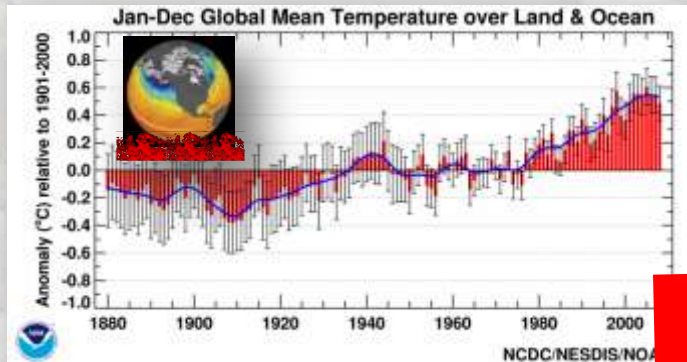
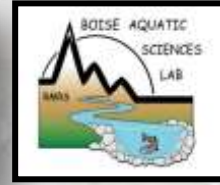
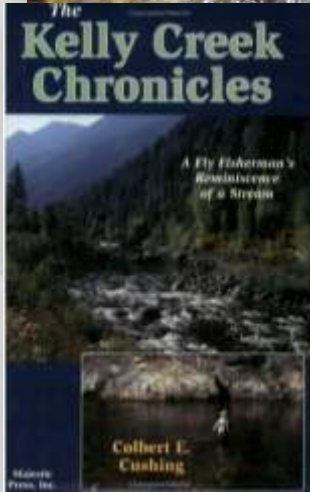


Stream Climate Trends and Aquatic Resource Vulnerability on the Nez Perce-Clearwater National Forests

Dan Isaak, US Forest Service
Rocky Mountain Research Station

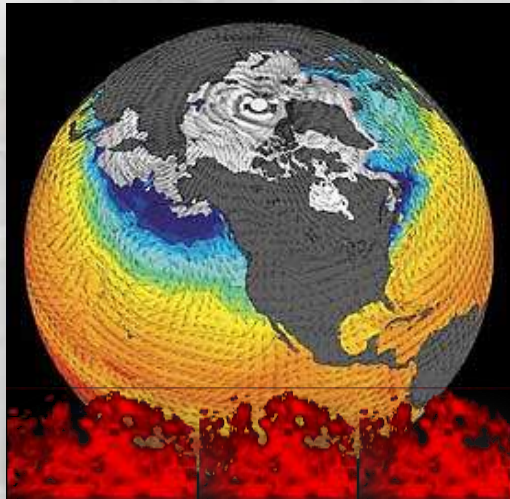


Clearwater-Nez is a Special Fishy Place



How Will Global Climate Change Affect My Streams & Favorite Fishes?

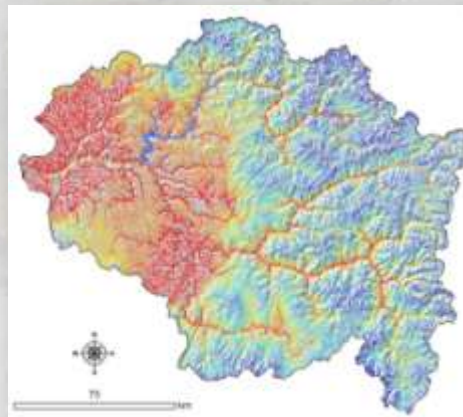
Global climate



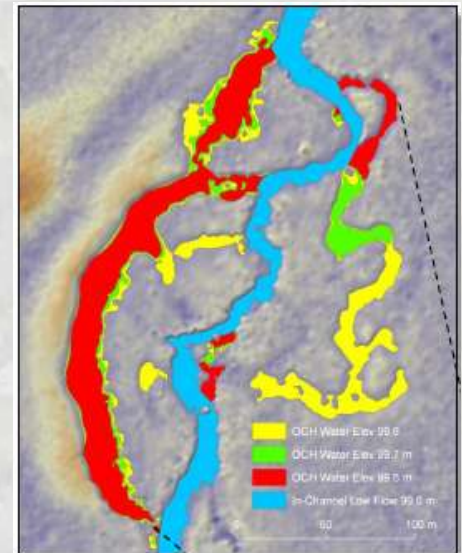
Regional climate



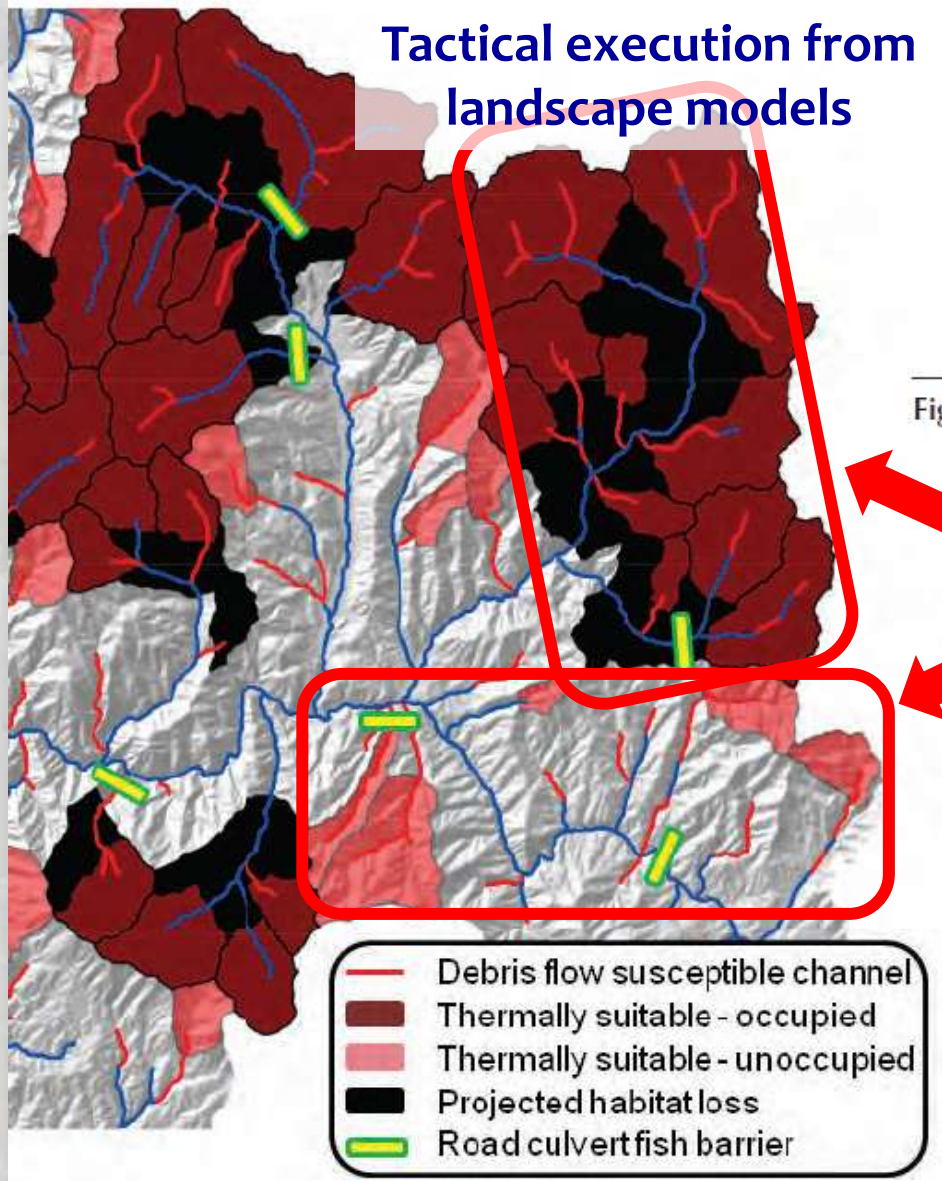
River network temperatures



Stream reach



Accurate Local Information Needed to Empower Local Decision Makers



I'm going to invest here...
... instead of here



There's A Lot on the Line...

Climate Boogeyman



Recreational Fisheries

Low Flows Prompt Fishing Closure On Upper Beaverhead River And Reduced Limits On Clark Canyon Reservoir

Wednesday, September 29, 2004
Fishing



High Water

**\$4 Billion on Fish & Wildlife
Recovery Efforts in PNW
Since 1980 (ISAB/ISRP 2007)**



ESA Listed Species

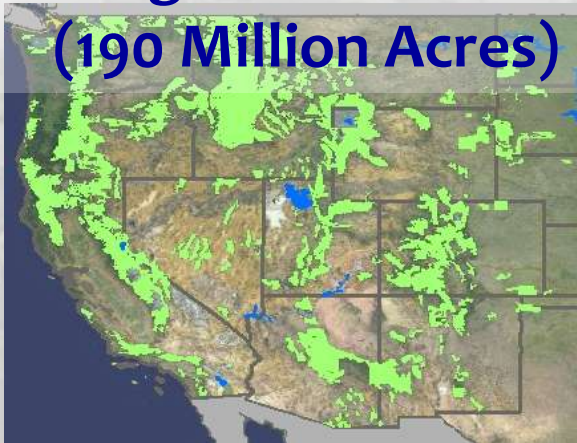


Water Development



Green Team has Huge Potential Synergies for Information Development & Application

Large land-base
(190 Million Acres)



“Boots-on-the-Ground”



USFS has ~600 fish bios/hydros.
(That’s an aquatics army!)



Managers collecting
mountains of useful data



Research branch develops
information & connects people

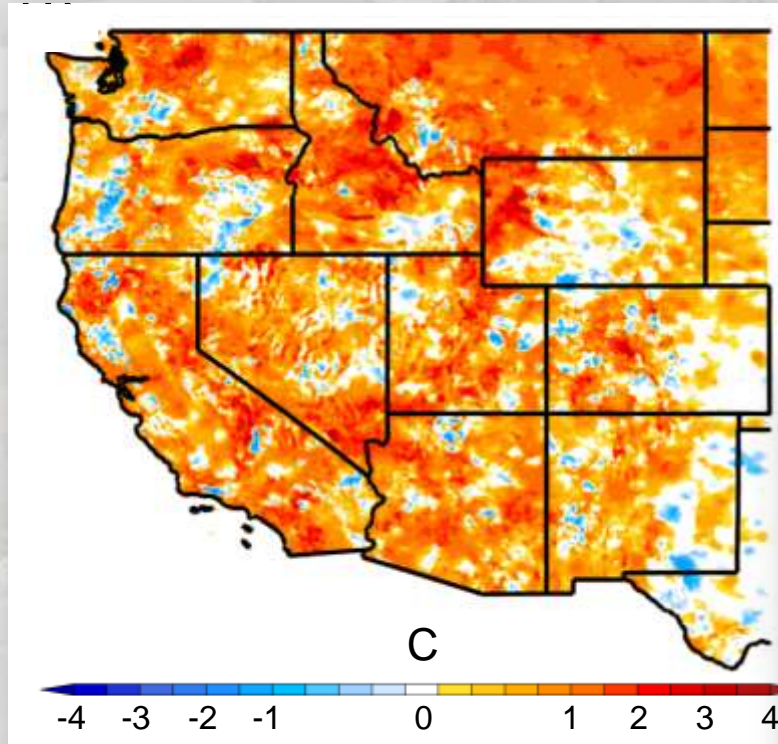


General outline:

- 1) Historical trends & future predictions for streams (flow, temperature, sediment regimes) western U.S. & Clearwater/Nez Perce NF
- 2) How could aquatic resources be affected?
- 3) Tools & monitoring systems for climate-smart prioritization. What are our goals?
- 4) Key uncertainties (some resolvable, some not)

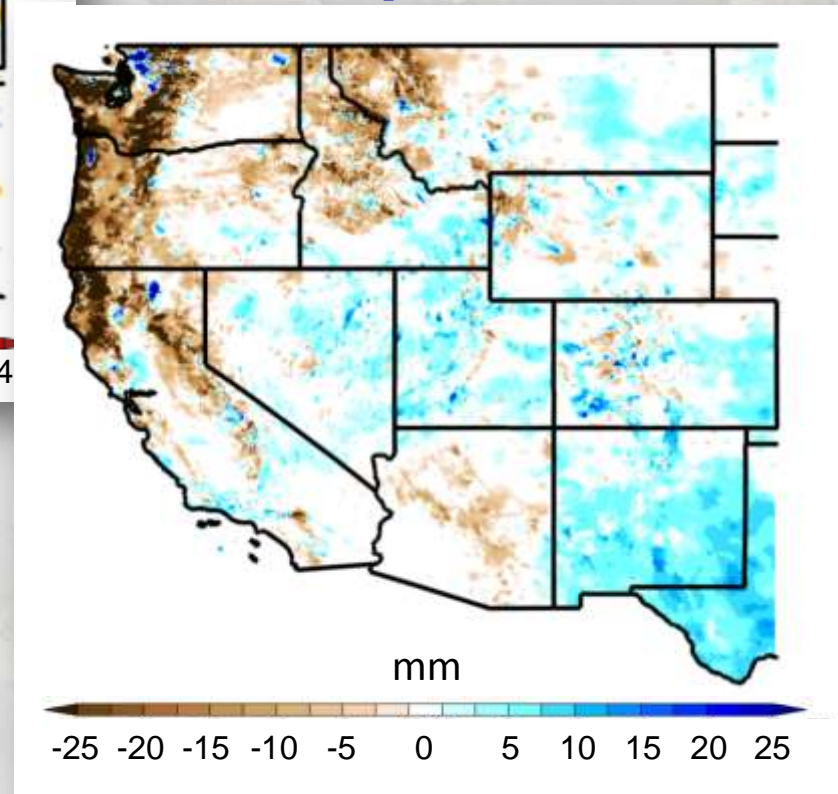
Western US Observed Climate Trends (1950 – 2009)

Air temperatures



(1950 – 2009)

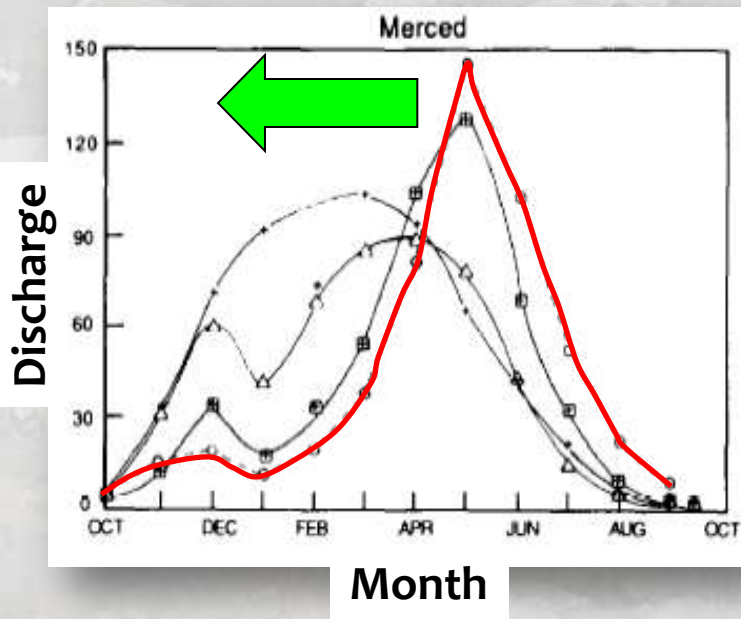
**Total Annual
Precipitation**



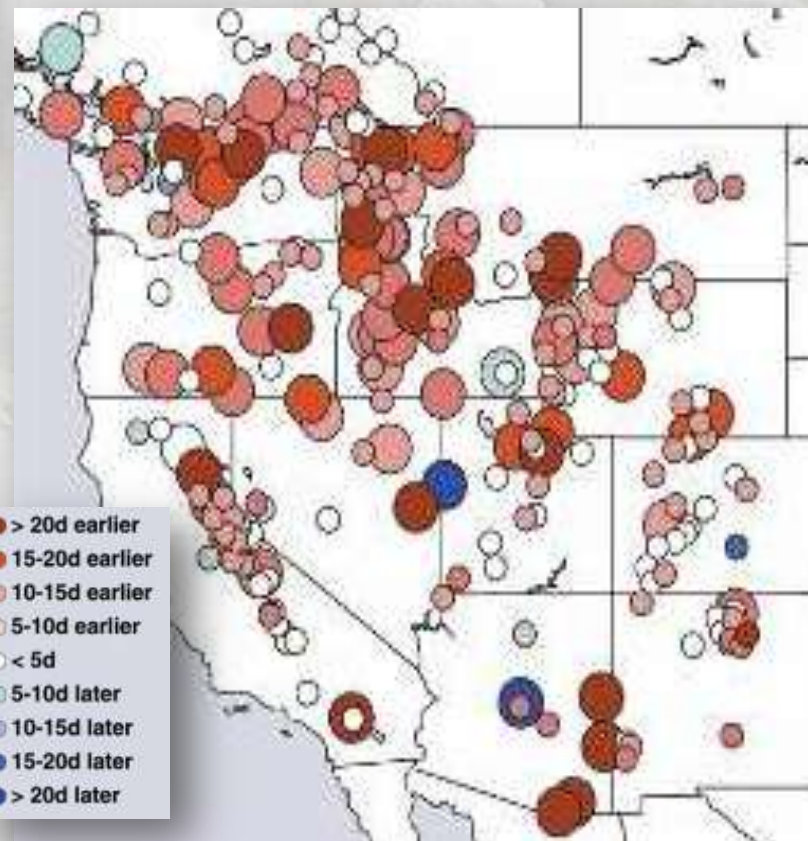
**What does it mean
for streams and
stream critters?**

Trends in Stream Runoff Timing

(1948-2000)



Earlier snowmelt & river runoff

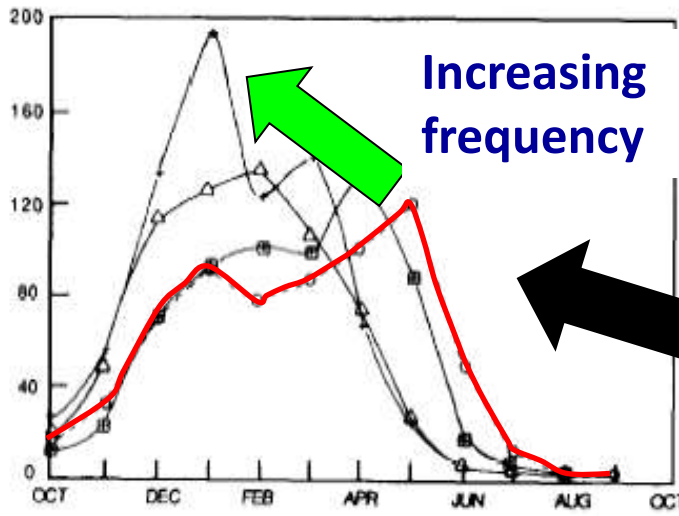


Stewart et al. 2005

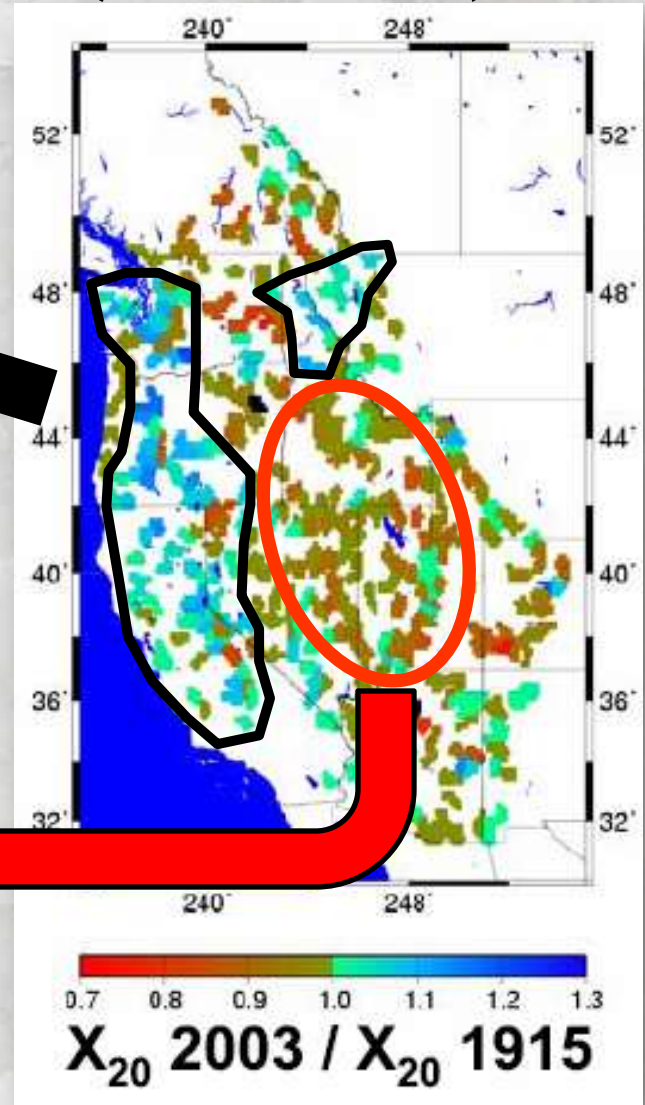
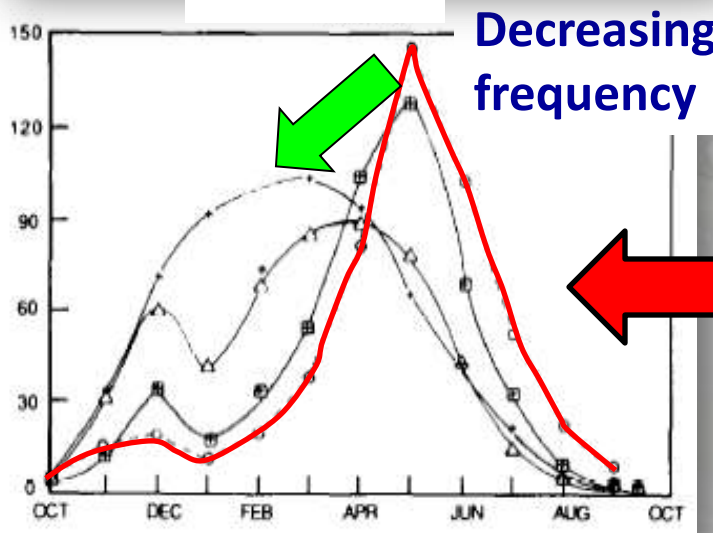
20th Century Trends in 20-Year Flood Frequencies (1915–2003)



Discharge

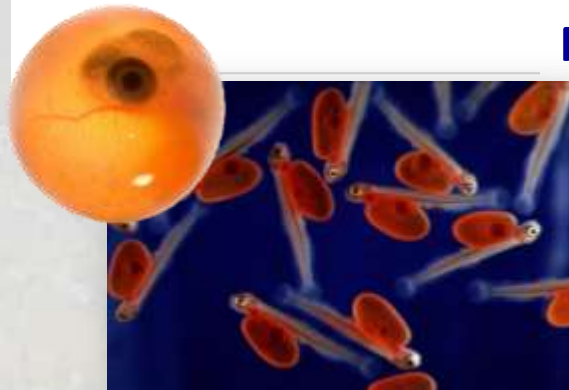
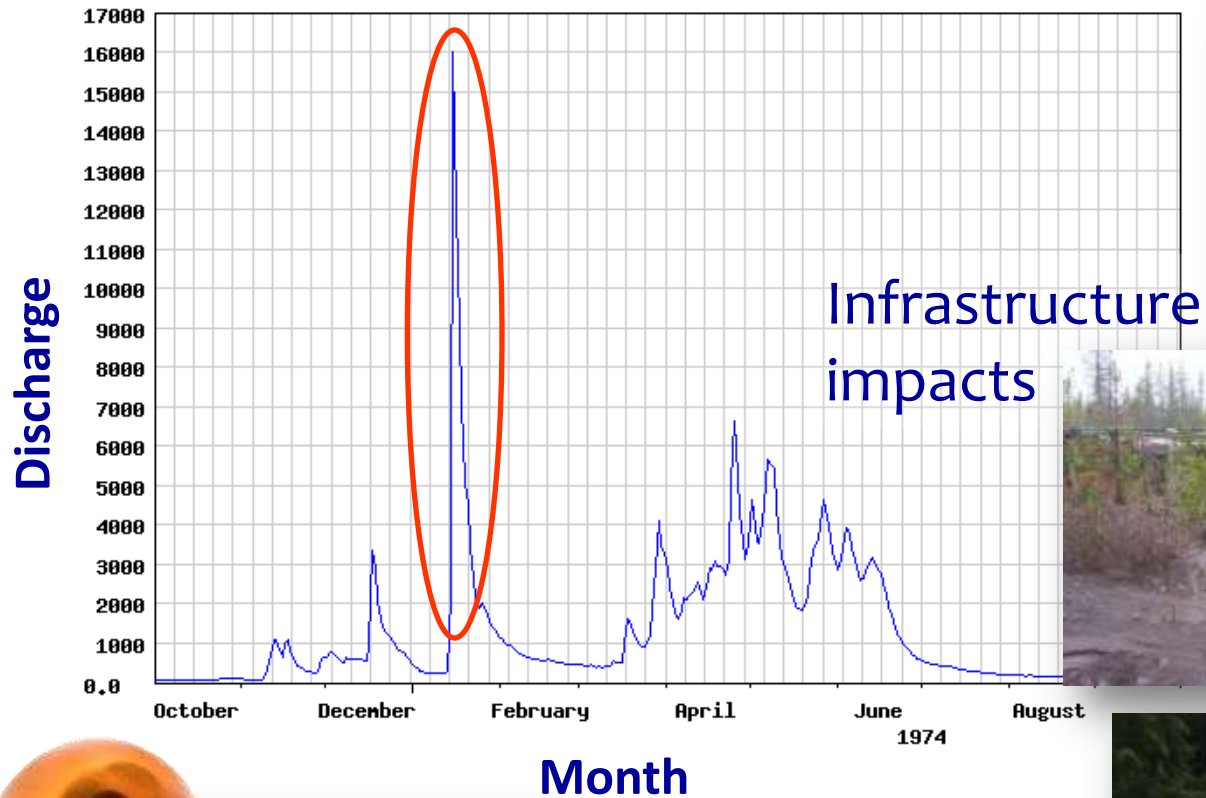


