggest an increased intensity of precipitation, stronger storm (but maybe fewer)
- This combination points to ar increased frequency of river flooding in fall and winter

 Models project more winter flooding in sensitive "transient runoff" river basins that are common in the Cascades
 Likely reducing survival rates for incubating eggs and rearing parr

Ratio of 20-year Flood Statistics (21st Century ÷ 20th Century)

0	< 0.9	0	1.3 - 1.5
0	0.9 - 1.1	•	1.5 - 1.7
0	1.1 - 1.3	•	> 1.7

2020s

A1B



2080s

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Climate Scenarios

Site-specific Data

Primary Data

Reservoir Model Input Data

Research Site Data Spreadsheet

Site: SKYKOMISH RIVER NEAR GOLD BAR WA

SKYKOMISH RIVER NEAR GOLD BAR WA

Site Info: SKYGB (6015)

USGS Id: 12134500

Latitude (DMS): 47 50 15 Longitude (DMS): 121 39 56 Latitude (Decimal): 47.8375 Longitude (Decimal): -121.6656 Area: 535 miles² Nash Sutcliffe Efficiency = 0.69

General FTP directory

Raw Data

- · vic streamflow daily dt 2020.dat
- vic_streamflow_daily_dt_2040.dat
- vic_streamflow_daily_dt_2080.dat
- vic_streamflow_daily_hd_2020.dat
- vic_streamflow_daily_hd_2040.dat
- vic streamflow daily hd 2080.dat
- · vic streamflow daily historical.dat
- vic streamflow daily tr.dat
- vic streamflow monthly dt 2020.dat
- vic_streamflow_monthly_dt_2040.dat
- vic_streamflow_monthly_dt_2080.dat
- vic_streamflow_monthly_hd_2020.dat
- vic streamflow monthly hd 2040.dat
- vic streamflow monthly hd 2080.dat
- vic_streamflow_monthly_historical.dat
- vic_streamflow_monthly_tr.dat

Bias-Adjusted Data

- nat_bias_adjusted_vic_streamflow_daily_dt_2020.dat
- nat bias adjusted vic streamflow daily dt 2040.dat
- nat_bias_adjusted_vic_streamflow_daily_dt_2080.dat
- nat bias adjusted vic streamflow daily hd 2020.dat
- nat_bias_adjusted_vic_streamflow_daily_hd_2040.dat
- nat_bias_adjusted_vic_streamflow_daily_hd_2080.dat
- nat_bias_adjusted_vic_streamflow_daily_historical.dat
- nat_bias_adjusted_vic_streamflow_daily_tr.dat
- nat_bias_adjusted_vic_streamflow_monthly_dt_2020.dat
- nat_bias_adjusted_vic_streamflow_monthly_dt_2040.dat
- nat_bias_adjusted_vic_streamflow_monthly_dt_2080.dat
- nat bias adjusted vic streamflow monthly hd 2020.dat
- nat bias adjusted vic streamflow monthly hd 2040.dat
- nat bias adjusted vic streamflow monthly hd 2080.dat
- nat_bias_adjusted_vic_streamflow_monthly_historical.dat
- nat_bias_adjusted_vic_streamflow_monthly_tr.dat

http://www.hydro.washington.edu/2860/products/sites/?site=6015





Snow and Runoff Scenarios (Skykomish R at Gold Bar) A1B and B1 emissions, 10 GCMs, HD downscaling



All these scenarios have less accumulated snowpack and a shorter snow season

They also show increased winter/spring flows, earlier snowmelt, and an earlier snowmelt recession

Ensemble Mean

Historical Mean





These scenarios show daily peak flow magnitudes increasing, while 7Q10 low flow magnitudes decline. Different climate model scenarios (in red and yellow) have different impacts, however.

Western Washington's "maritime" summer climate becomes as warm as today's interior Columbia Basin, temperatures in the interior Columbia Basin become as warm as today's Central Valley in California

1980s

2040s A1B



Mantua, Tohver and Hamlet 2010: Climatic Change

Projected Summertime Temperatures Skagit River Basin

Historical

Summer Mean Surface Air Temperature and Maximum Stream Temperature



EPA and WA DOE criteria for thermal habitats for salmon:

13°C – spawning, incubation and optimal growth temperature for salmon and trout

16°C – core summer salmon habitat temperature

Thermal exceedancesprojected for 2 areas:upper basin tributarieslower mainstem site





Thermal stress season

Extended periods with weekly average water temperatures > 21C - the season of thermal migration barriers for migrating salmon predicted to last up to 11 weeks in the mainstem Stillaguamish River

Mantua, Tohver and Hamlet 2010: Climatic Change

Upwelling food webs in our coastal ocean

Cool water, weak stratification high nutrients, a productive "<u>subarctic</u>" food-chain with abundant forage fish and few warm water predators

Recently, warm ocean years have generally been poor for NW chinook, coho and sockeye, but good for Puget Sound pink and chum salmon.