Discharge



Increases in Winter Floods

Rain-on-snow events



Fish
egg/embryo
mortality

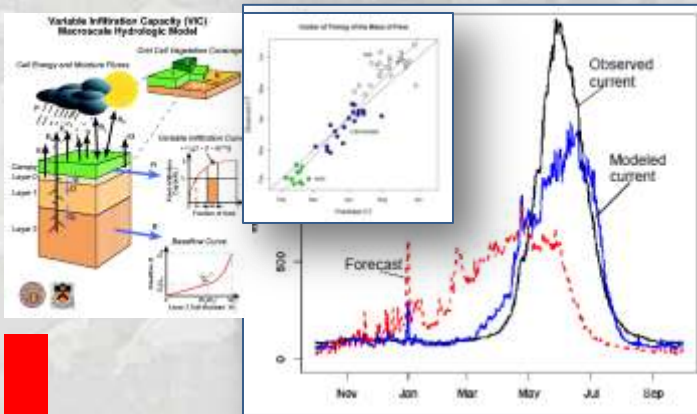


VIC Streamflow Scenarios

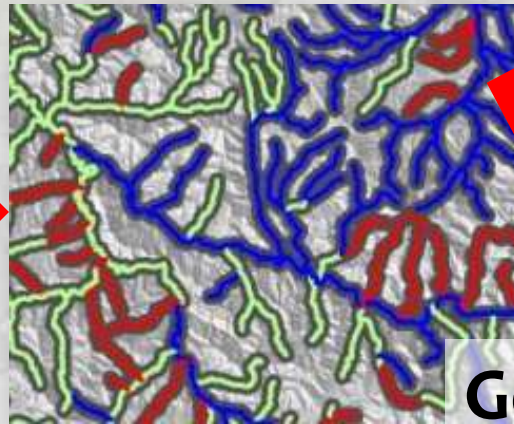
Ecological Flow Metrics



**A1B IPCC Scenarios
for the western U.S.**



NHD+ stream segment resolution



Google **“Stream flow Metrics”**

Website: http://www.fs.fed.us/rm/boise/AWAE/projects/modeled_stream_flow_metrics.shtml

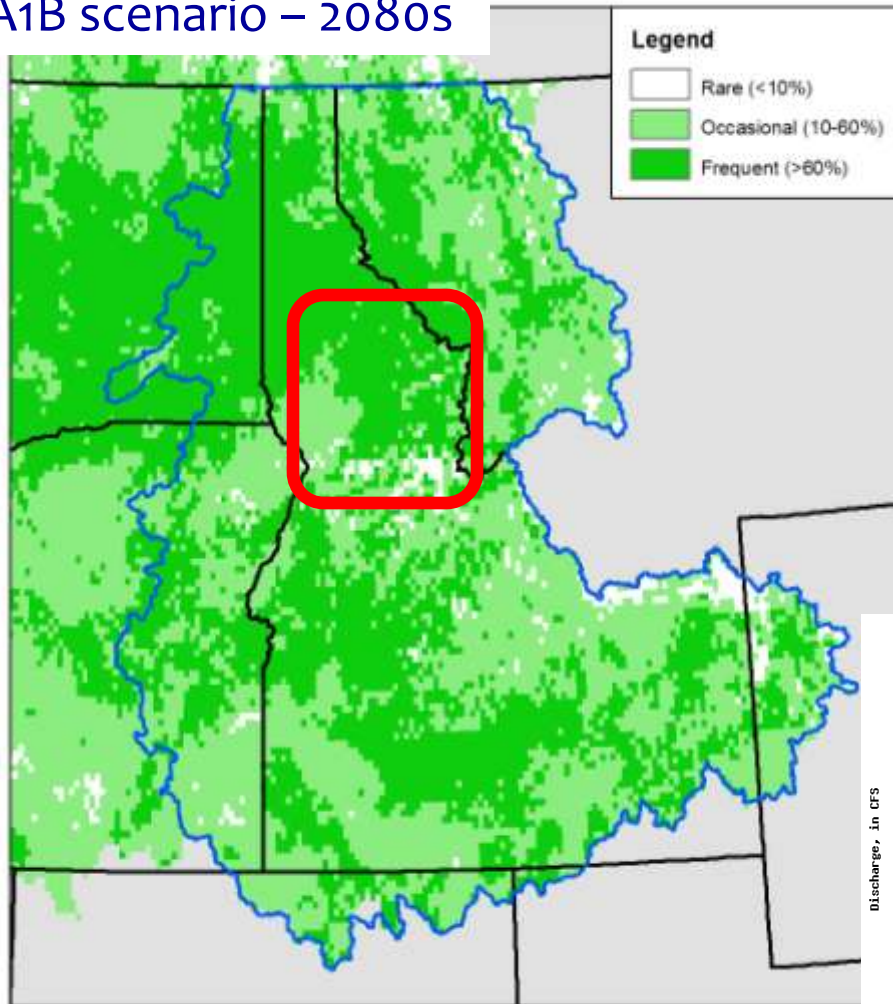
Wenger et al. 2010. *Water Resources Research* 46, W09513



VIC Streamflow Scenario

Winter flood frequency (95% event)

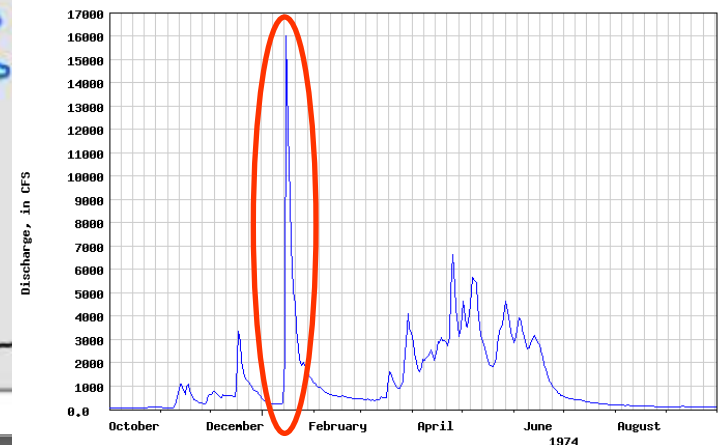
A1B scenario – 2080s



- Predictions linked to stream segments for 1:100,000 NHD Plus

- Scenarios:

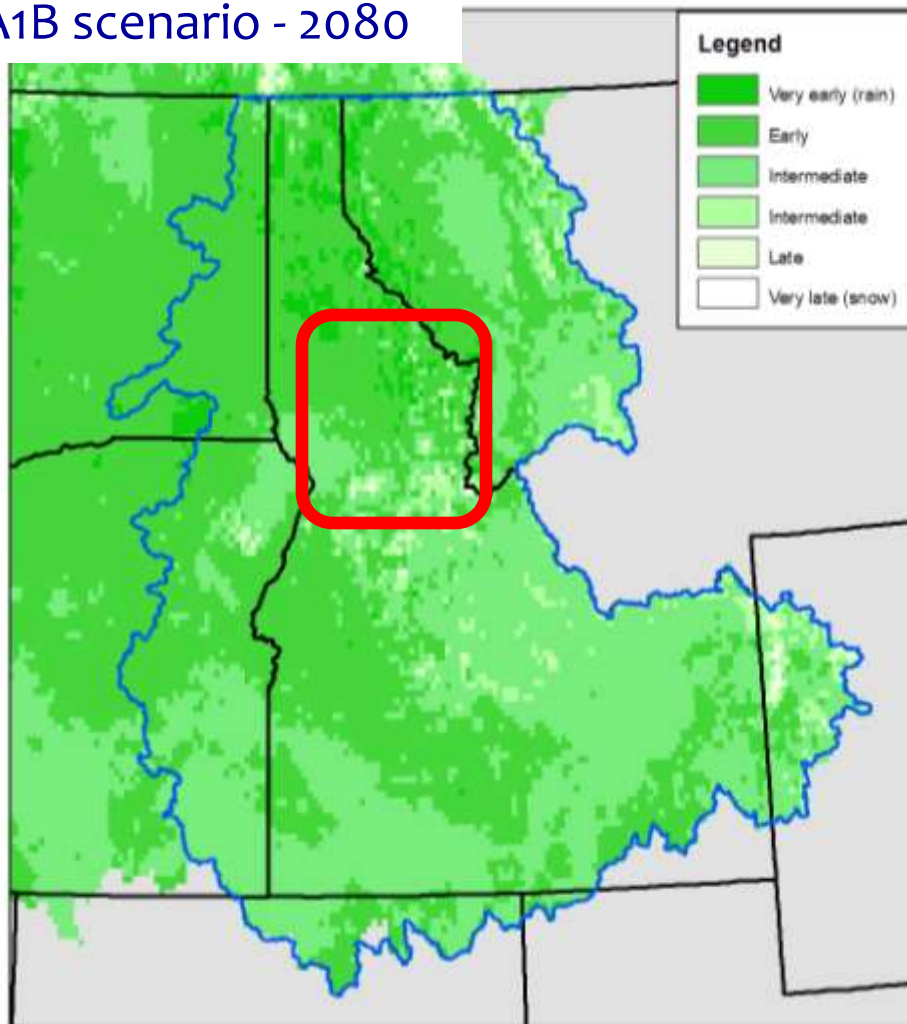
- 1) historical (1980s);
- 2) A1B mid-century (2040s – ensemble GCMs);
- 3) A1B late-century (2080s – ensemble GCMs)



VIC Streamflow Scenario

Runoff timing (Center of annual flow mass)

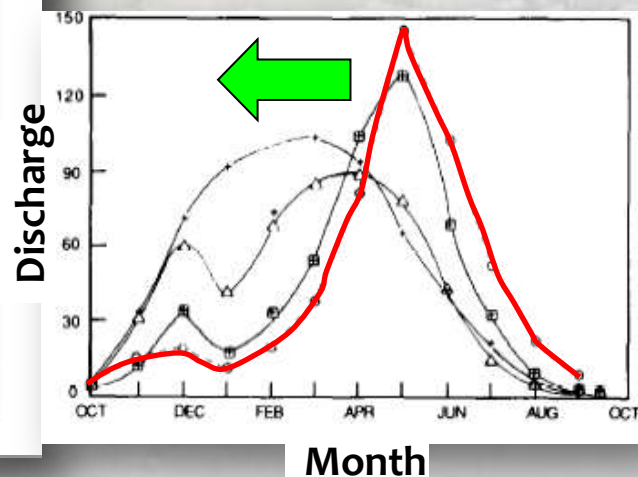
A1B scenario - 2080



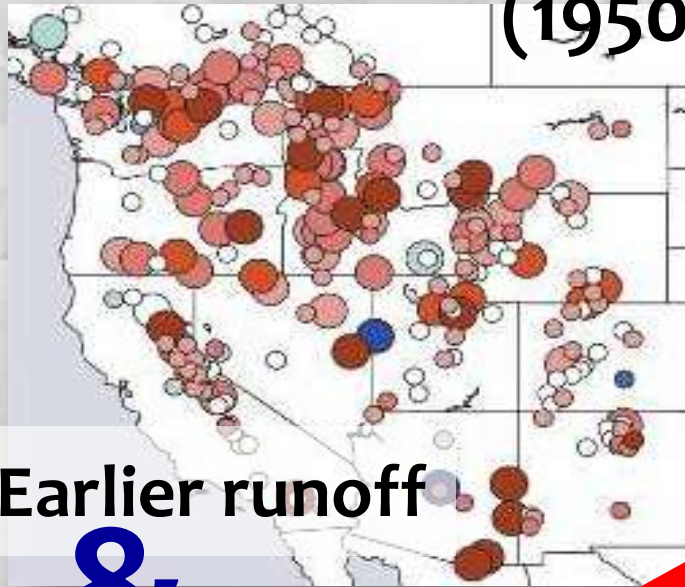
- Predictions linked to stream segments for 1:100,000 NHD Plus

- Scenarios:

- 1) historical (1980s);
- 2) A1B mid-century (2040s – ensemble GCMs);
- 3) A1B late-century (2080s – ensemble GCMs)

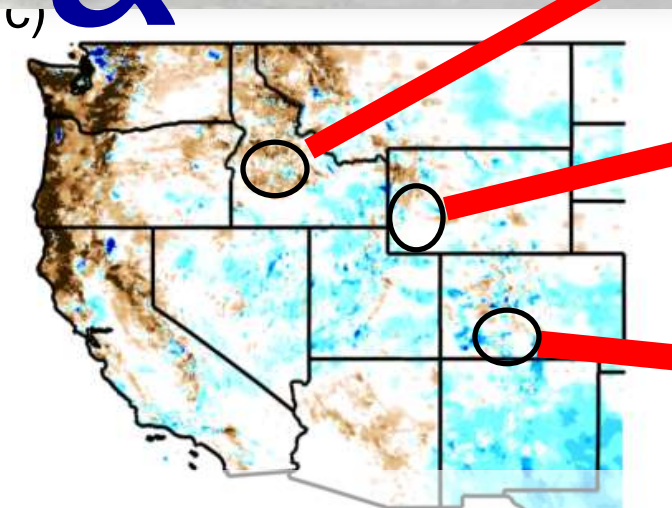


Summer Flow Trends (1950–2009)

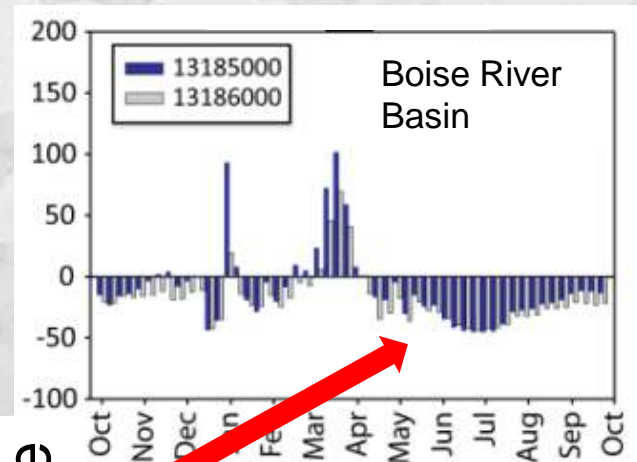


Earlier runoff

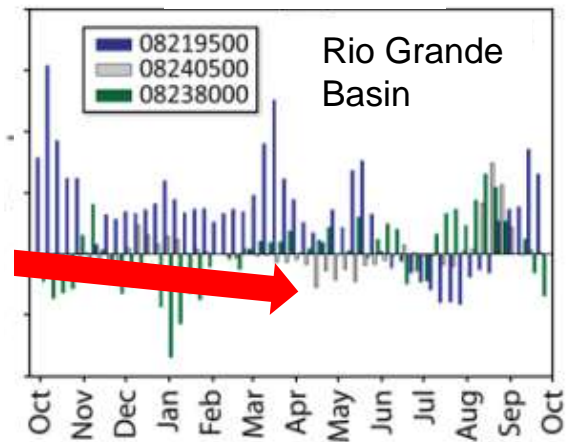
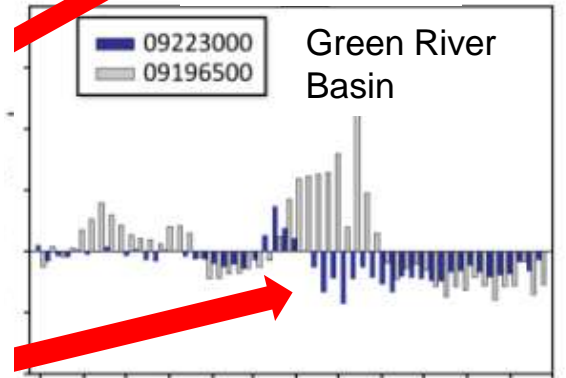
&



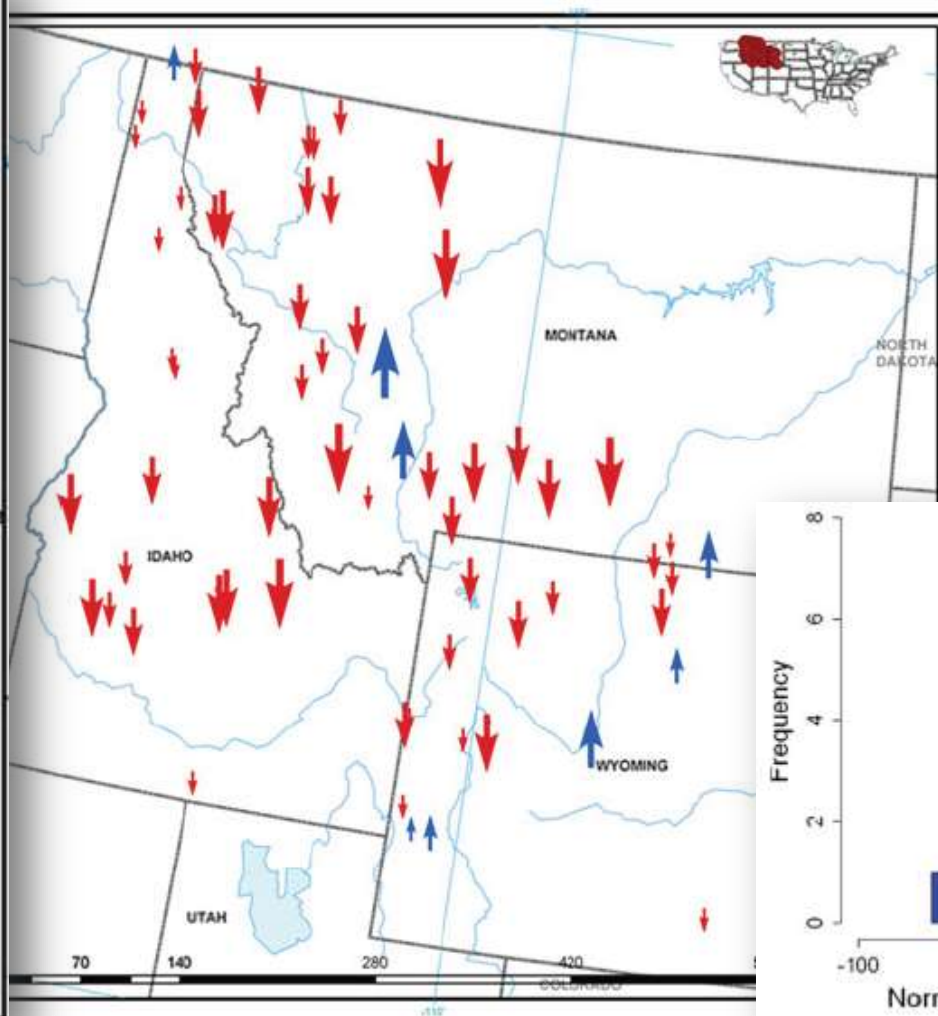
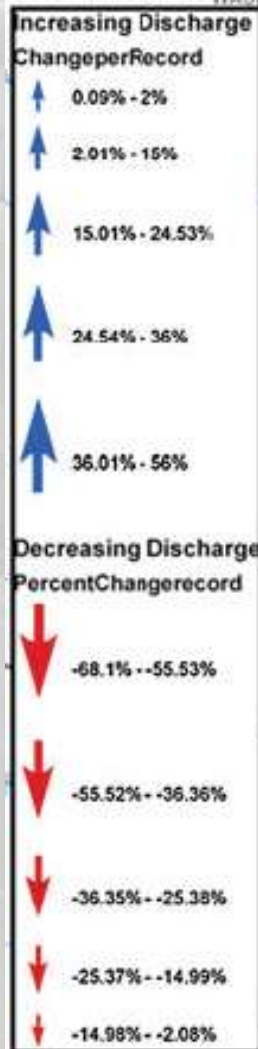
precipitation trends



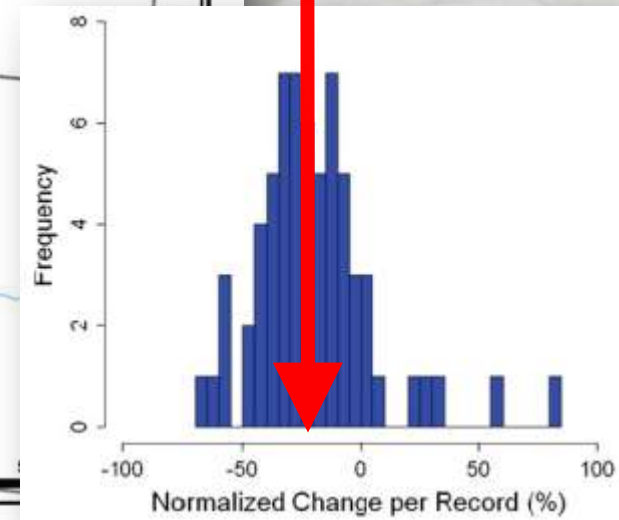
% Change in Stream Discharge



August Flow Declines Common Across Northern Rockies (1950-2008)

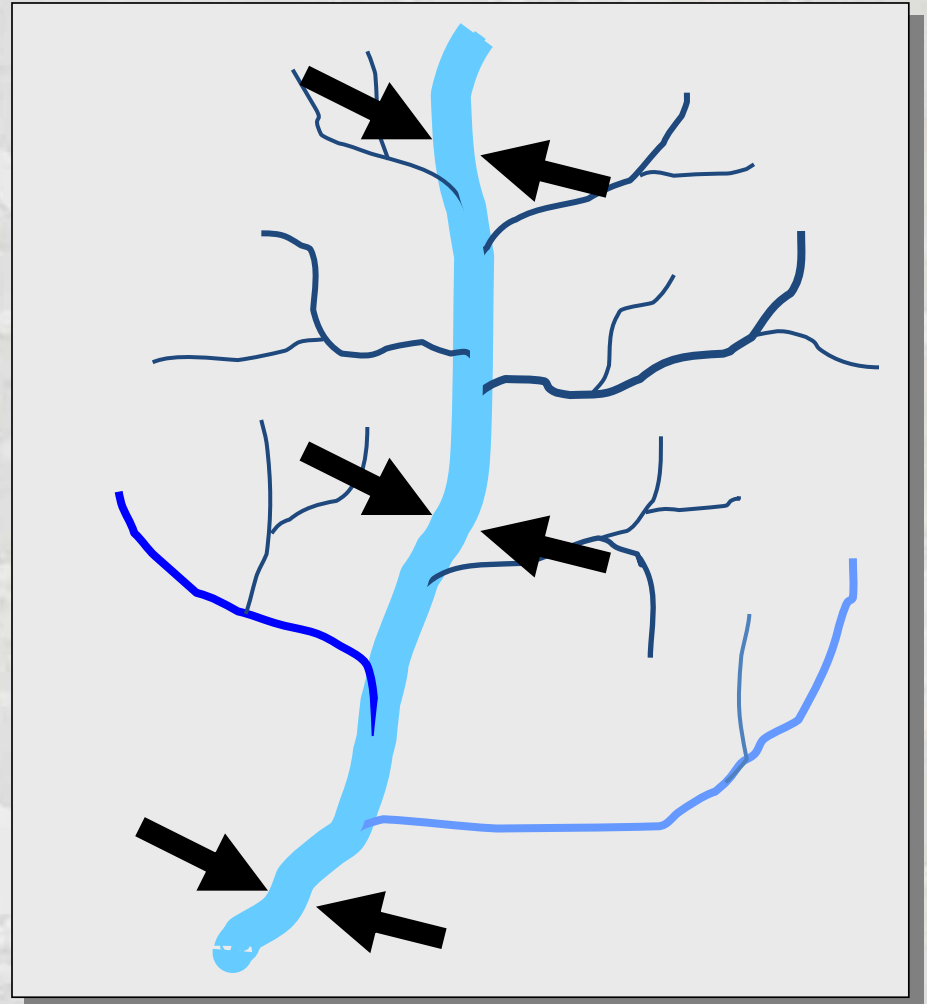


21% Average Decline



Leppi et al. 2012. Impacts of climate change on August stream discharge in the Central-Rocky Mountains. *Climatic Change* **112**: 997-1014.

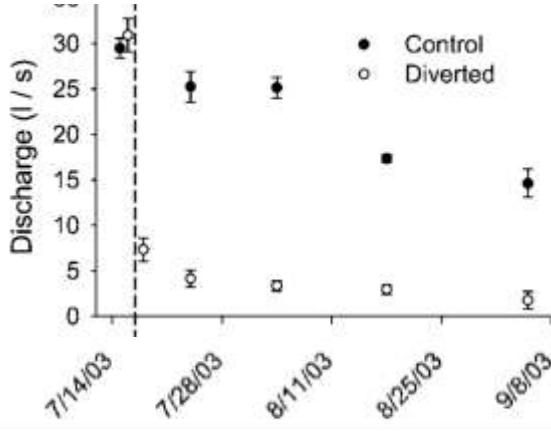
Flow Declines ~ Smaller & More Fragmented Habitats



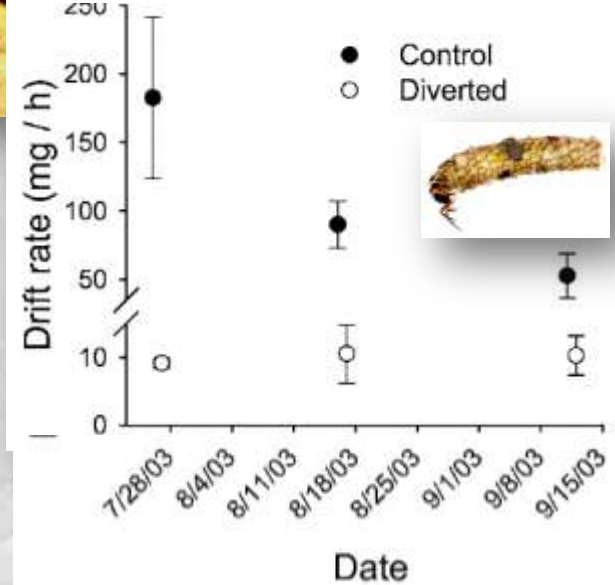
Fish passage issues exacerbated

Flow Declines ~ Less Productive Habitats

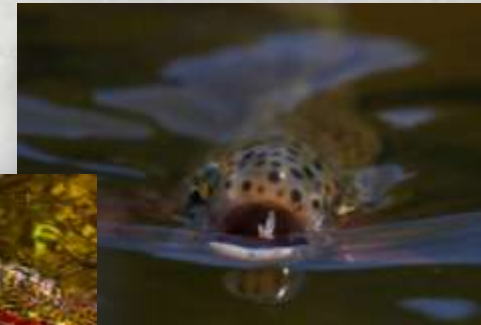
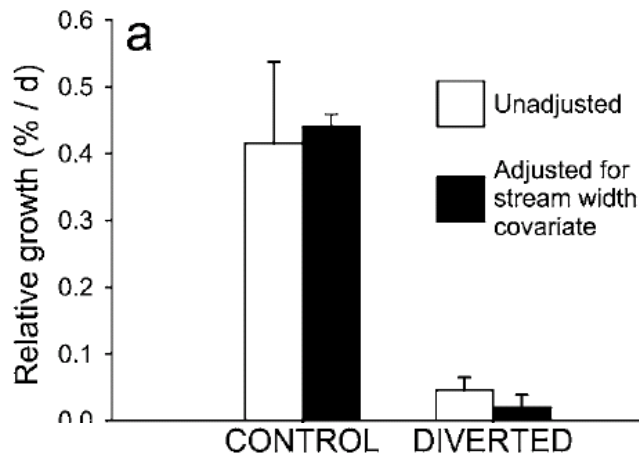
Less water & velocity



Less aquatic insect drift



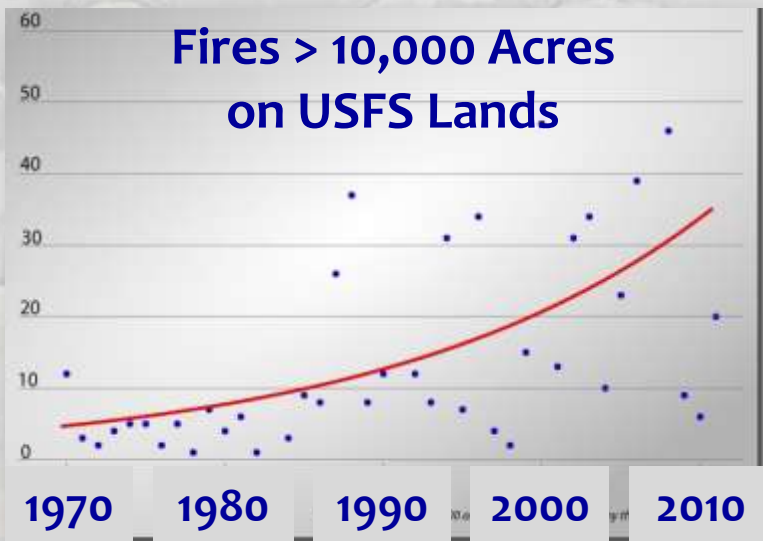
Less trout growth



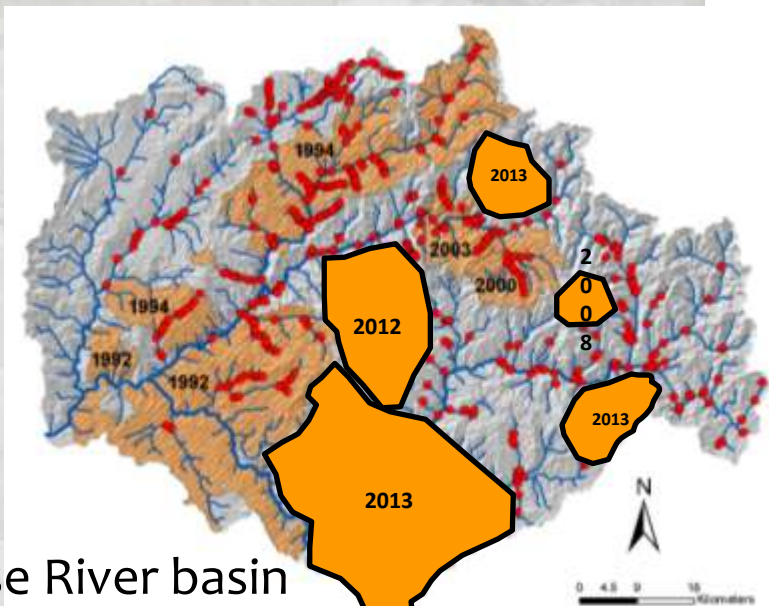
**You are a bug.
I will eat you**

Harvey et al. 2006. Reduced streamflow lowers dry-season growth of rainbow trout in a small stream. *Transactions of the American Fisheries Society* 135:998-1005.

Wildfires Increasing Westwide



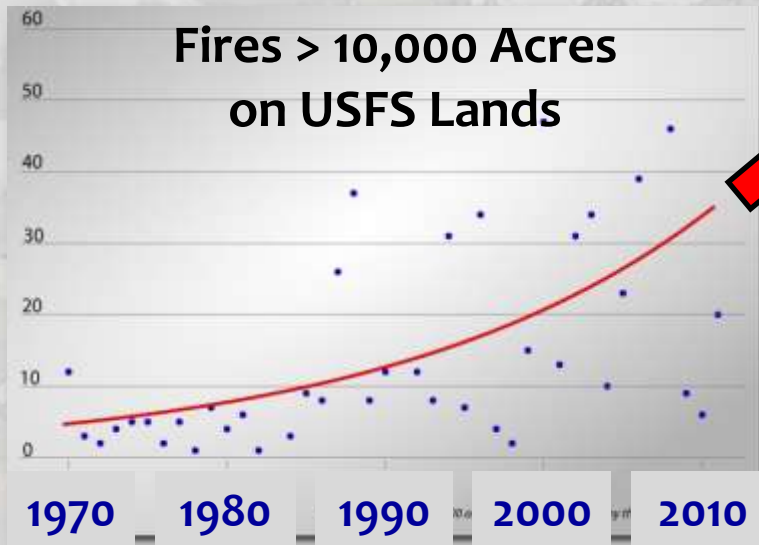
National Research Council. 2011



Boise River basin fires (1992-2013)... It just keeps burning

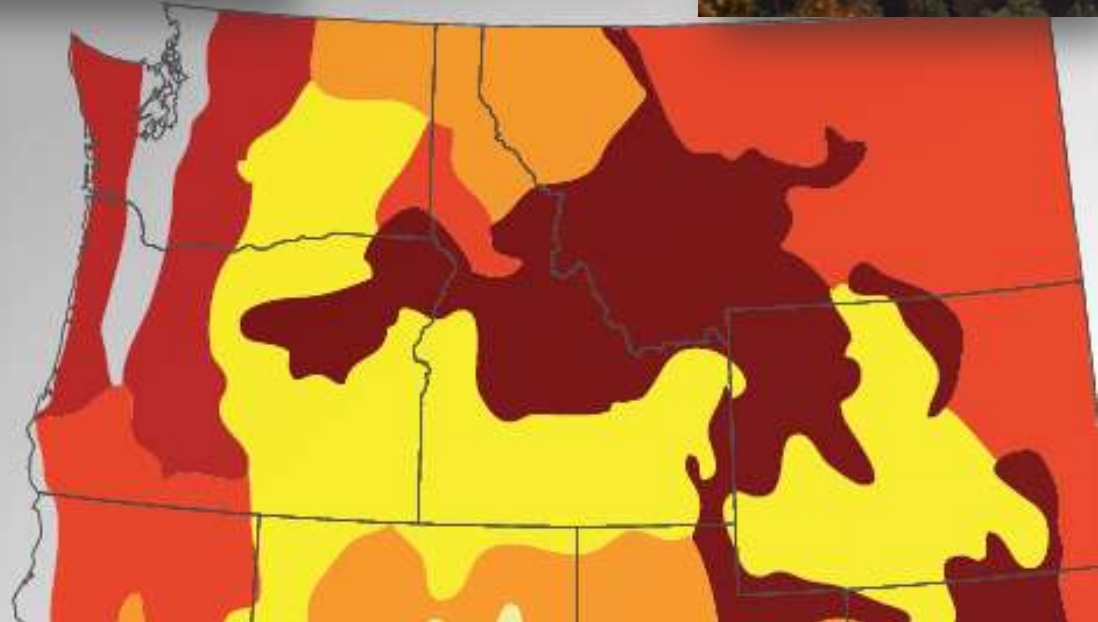


Future Means More & Bigger Fires



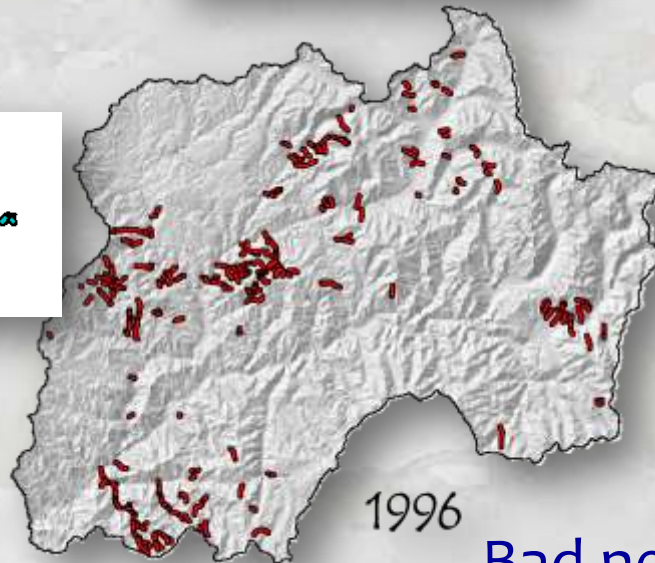
If +1.0 °C...

- at least 6 times more
- 5-6 times more
- 4-5 times more
- 3-4 times more
- 2 - 3 times more
- up to 2 times more



Sediment Loading to Stream Channels

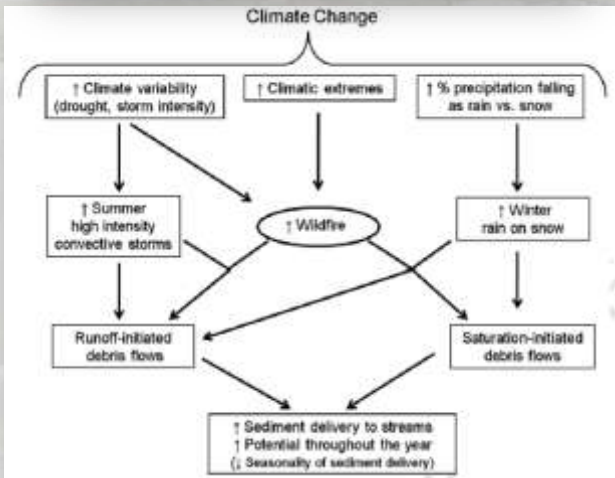
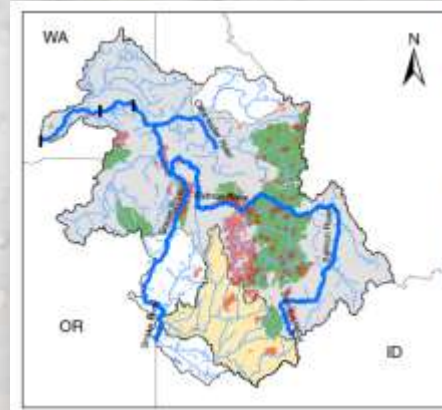
Thunderstorms & debris
flow torrents



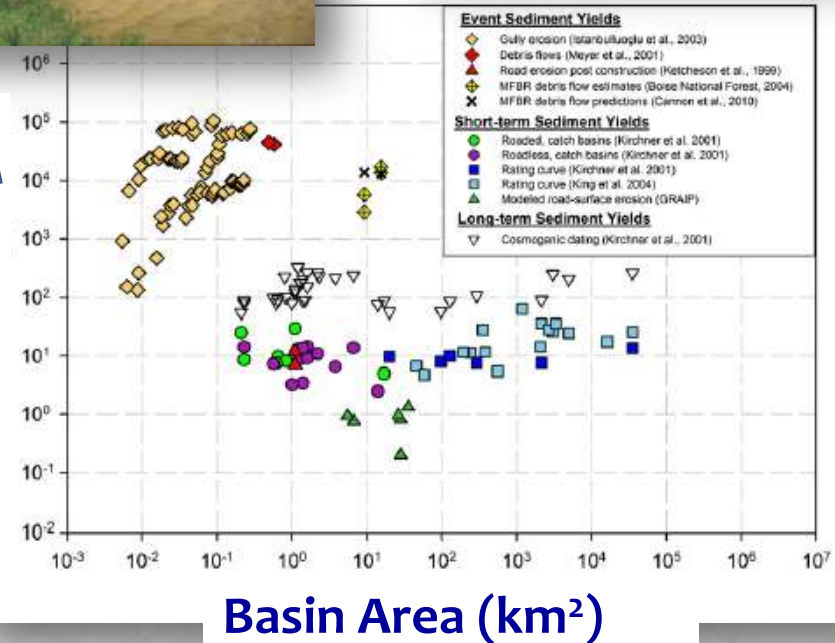
Bad news if you're a fish living here

Sediment Loading to Stream Channels

Channel form & habitats will evolve



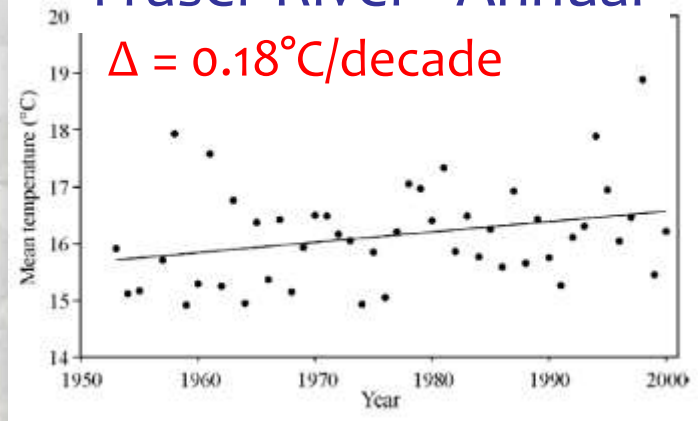
Sediment Yield
(tons/year/km²)



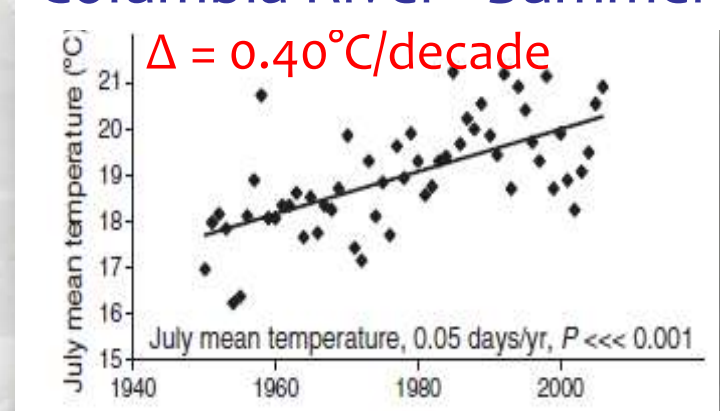
Goode et al. 2011. Enhanced sediment delivery in a changing climate in semi-arid mountain basins: Implications for water resource management and aquatic habitat in the northern Rocky Mountains. *Geomorphology* 139/140:1-15.

Temperature Trends In Northwest Rivers

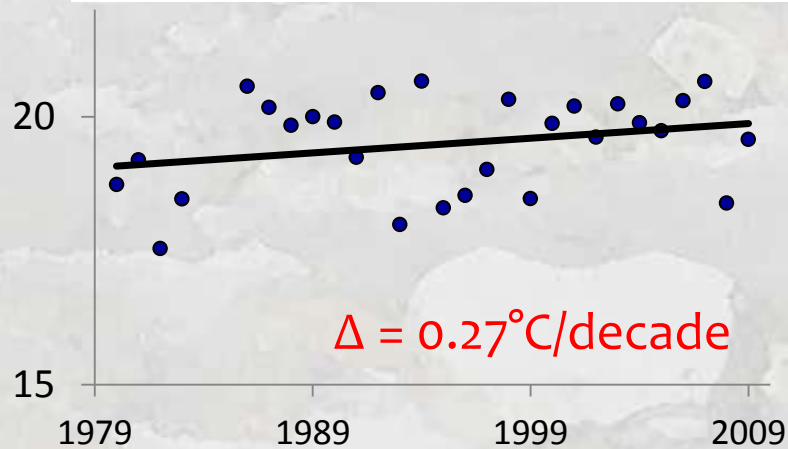
Fraser River - Annual



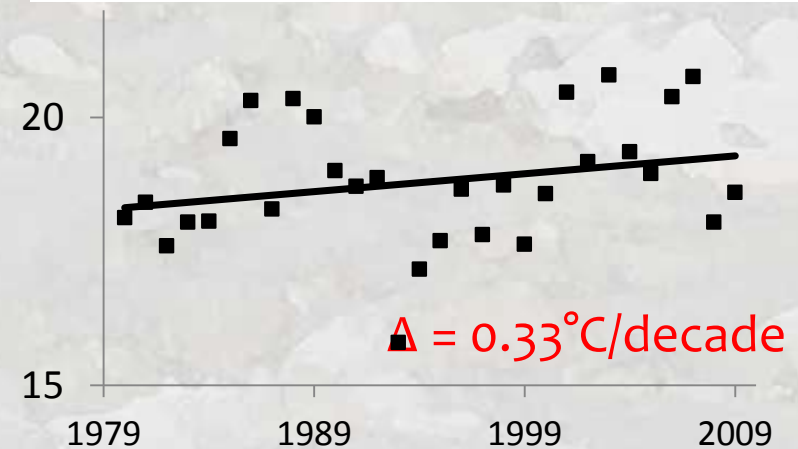
Columbia River - Summer



Snake River, ID - Summer

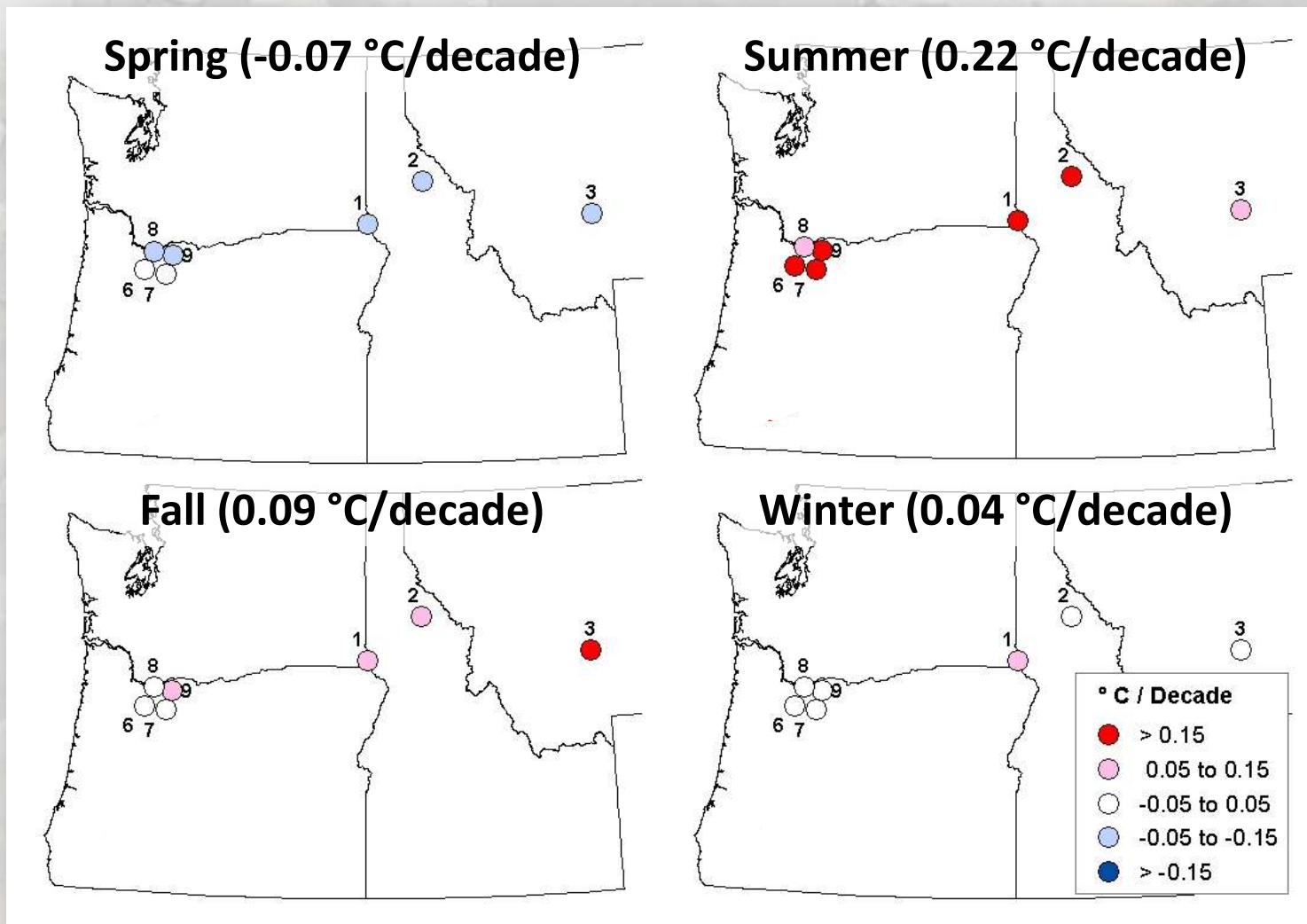


Missouri River, MT - Summer



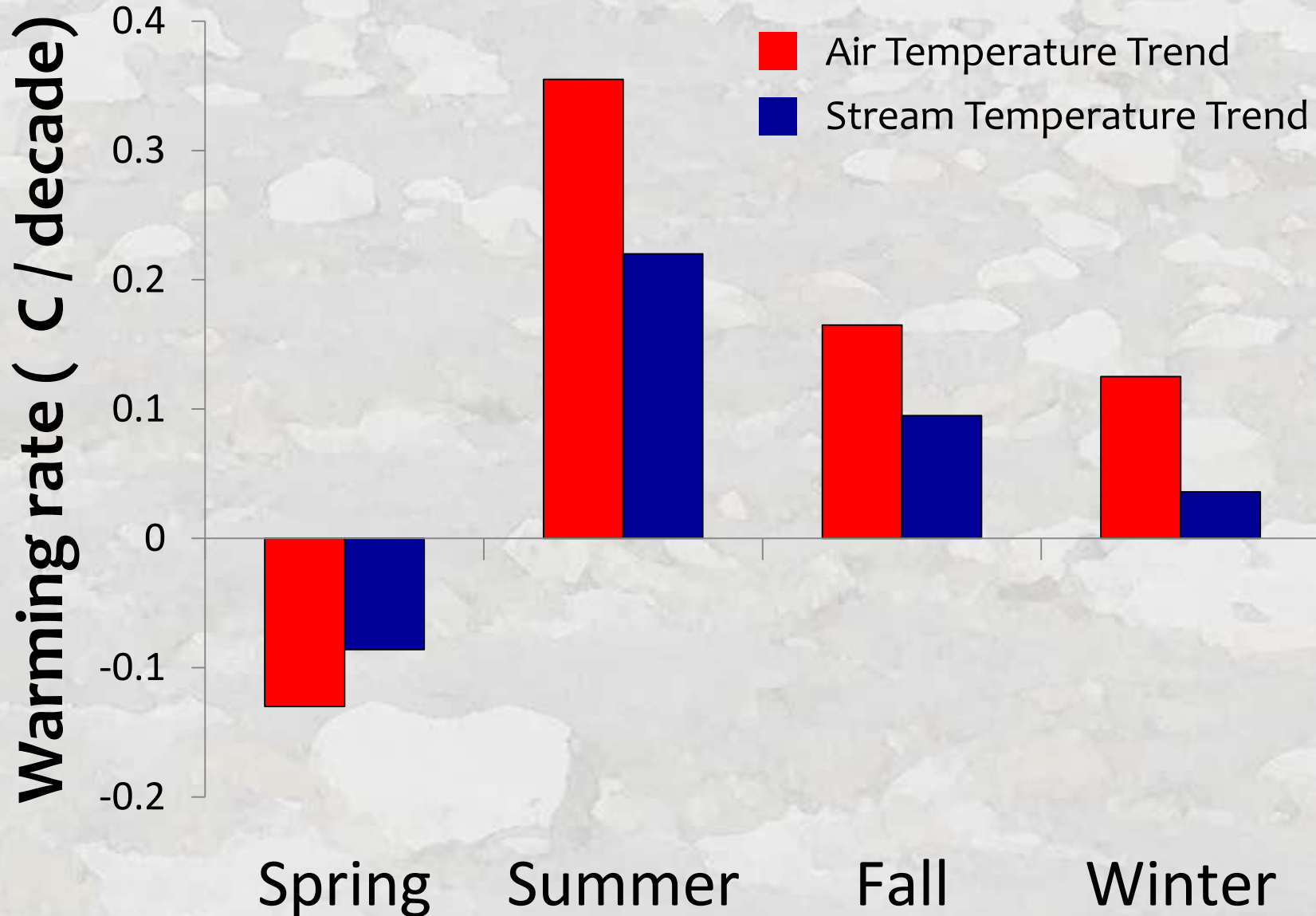
Seasonal Trends In Temperatures (1980-2009)