Warm stratified ocean, few nutrients, low productivity "<u>subtropical</u>" food web, a lack of forage fish and abundant predators



Impacts summary for PNW salmon



Impacts will vary depending on life history and watershed types

- Low flows+warmer water = increased pre-spawn mortality for summer run and stream-type salmon and steelhead
 - Clear indications for increased stress on Columbia Basin sockeye, summer steelhead, summer Chinook, and coho more generally



Increased winter flooding in transient rain+snow watersheds

 a limiting factor for egg-fry survival for fall spawners + yearling parr overwinter survival in high-gradient reaches

Salmon vulnerability to climate change

• Conceptual basis:

Existing stresses reduce salmon's ability to respond to climate change

Slide from Tim Beechie, NOAA NWFSC

Prototype – vulnerability mapping

Schematic of Vulnerability Categories

Vulnerability Mapping Legend

Slide from Tim Beechie, NOAA NWFSC

North Cascades Datasets

- Regional Climate and Change Summaries (1/16th deg)
 - <u>http://cses.washington.edu/picea/USFS_ORWA/pub/</u> (follow link to summaries for omernik 77)
 - source data: <u>http://www.hydro.washington.edu/2860/</u>
- High-resolution meteorology (30 arc-sec)
 - <u>http://cses.washington.edu/picea/mauger/met30s/pnw_30s/</u>
- High-resolution snow simulations (30 arc-sec)
 - <u>http://cses.washington.edu/picea/mauger/VIC_SNOW/pub/</u>

Regional Climate and Change Summaries

Website:

http://cses.washington.edu/picea/USFS_ORWA

Resolution:

1/16th degree (~5-7 km)

Source:

Columbia Basin Climate Change Scenarios Project (CBCCSP) Hamlet et al., 2010 http://www.hydro.washington.edu/2860/

Variables (daily time step):

temperature: average, min, max Precipitation runoff, baseflow, combined flow (runoff + baseflow) flow statistics: flood, low flow snow amount: swe, snow depth, peak swe Snow dates: peak swe, 10% accum, 90% accum relative humidity, vapor pressure deficit actual evapotranspiration, potential evapotranspiration soil moisture Change in max SWE

High-resolution Meteorology

Website:

http://cses.washington.edu/picea/mauge r/met30s/pnw_30s/

Resolution:

30 arc-seconds (~700-900 m)

Sources:

CBCCSP (1/16th degree daily met data): http://www.hydro.washington.edu/2860/ PRISM (30 arc-second climatologies): http://www.prism.oregonstate.edu/

Variables (monthly time step):

minimum temperature (monthly average) maximum temperature (monthly average) precipitation (monthly total)

Dec 2000: average maximum temperature

High-Resolution Snow Simulations

Website:

http://cses.washington.edu/picea/mauger/VIC _SNOW/pub/

Resolution:

30 arc-seconds (~700-900 m)

Sources:

CBCCSP (1/16th degree daily met data): http://www.hydro.washington.edu/2860/ PRISM (30 arc-second climatologies): http://www.prism.oregonstate.edu/ VIC macroscale hydrologic model http://www.hydro.washington.edu/Lettenmaier/Models/VIC/

Variables (daily time step):

snow amount: swe, snow depth, peak swe snow dates: peak swe, 10% accum, 90% accum

A1B 2040s: Change in Max SWE

Water balance deficit and future fire scenarios

2040s change in summer water deficit, relative To 1970-1999 Figure: R. Norheim

Left: Based on statistical fire models and WACCIA ensemble future climate and VIC modeling, Littell et al. 2010. Right: Littell et al. 2011. Ensemble of 10 GCMs, VIC hydrologic modeling, from R1/R6 analysis for USFS.

Water balance, increased disturbance, and hydrologic impacts

An example of a map showing the probability of debris-flow occurrence from basins burned by the 2002 Missionary Ridge Fire near Durango, CO. Map generated by incorporating the logistic regression statistical model into a GIS. USGS.

Post-fire (2008 Cascade fire near Red Lodge, MT. Blacktail Creek debris flow (*Photo by Drew Downs*)

Fire severity, proportion of watershed burned, and arrangement of burned patches contribute to fire effects on sediment transport

Image from http://www.getsomebass.com