Unregulated sites (7) with 30 years of annual data

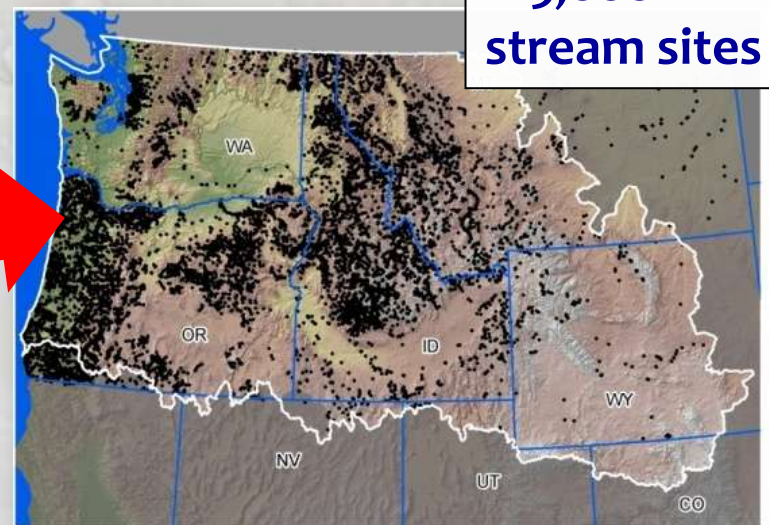
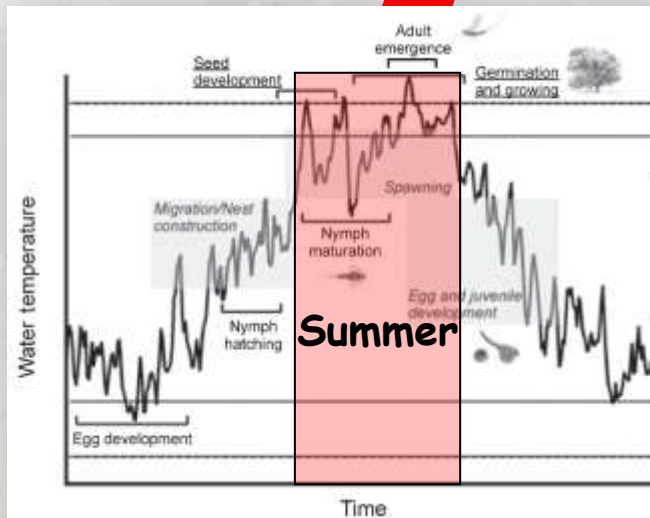
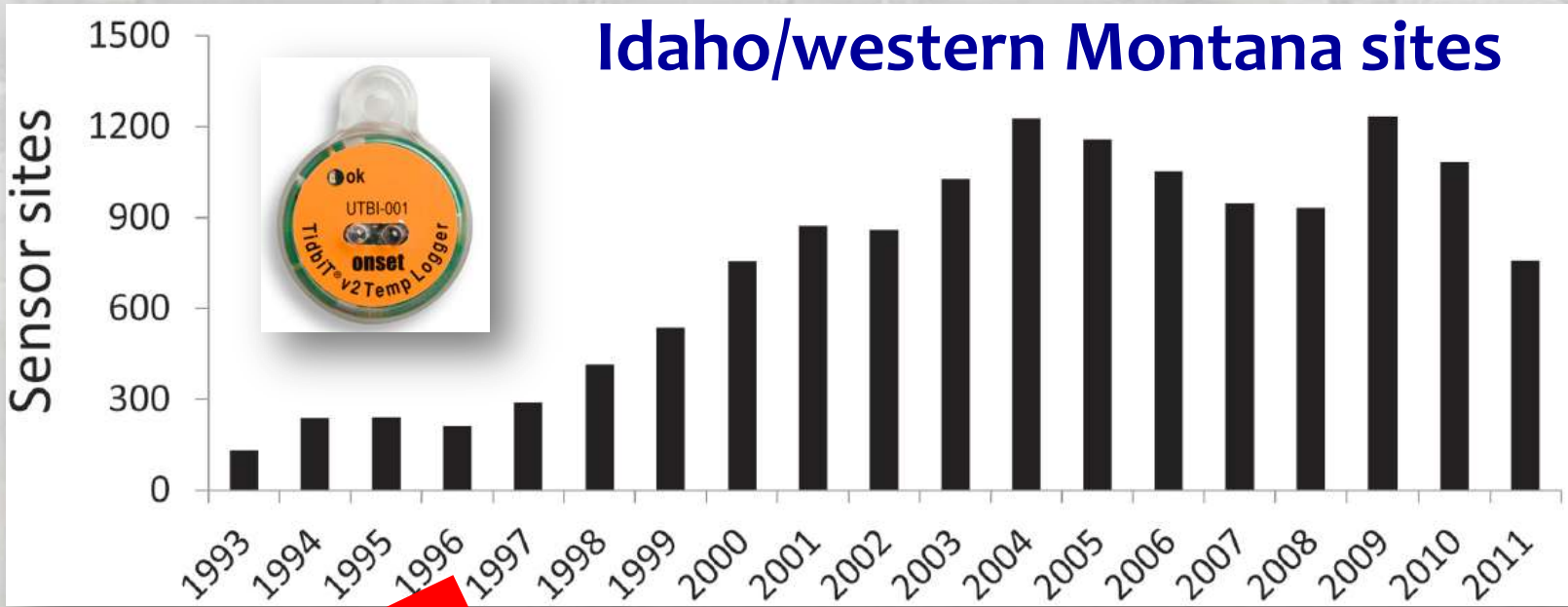


Stream Temperatures Track Air Temps

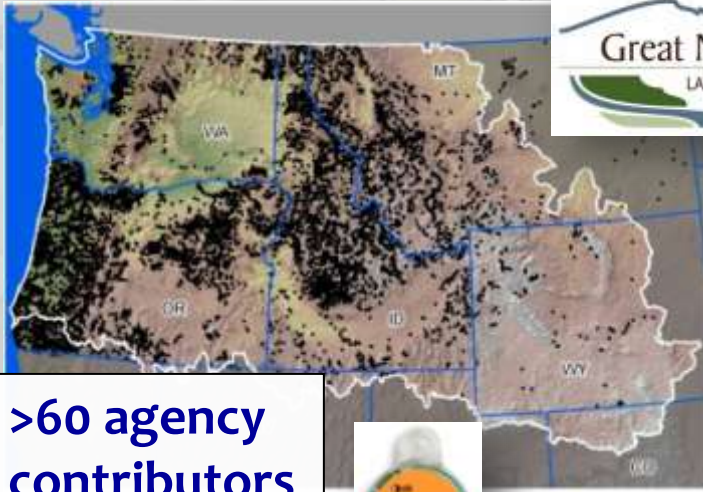
Streams warm about 60% as fast



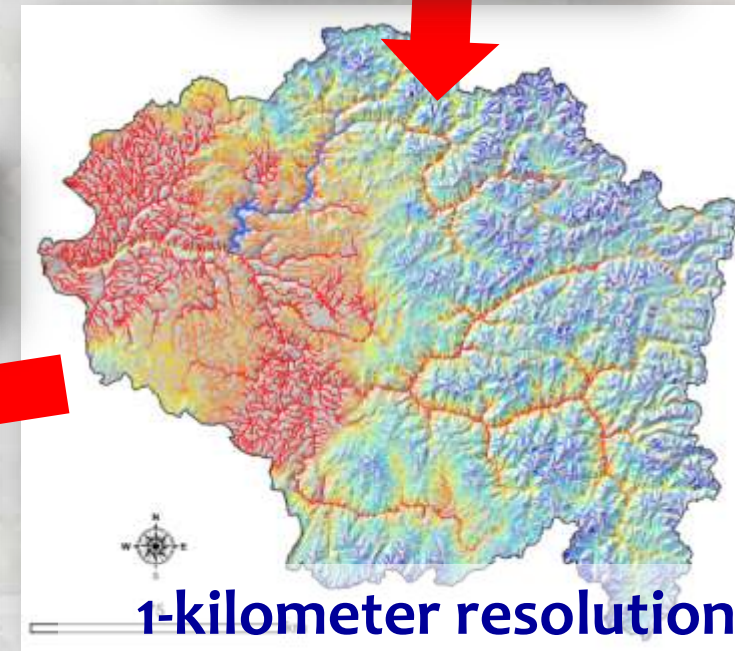
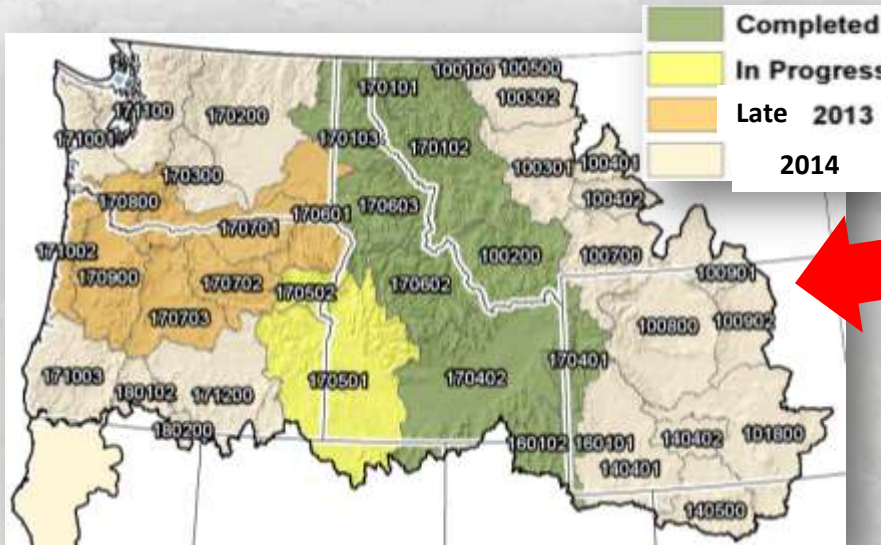
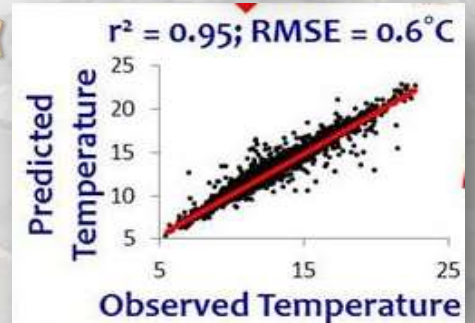
Lots of Summer Temp Data Out There...



NorWeST Stream Temp Scenarios



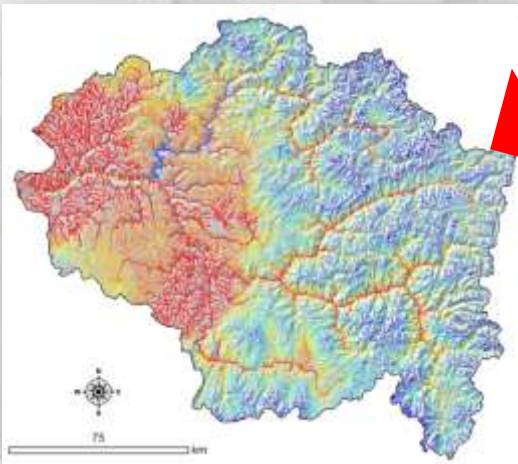
>60 agency contributors



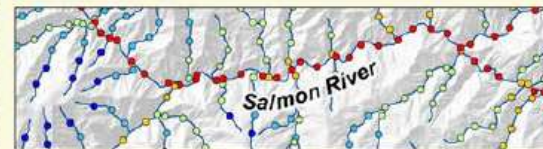
1-kilometer resolution

Website Distributes Scenarios & Temperature Data as GIS Layers

1) GIS shapefiles of stream temperature scenarios

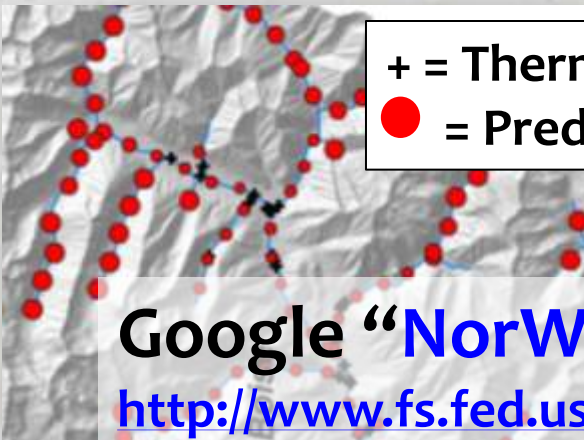


NorWeST
Stream Temp



Regional Database and Modeled Stream Temperatures

2) GIS shapefiles of stream temperature model prediction precision



+ = Thermograph
● = Prediction SE

3) Temperature data summaries

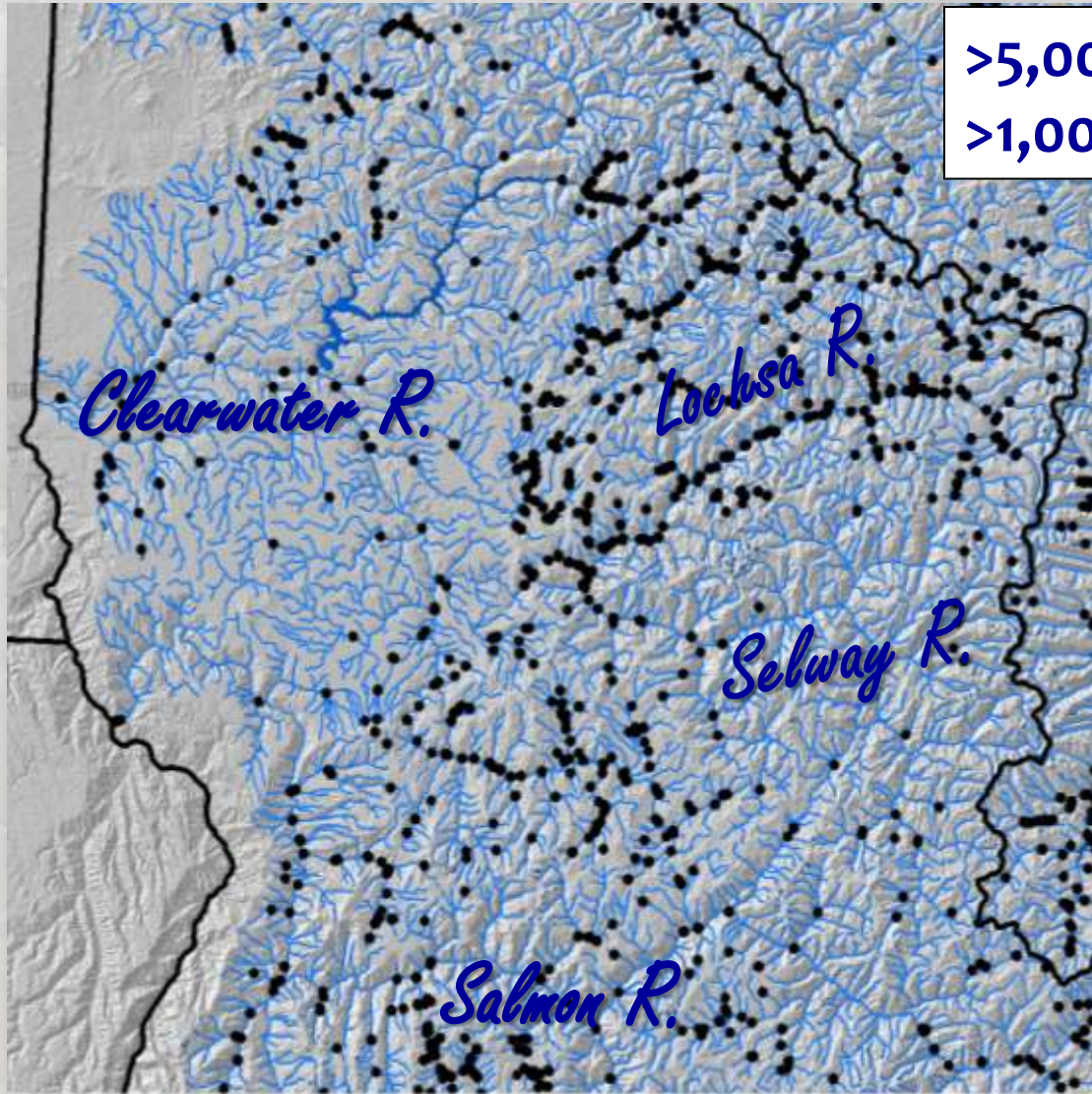


Google **NorWeST** or go here...

<http://www.fs.fed.us/rm/boise/AWAE/projects/NorWeST.shtml>

Clearwater-Nez Temperature Dataset is *World Class!*

>5,000 August means
>1,000 stream sites



•Temperature site



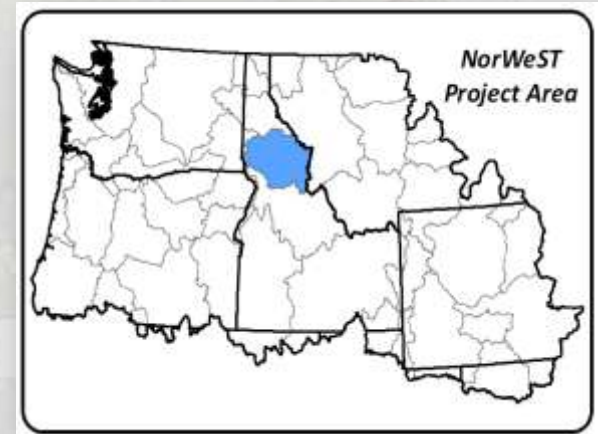
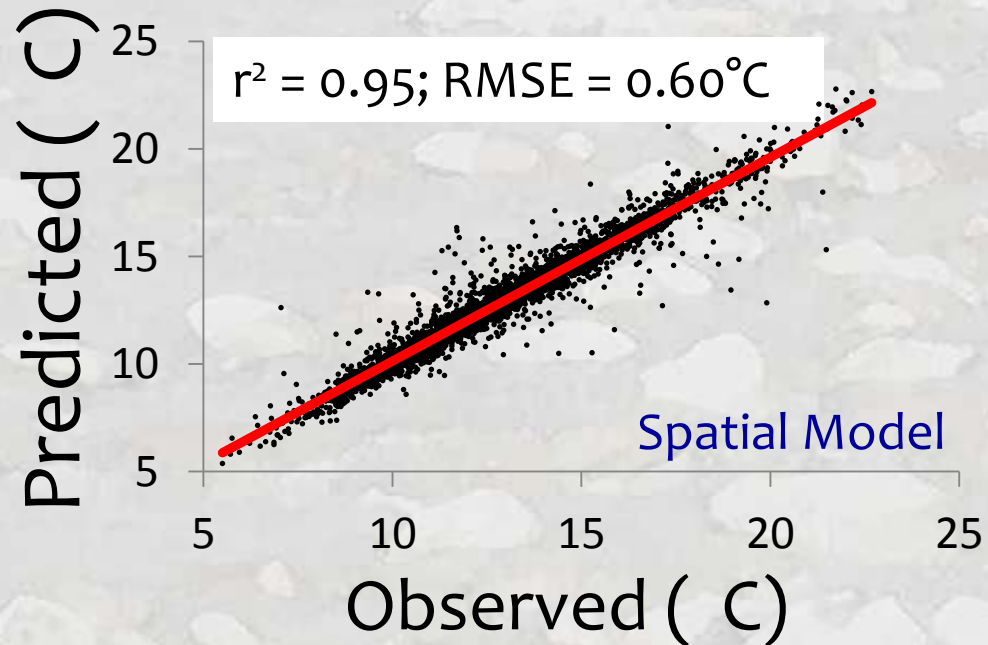
Clearwater-Nez River Temp Model

Mean August Temperature

Covariate Predictors

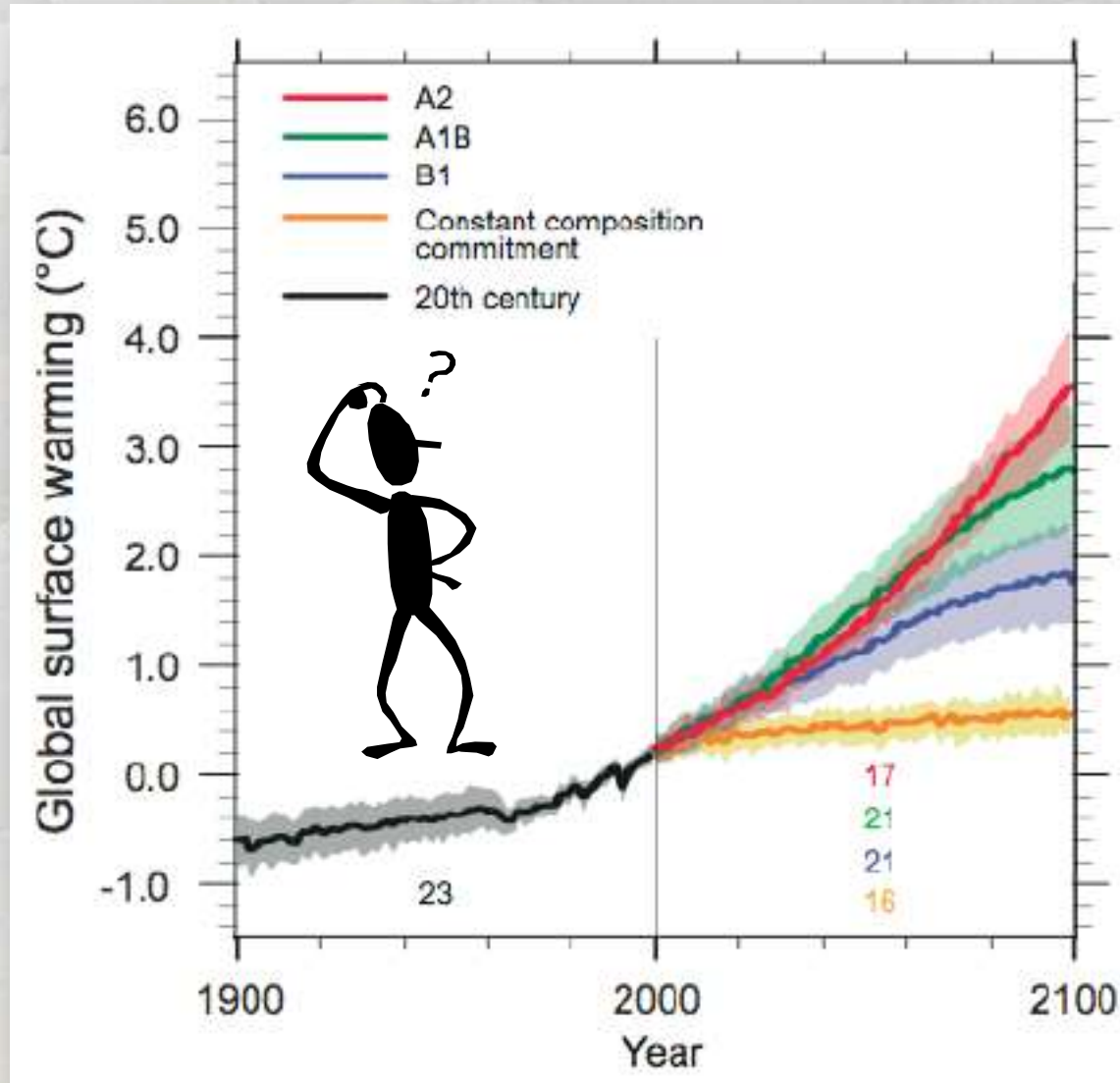
1. Elevation (m)
2. Canopy (%)
3. Stream slope (%)
4. Ave Precipitation (mm)
5. Latitude (km)
6. Lakes upstream (%)
7. Baseflow Index
8. Watershed size (km²)

9. Discharge (m³/s)
USGS gage data
10. Air Temperature (°C)
RegCM3 NCEP reanalysis
Hostetler et al. 2011



Models Enable Climate Scenario Maps

Many possibilities exist...



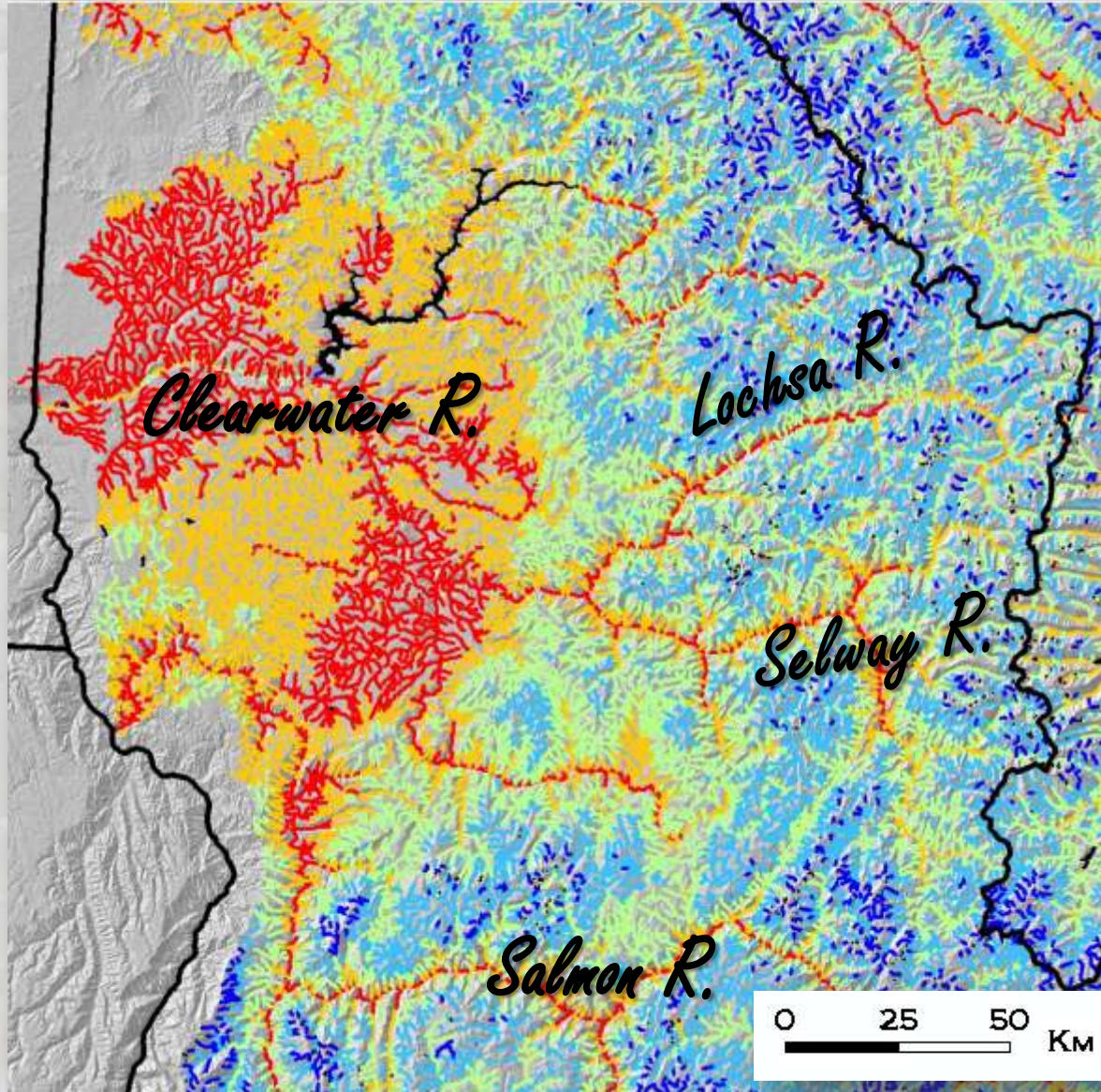
Adjust...

- Air
- Discharge
- %Canopy

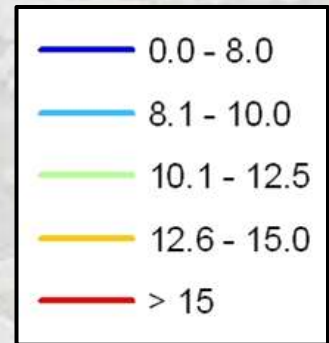
... values to
create scenarios

Clearwater-Nez Stream Temp Scenarios

Historic (1993-2011 Average August)



Temperature (C)

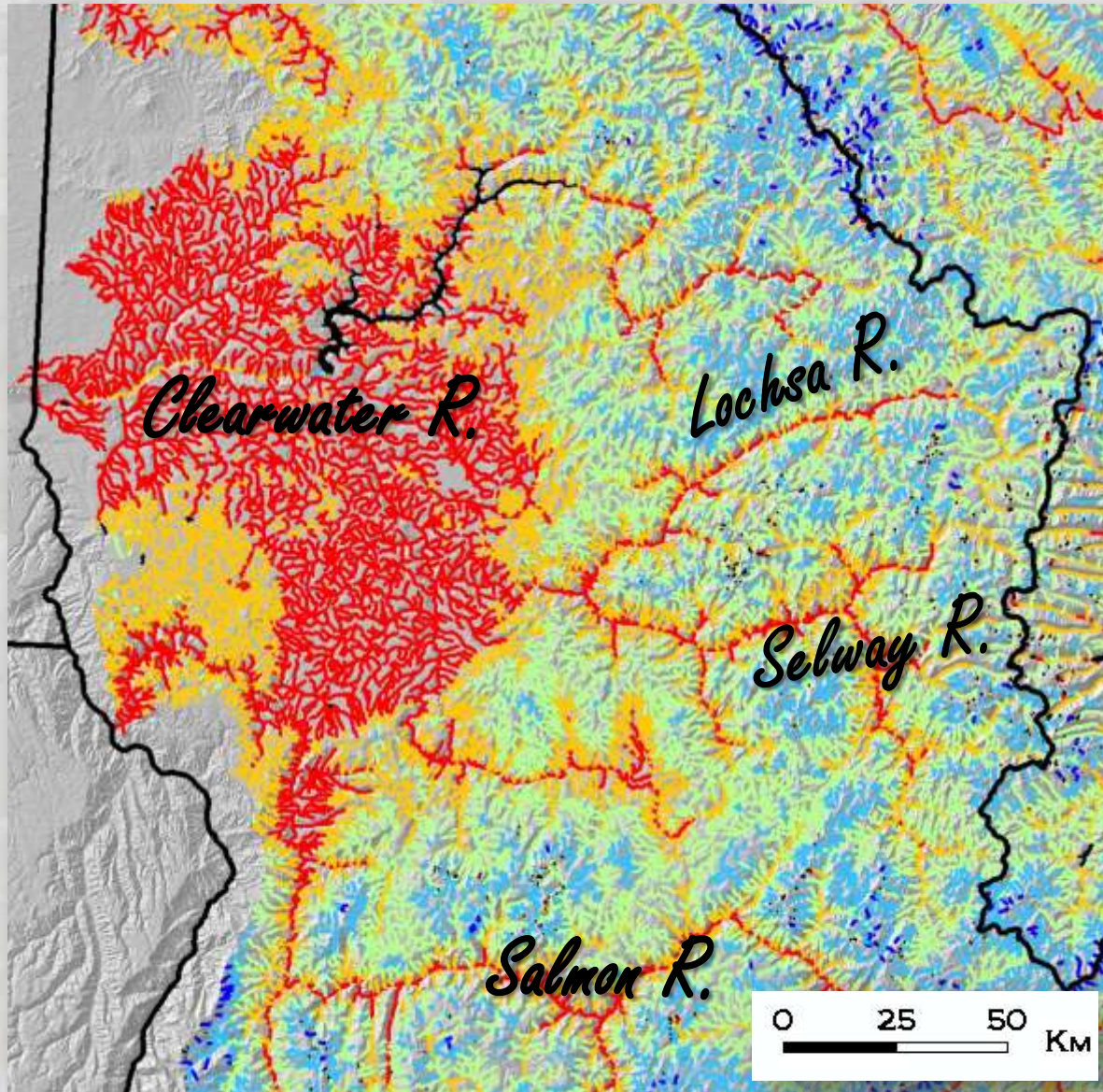


**1 kilometer
model
resolution**

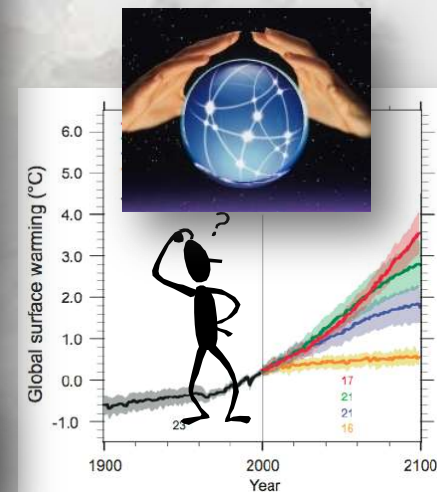
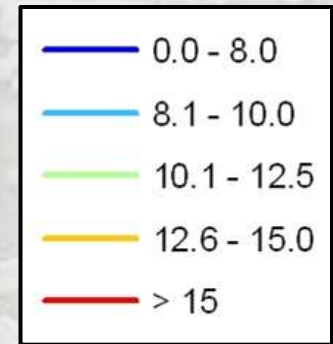


Clearwater-Nez Stream Temp Scenarios

+1.00°C Stream Temp (~2040s)

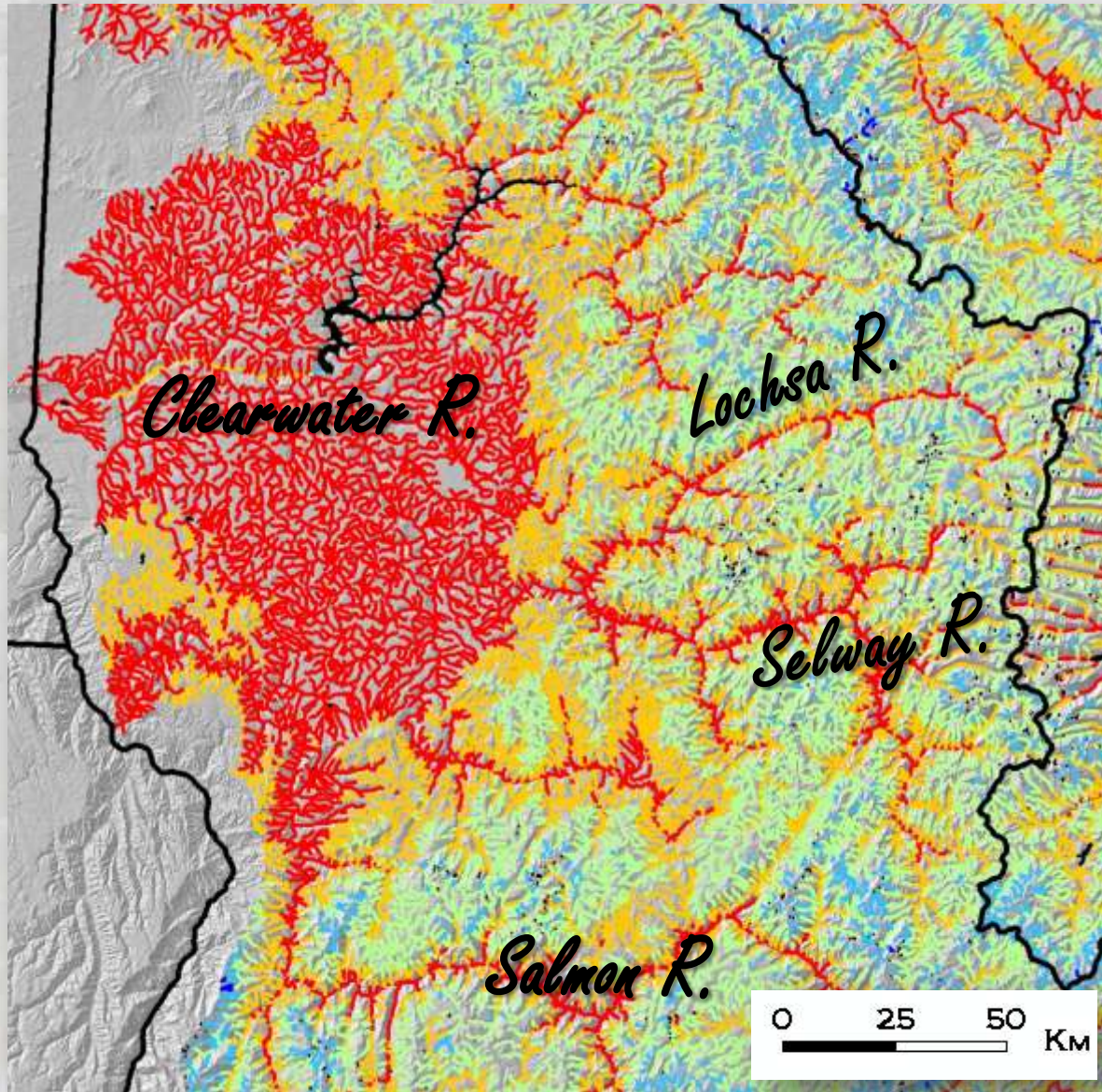


Temperature (C)

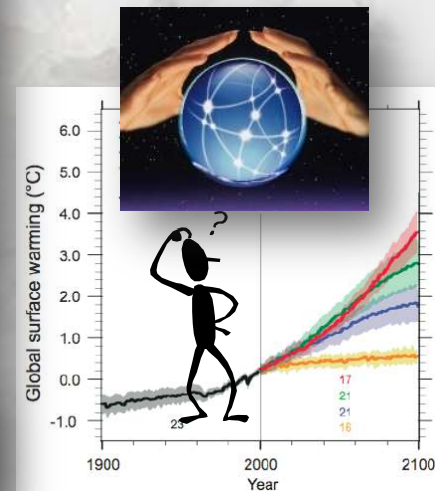
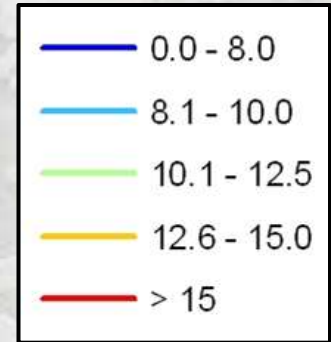


Clearwater-Nez Stream Temp Scenarios

+2.00°C Stream Temp (~2080s)



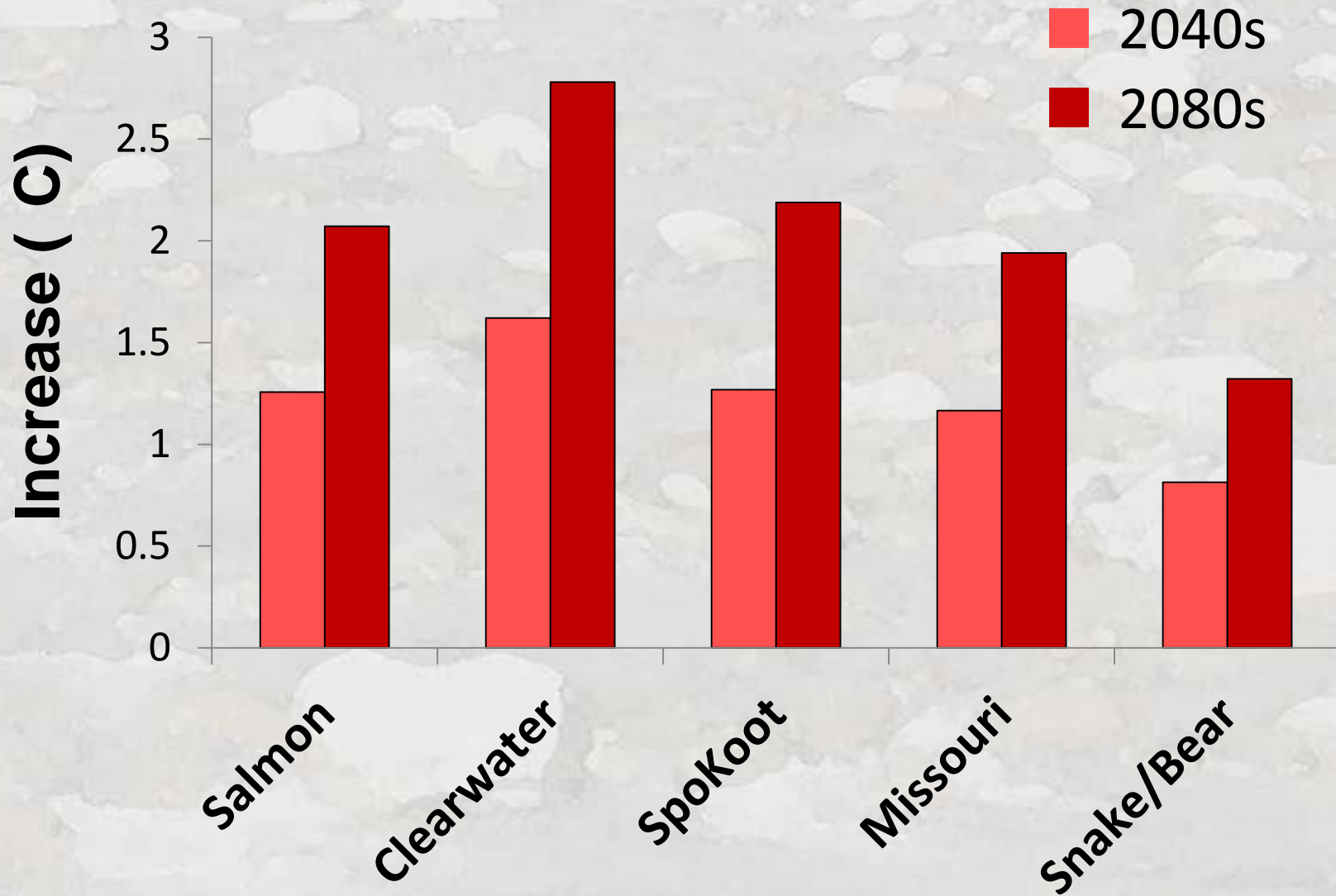
Temperature (C)



Future Stream Temperature Increases

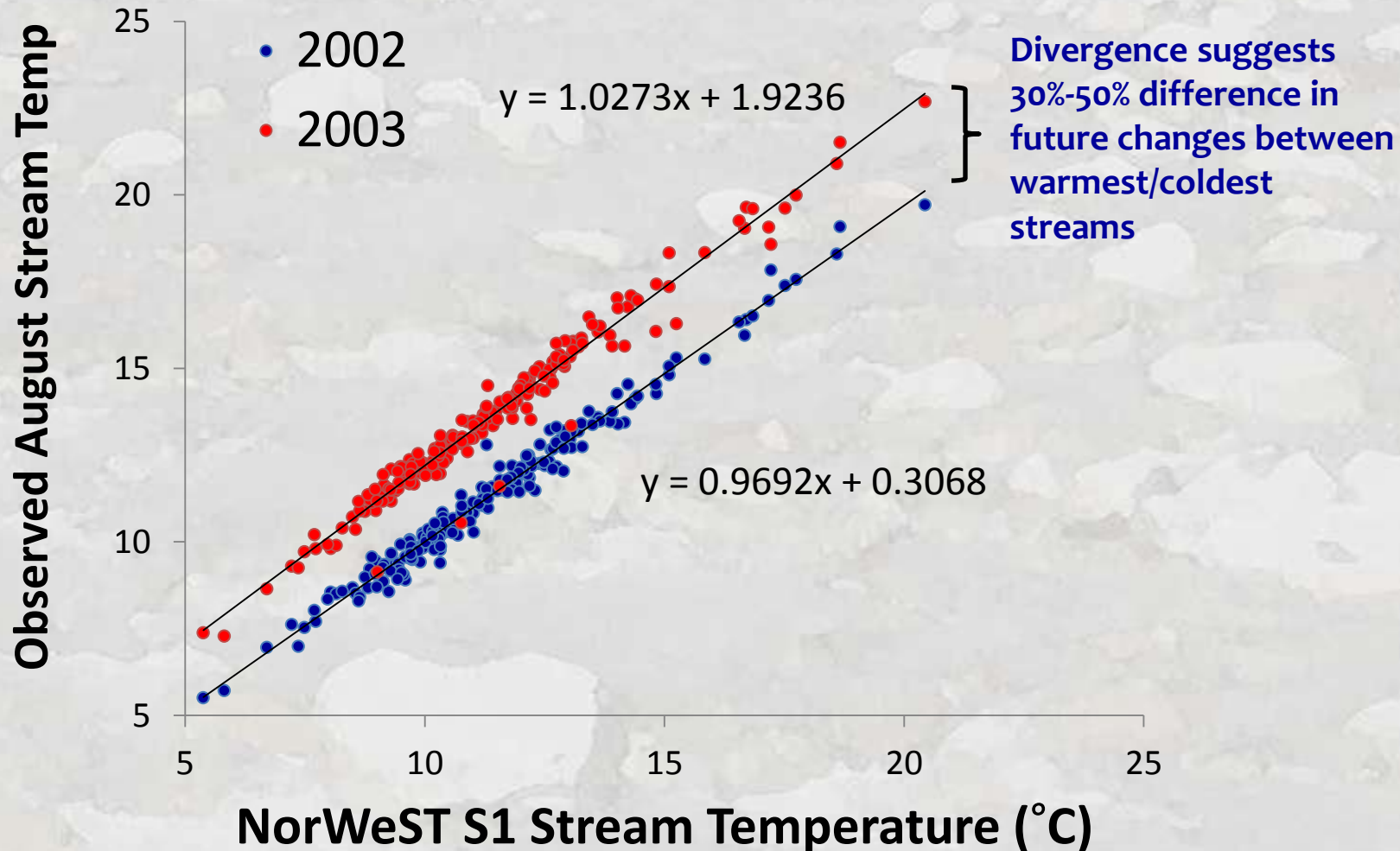
Scenario: A1B ensemble averages from CIG (delta-hybrid)

Baseline: 1980s (1970-1999) period



Differential Stream Temperature Warming

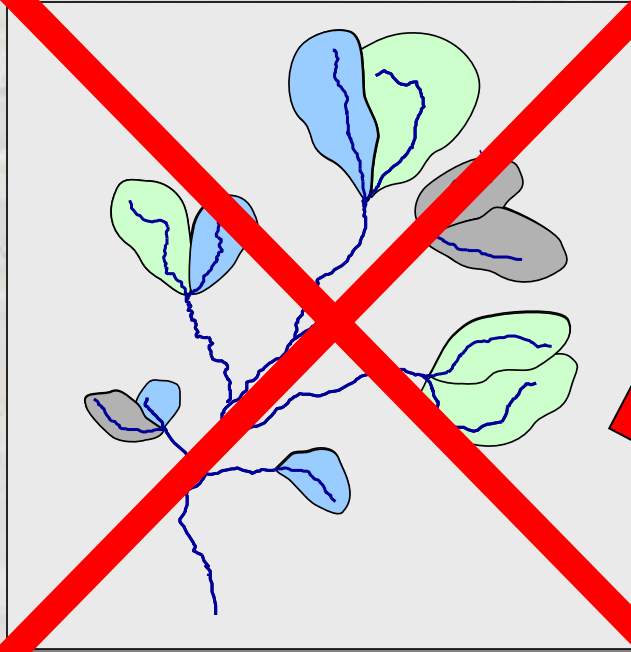
Cold streams warm slower (data are Clearwater monitoring data referenced to NorWeST predictions)



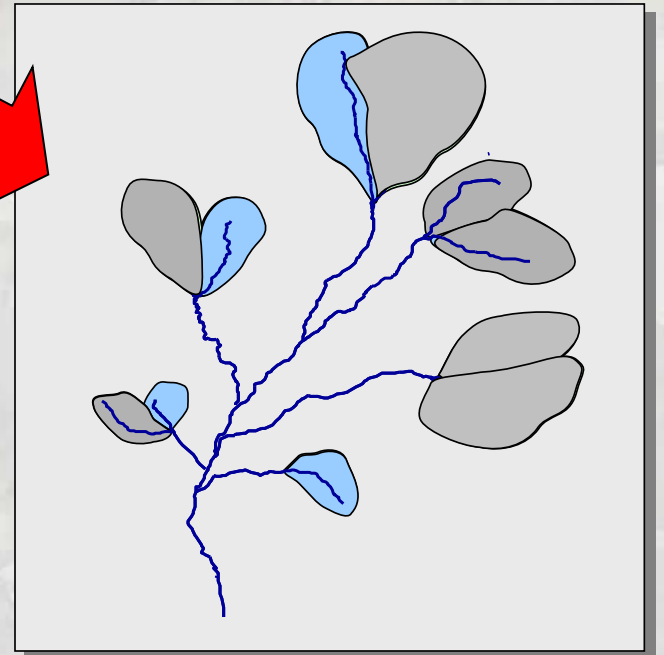
“Balance of Nature”

Paradigm no Longer Valid

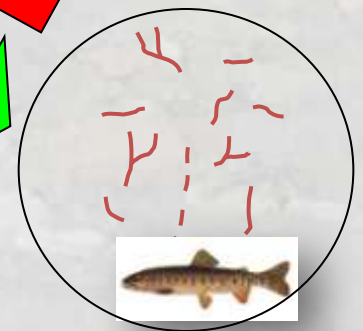
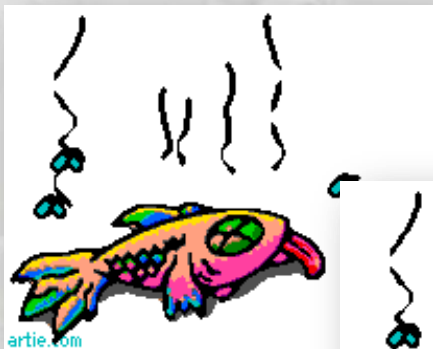
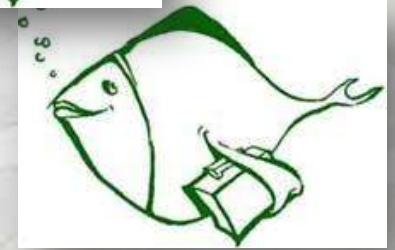
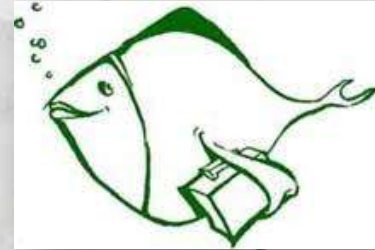
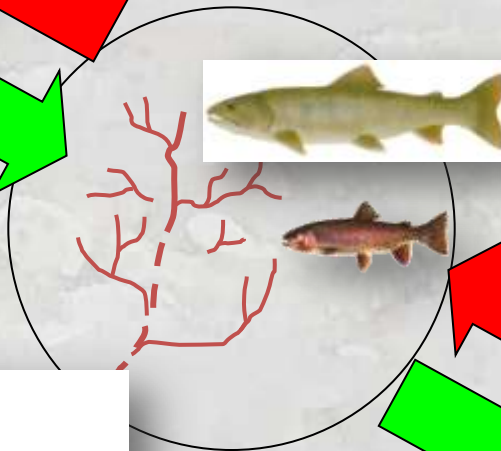
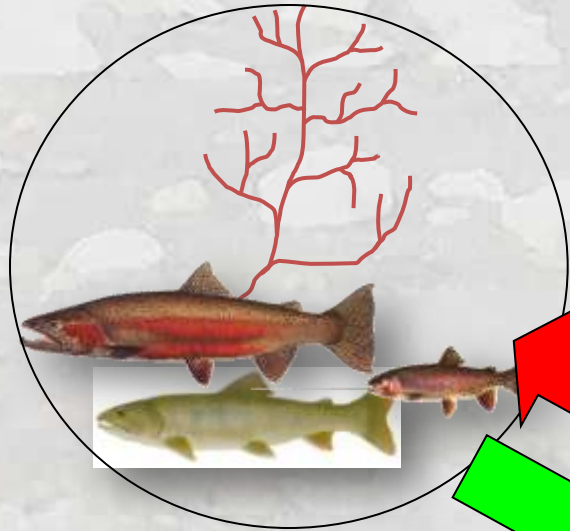
Dynamic Equilibrium



Dynamic Dis-Equilibrium



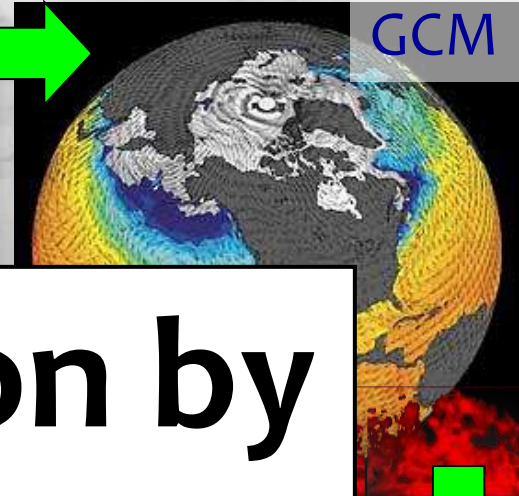
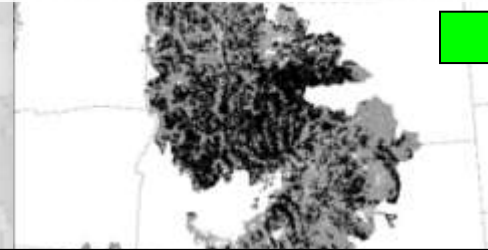
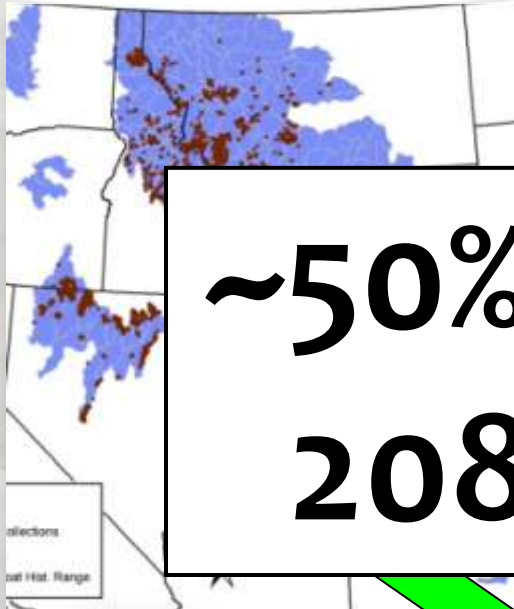
There Will be Winners & Losers



Western US Trout Climate Assessment

Fish survey database
~10,000 sites

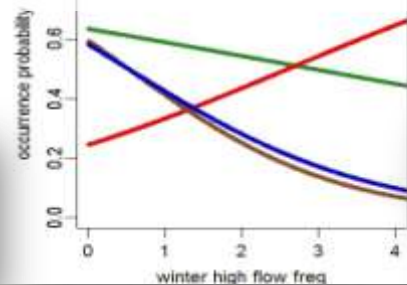
Historic Distributions



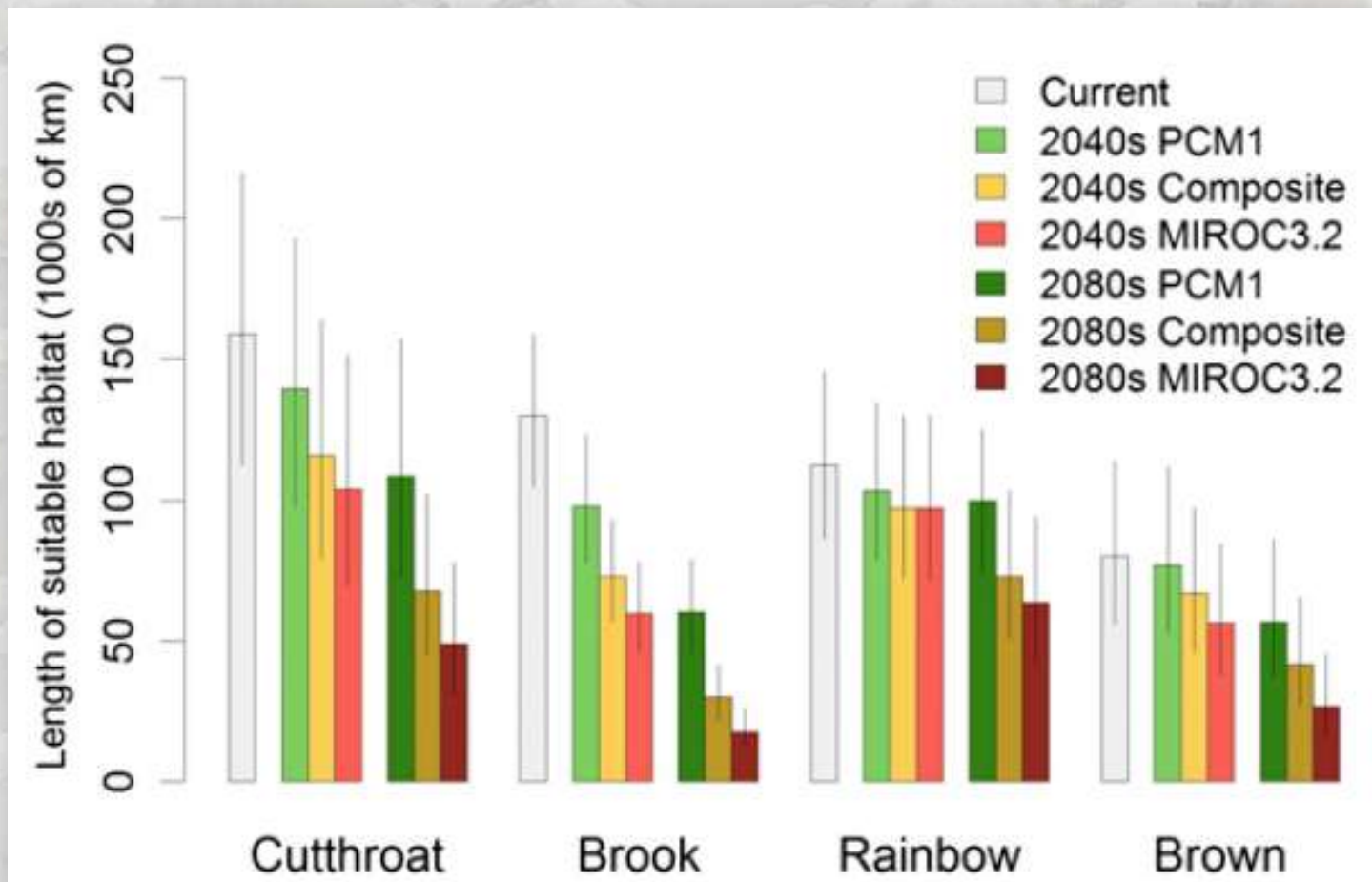
GCM

**~50% reduction by
2080 under A1B**

Habitat
Response Curves



Species Vary in Climate Response



**Predicted
reduction
(2080) =**



57%



77%

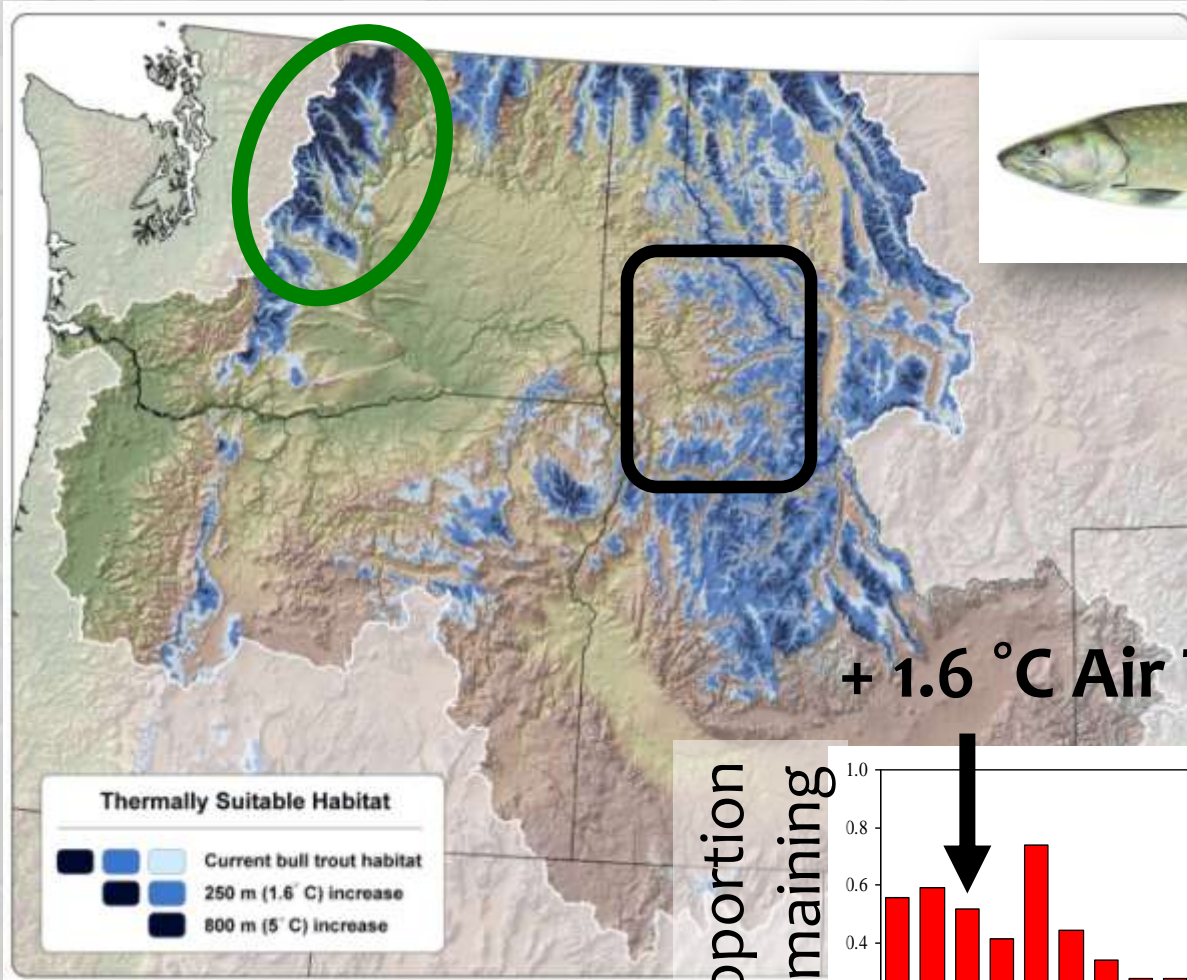


35%



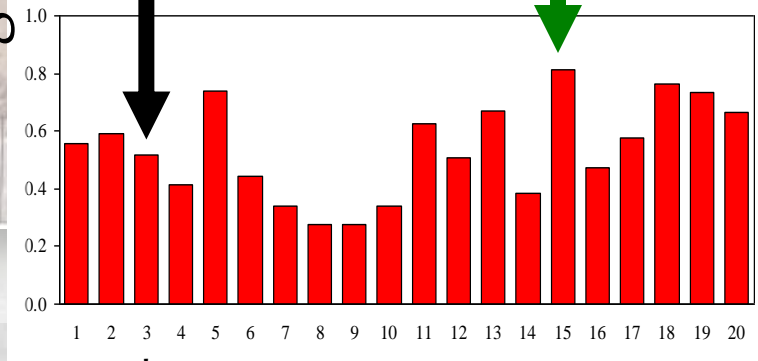
48%

Spatial Variation in Habitat Loss



+ 1.6 °C Air Temperature

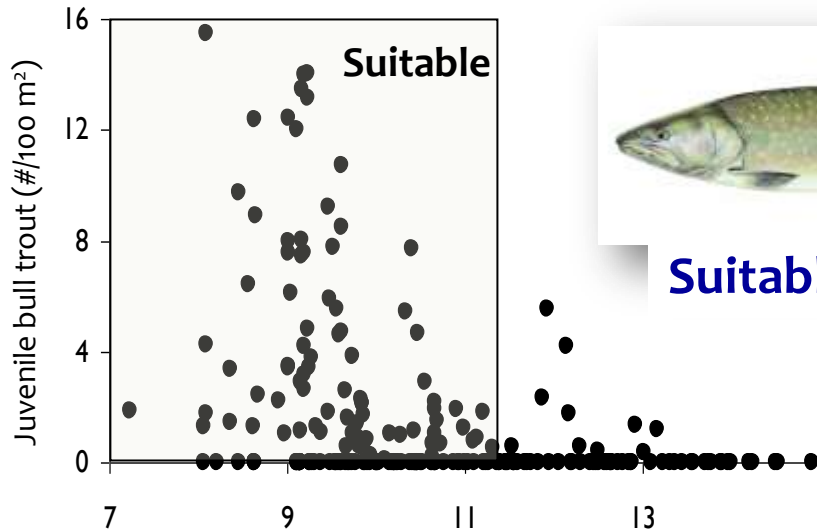
Proportion Remaining



3rd Code HUC Subregion

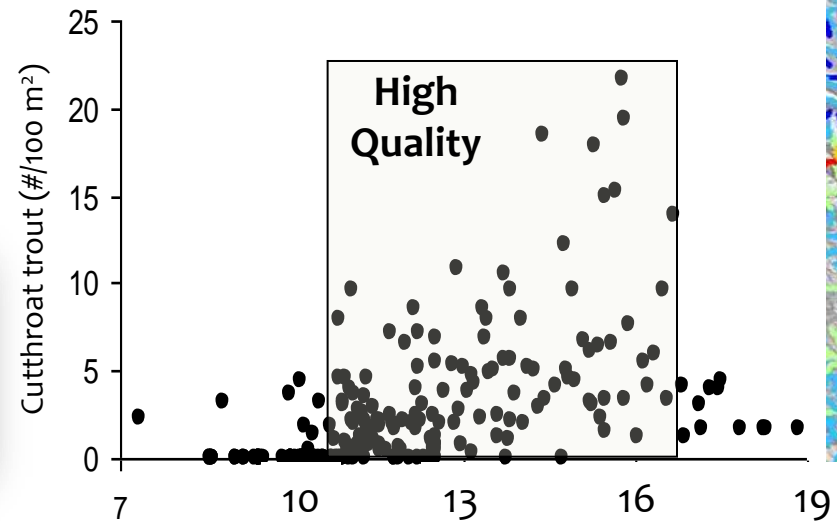
NorWeST Scenarios Increase Accuracy

Species-Specific Thermal Criteria



Suitable habitat < 11.2°C

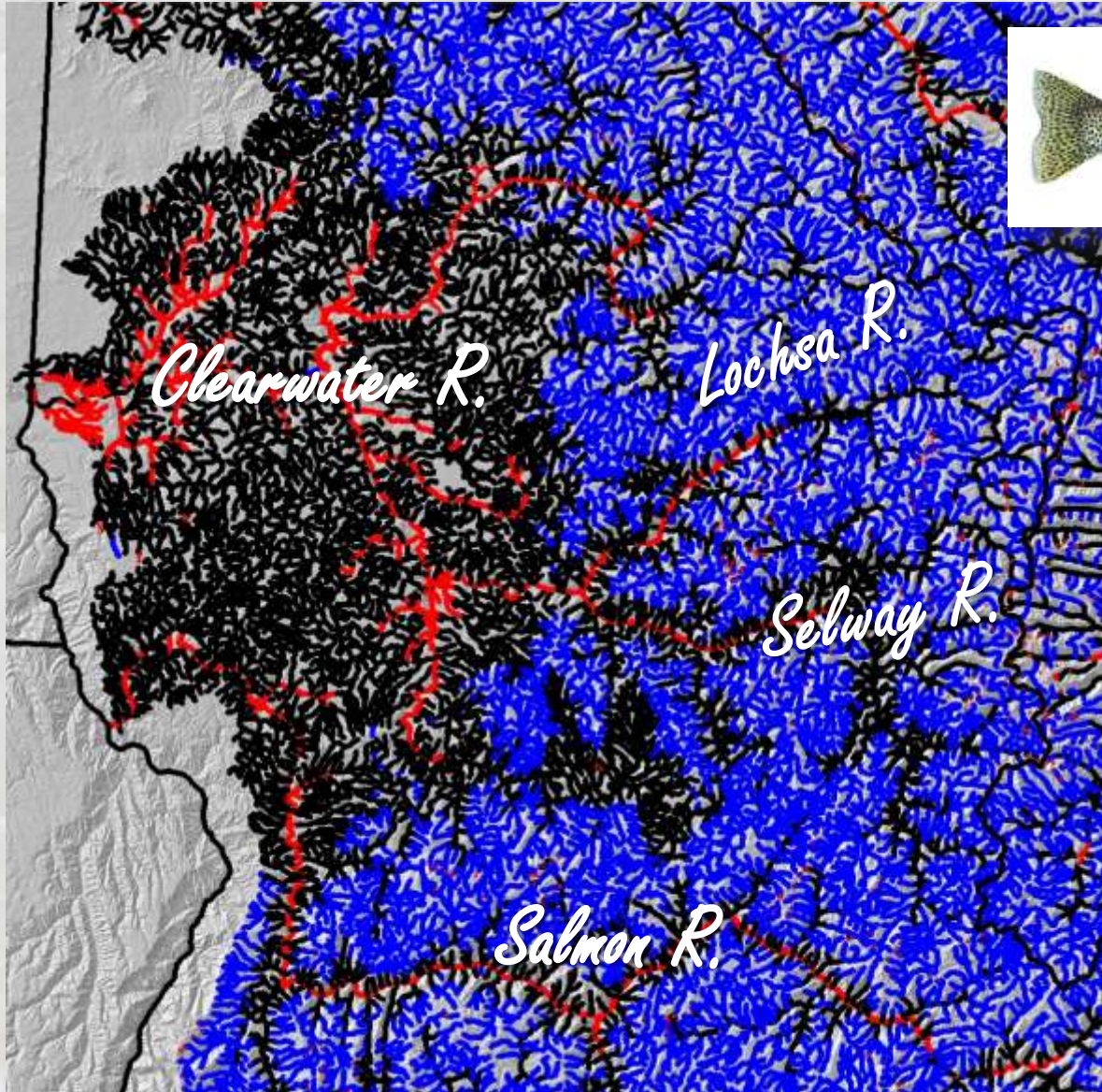
NorWeST August Temperature



High-quality habitat = 11.0-17.0°C

NorWeST August Temperature

Climate Effects on Cutthroat Thermal Habitat Historic (1993-2011 Average August)

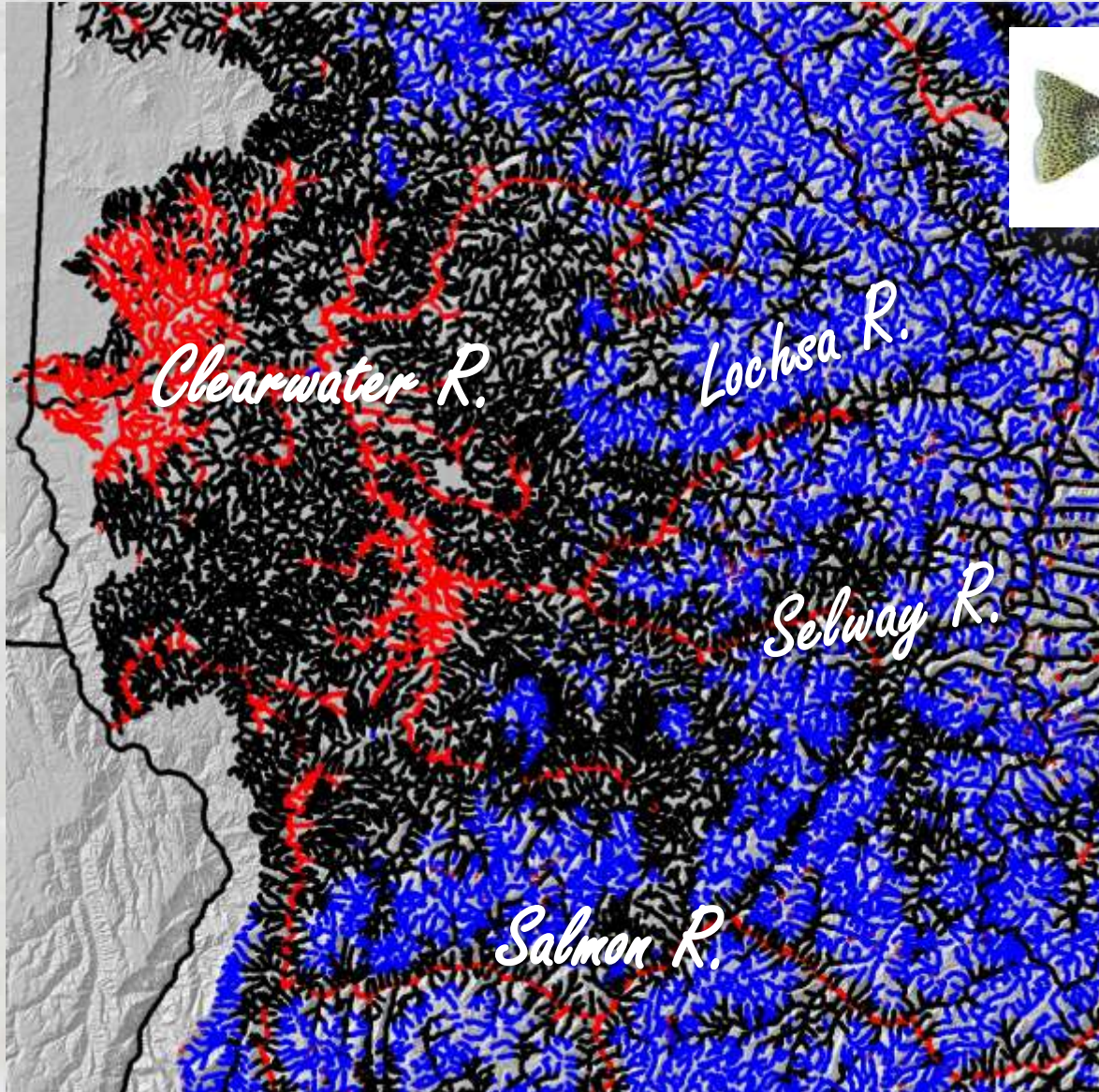


-  Suitable
-  Too Hot
-  Too Cold

Thermal habitat
= 11.0-17.0°C

Climate Effects on Cutthroat Thermal Habitat

+1.00°C Stream Temp (~2040s)

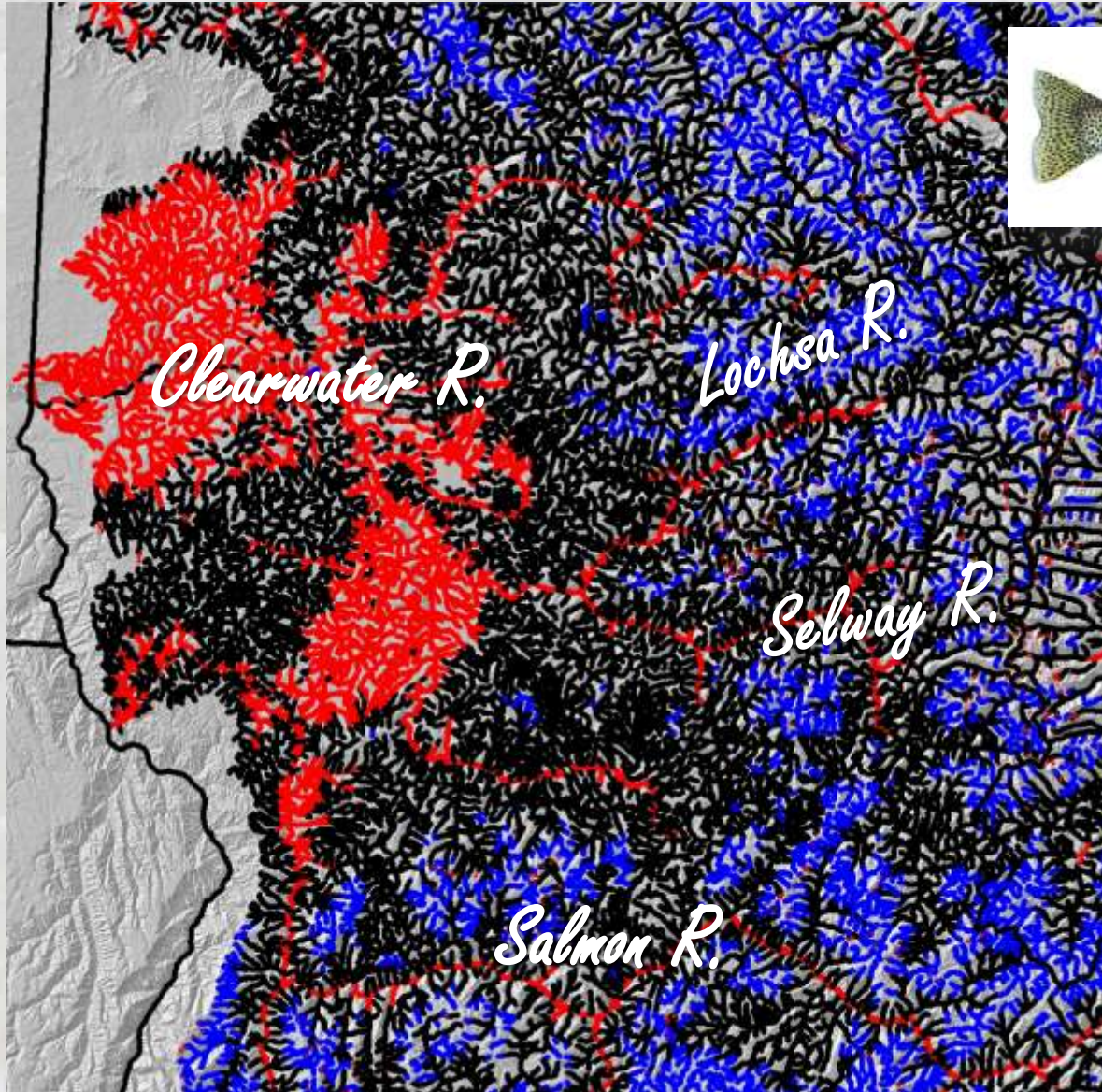



-  Suitable
-  Too Hot
-  Too Cold

Thermal habitat
= 11.0-17.0°C

Climate Effects on Cutthroat Thermal Habitat

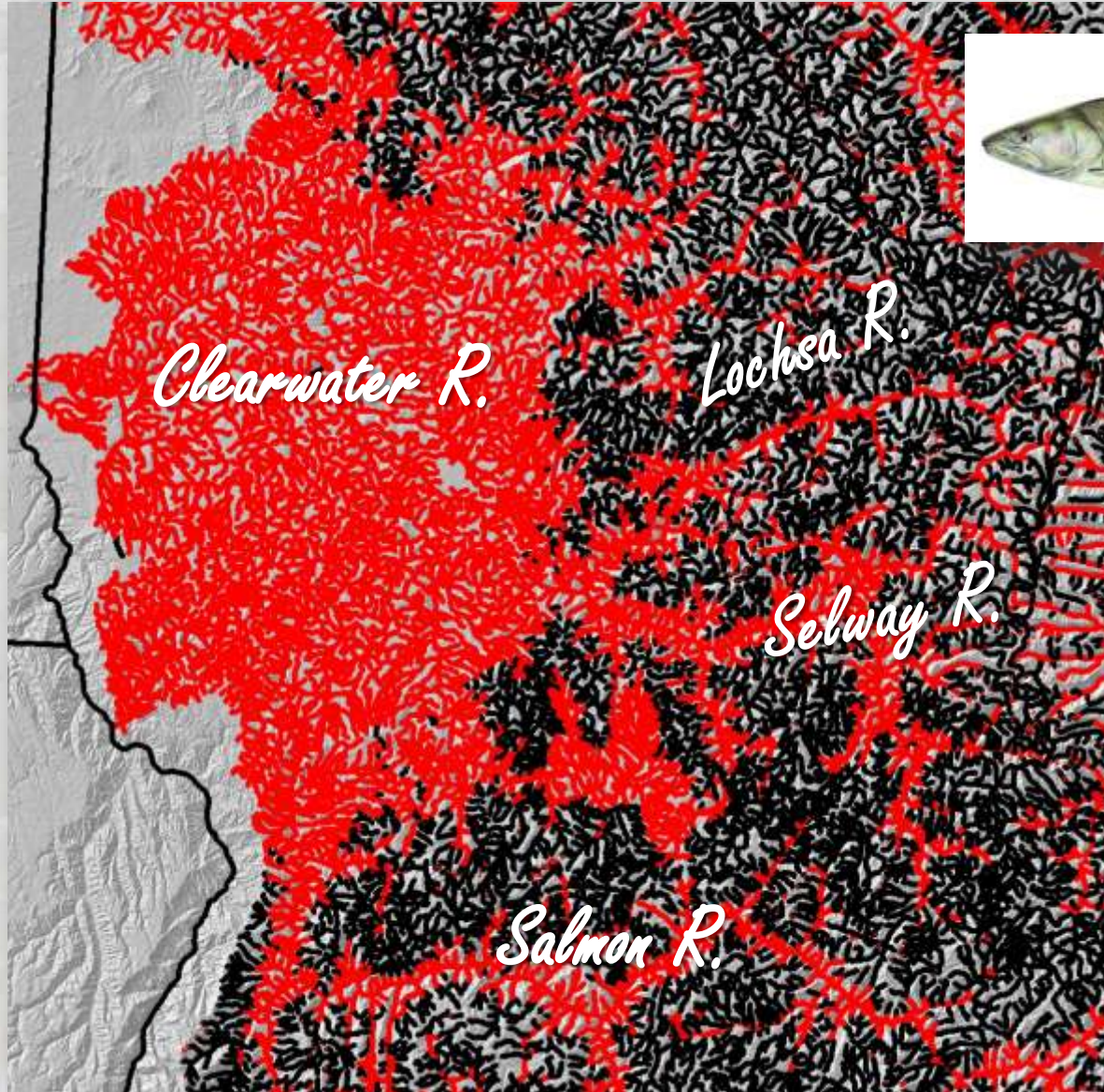
+2.00°C Stream Temp (~2080s)



-  Suitable
-  Too Hot
-  Too Cold

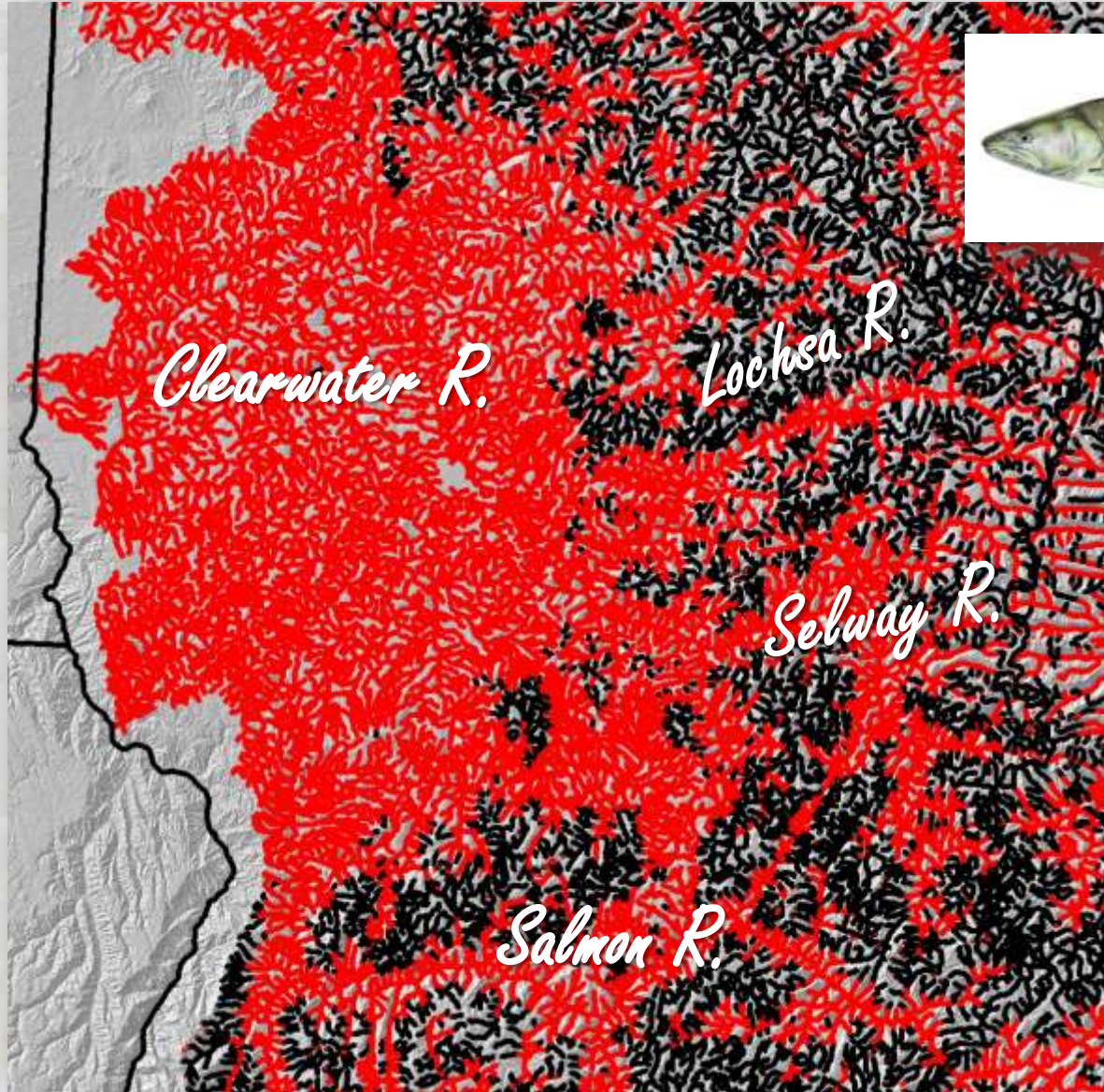
Thermal habitat
= 11.0-17.0°C

Climate Effects on Bull Trout Thermal Habitat Historic (1993-2011 Average August)



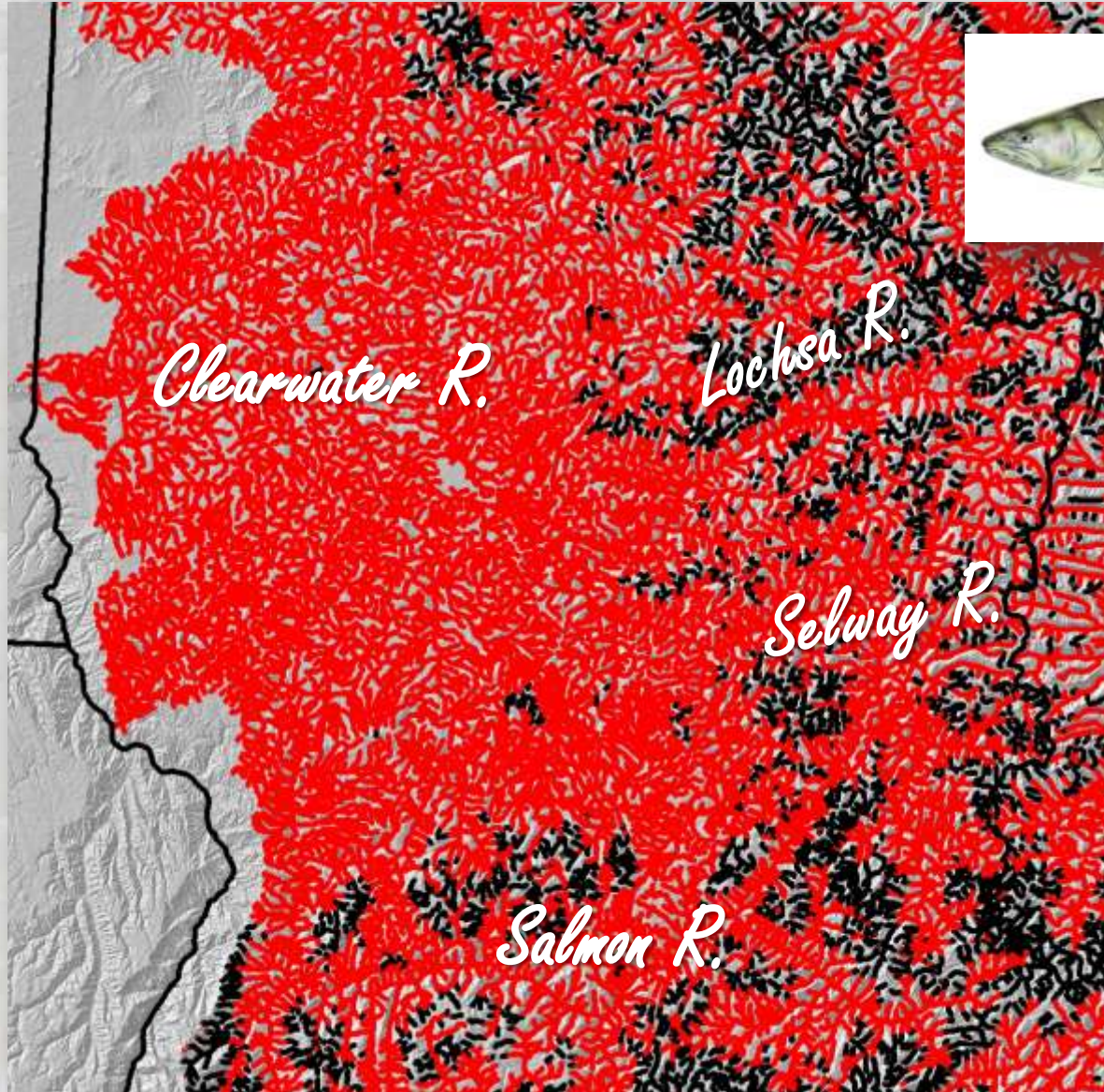
-  Suitable
 -  Unsuitable
- Thermal
habitat < 11.0°C

Climate Effects on Bull Trout Thermal Habitat +1.00°C Stream Temp (~2040s)



- Suitable
 - Unsuitable
- Thermal
habitat < 11.0°C

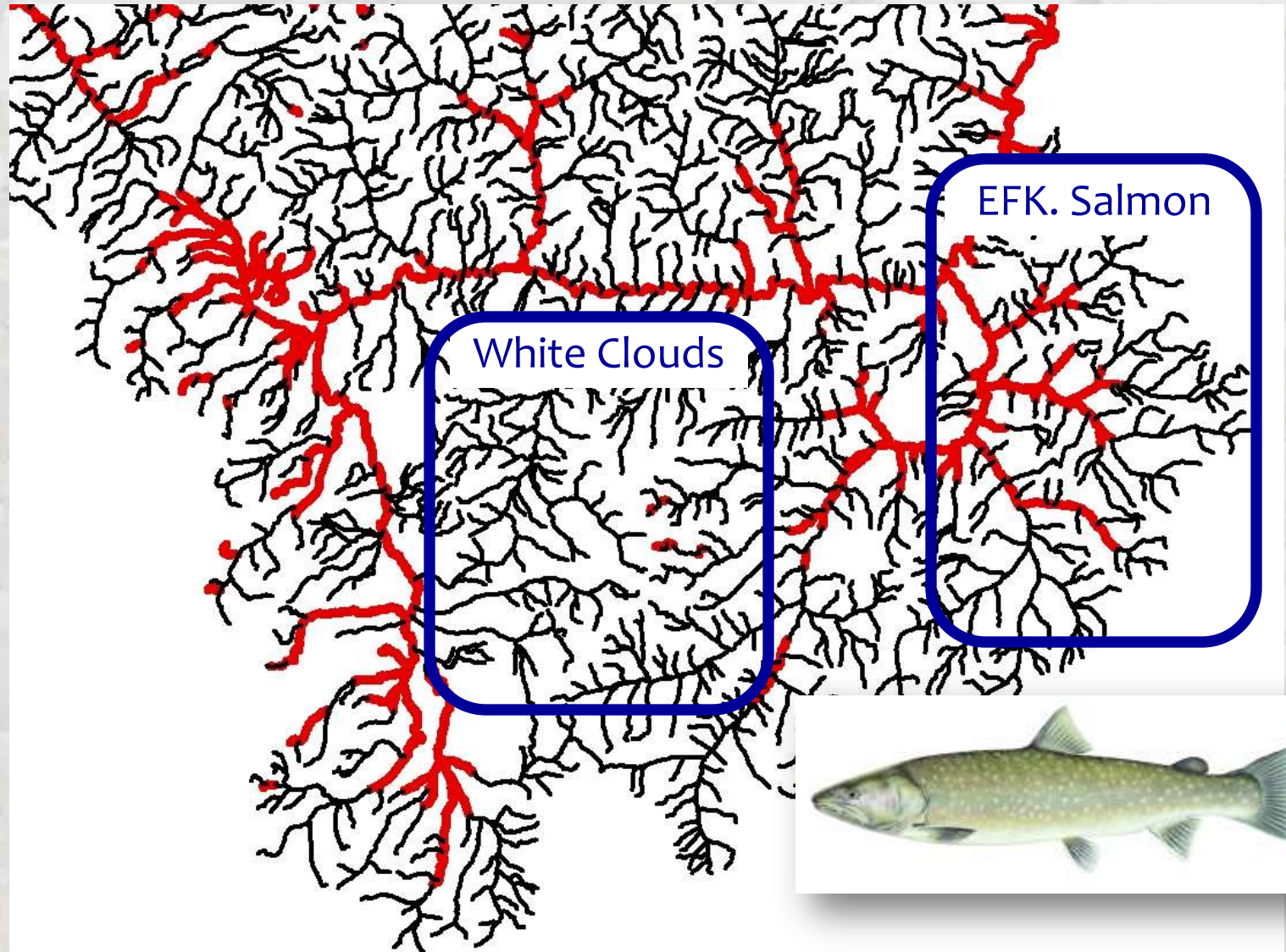
Climate Effects on Bull Trout Thermal Habitat +2.00°C Stream Temp (~2080s)



- Suitable
 - Unsuitable
- Thermal habitat < 11.0°C

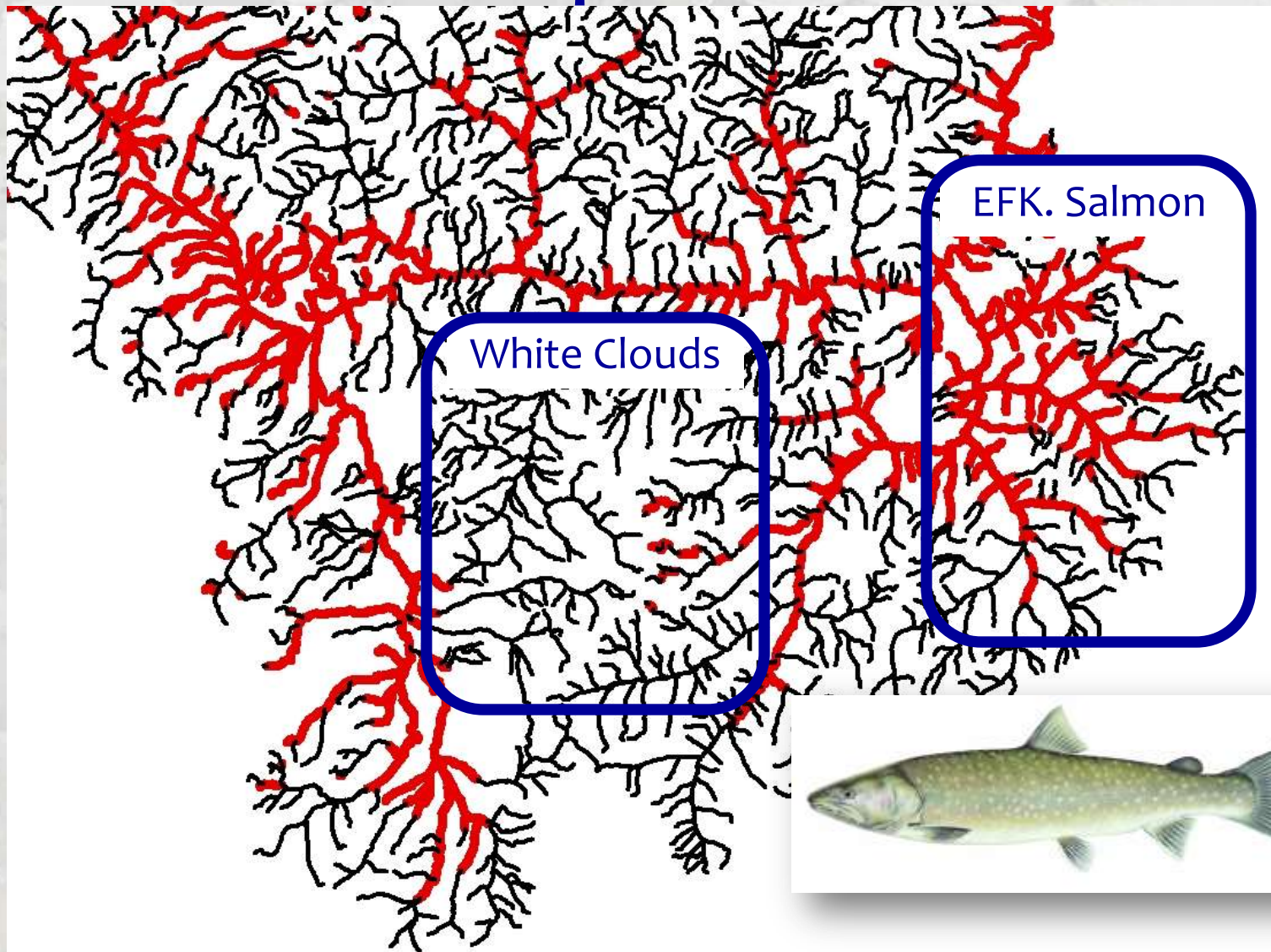
Spatial Variation in Habitat Loss

Historical scenario

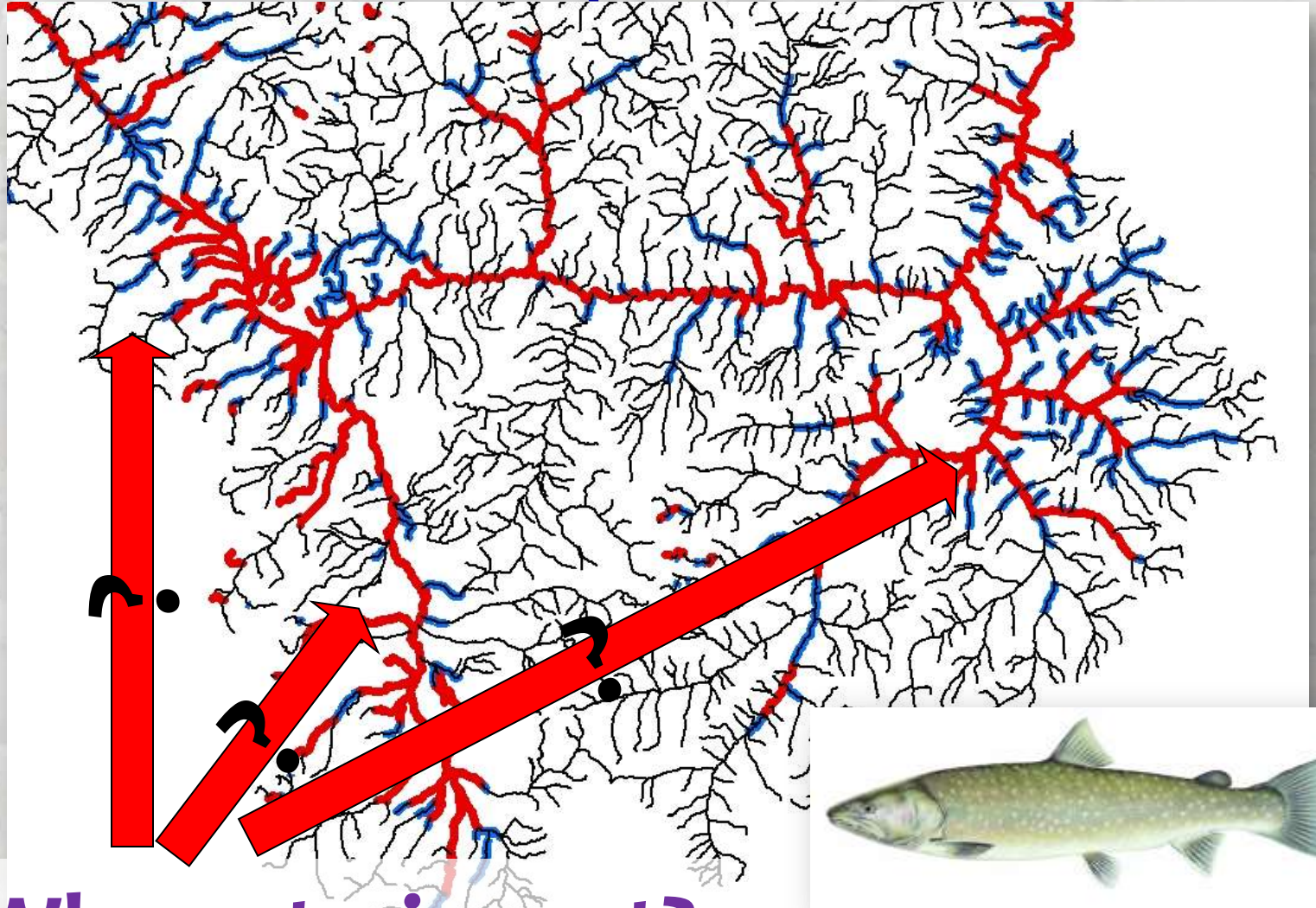


Spatial Variation in Habitat Loss

+1°C stream temperature scenario



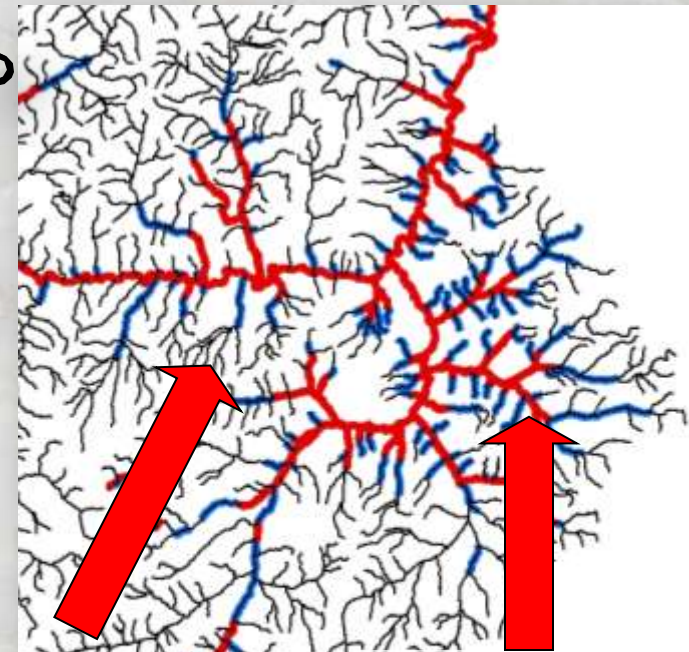
Difference Map Shows Vulnerable Habitats +1°C stream temperature scenario



Where to invest?

Climate-Smart Strategic Prioritization of Restoration

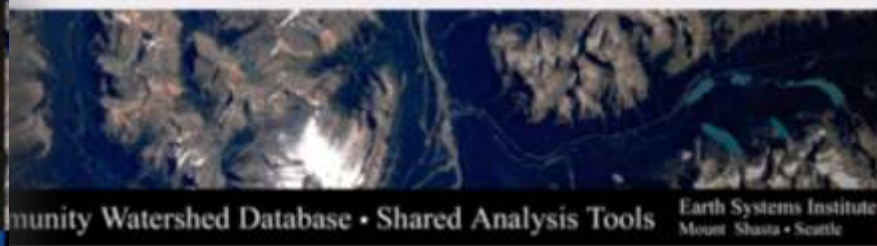
- Maintaining/restoring flow...
- Maintaining/restoring riparian...
- Restoring channel form/function...
- Prescribed burns limit wildfire risks...
- Non-native species control...
- Improve/impede fish passage...



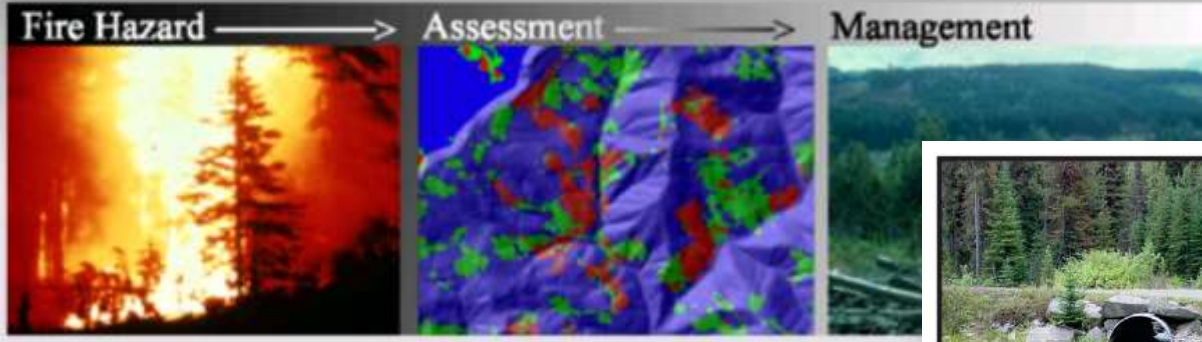
**High
Priority**

**Low
Priority**

Additional Prioritization Tools...



Home | Watershed Database | Analysis Tools | QMP | Support/Services | Projects | Groups | Links | Contact



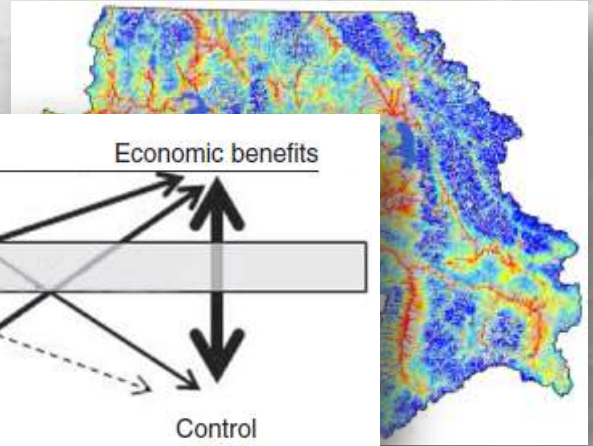
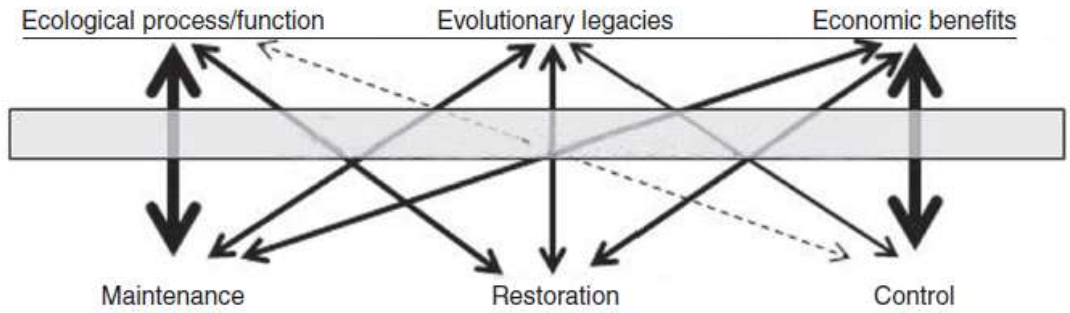
The Geomorphic Road Analysis and Inventory Package (GRAIP)



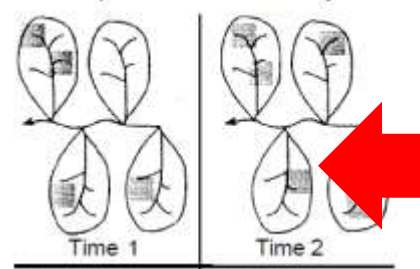
How do we Bring it All Together?

What is "Optimal" Management?

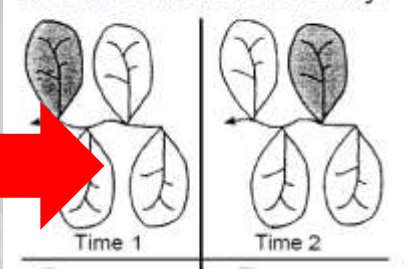
What are our Goals?



A. Dispersion of Activity

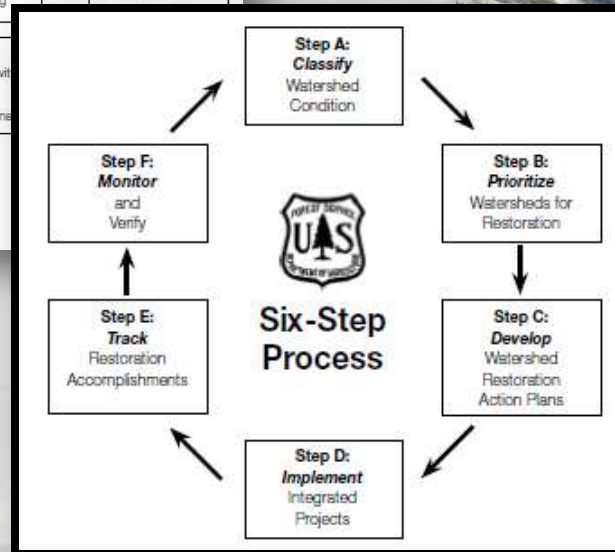
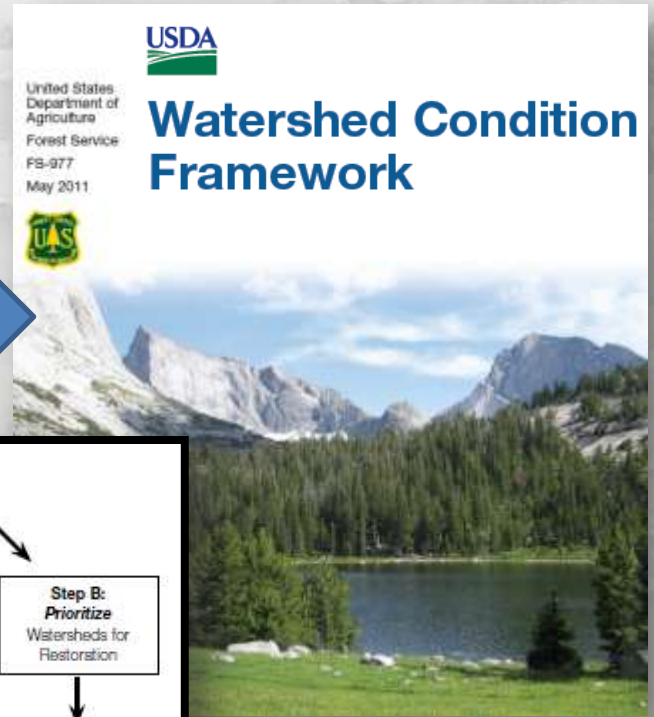
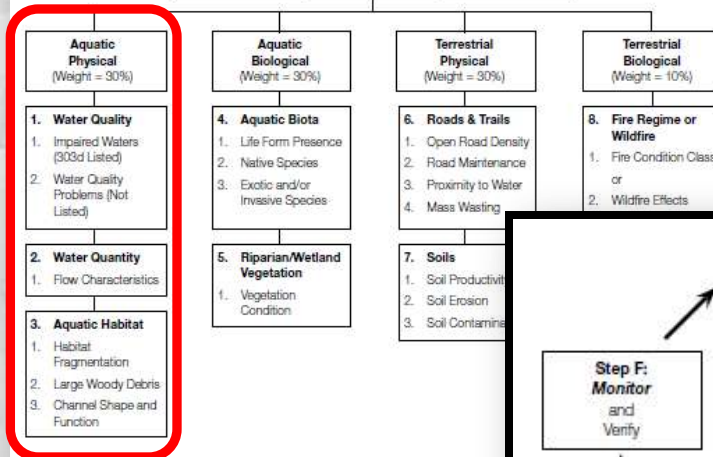


B. Concentration of Activity



Integrate with...

Watershed Condition Indicators



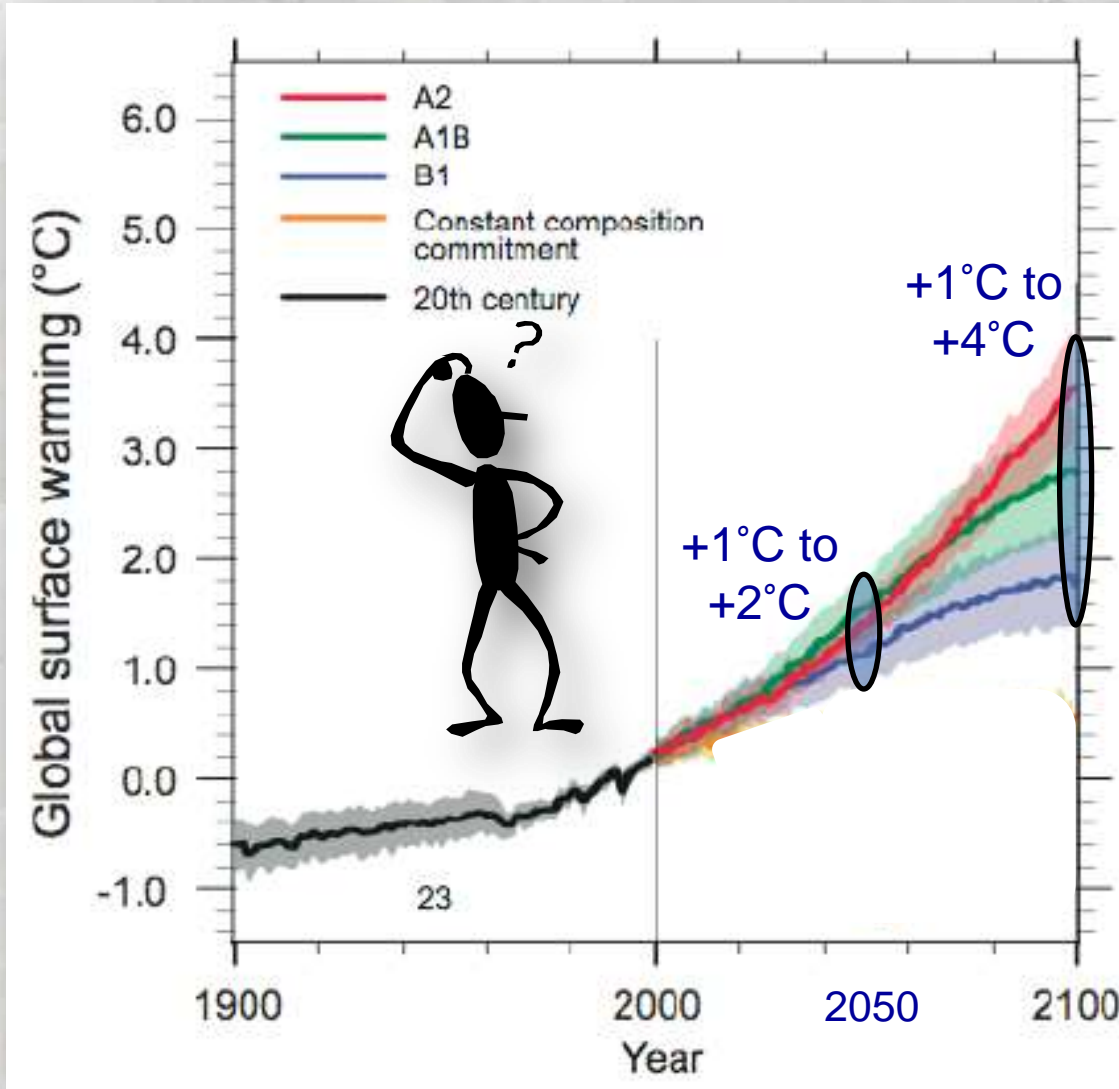
Forest Plan Revisions

 United States Department of Agriculture
 Forest Service
 Northern Region
 March 2007

Proposed
Land Management Plan
Clearwater National Forest

Significant Unknown:

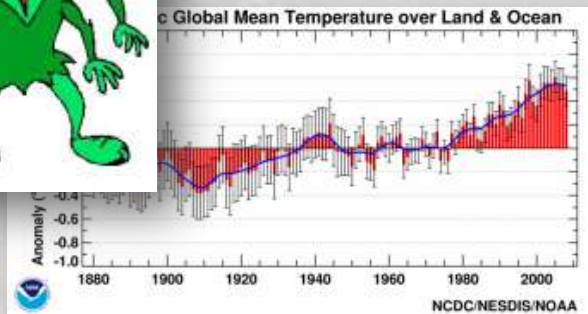
Where Do We Level Off (+1C, +3C, etc.)
& How Fast do We Get There?



A2?
A1B?
B1?

The Clock is Ticking...

Distribution Shifts Already in Many Species



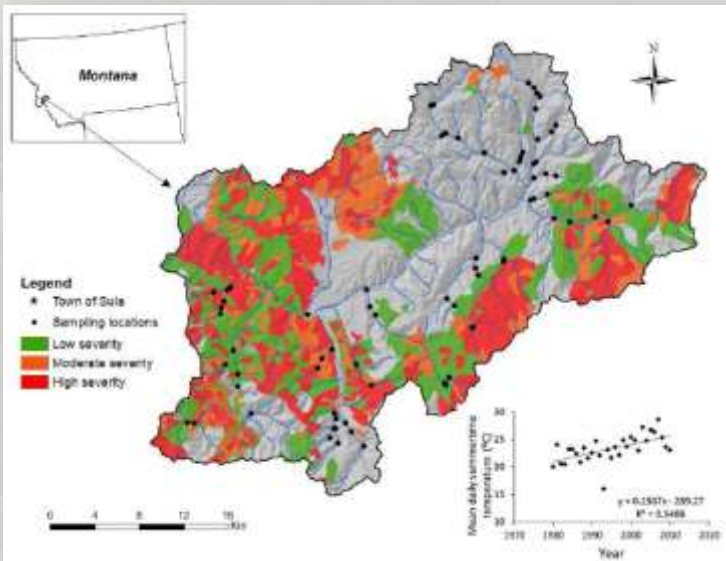
Average distribution shift
6.1 km/decade poleward
OR
6.1 m/decade higher elevation



Parmesan and Yohe. 2003. *Nature* 421:37-42.

Distribution Shifts in Montana Bull Trout Populations

- Resurveyed Rich et al. 2003 sites 20 years later
- 77 sites, 500 m in length
- Modeled extirpations/colonizations accounting for detection efficiency



Eby et al. In Review. Evidence of climate-induced range contractions for bull trout to cooler, higher elevation sites in a Rocky Mountain watershed, U.S.A. *Global Change Biology*

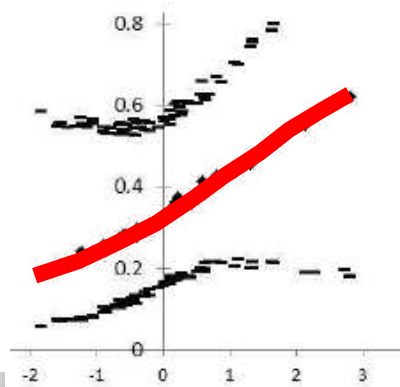
Distribution Shifts in Montana Bull Trout Populations



Extirpation probability (95%CI)

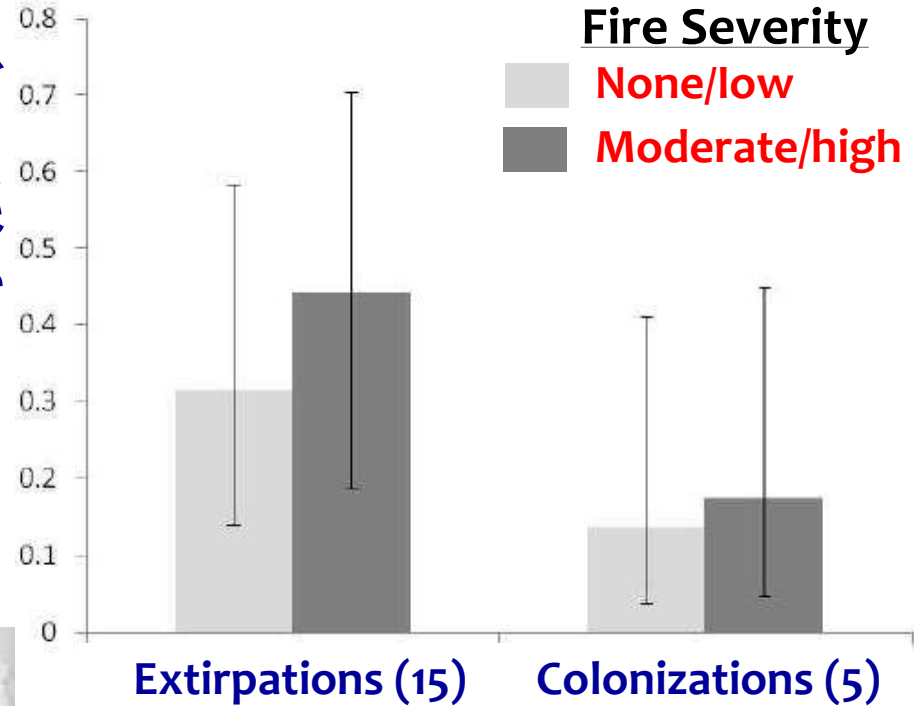


Standardized elevation



Standardized temperature

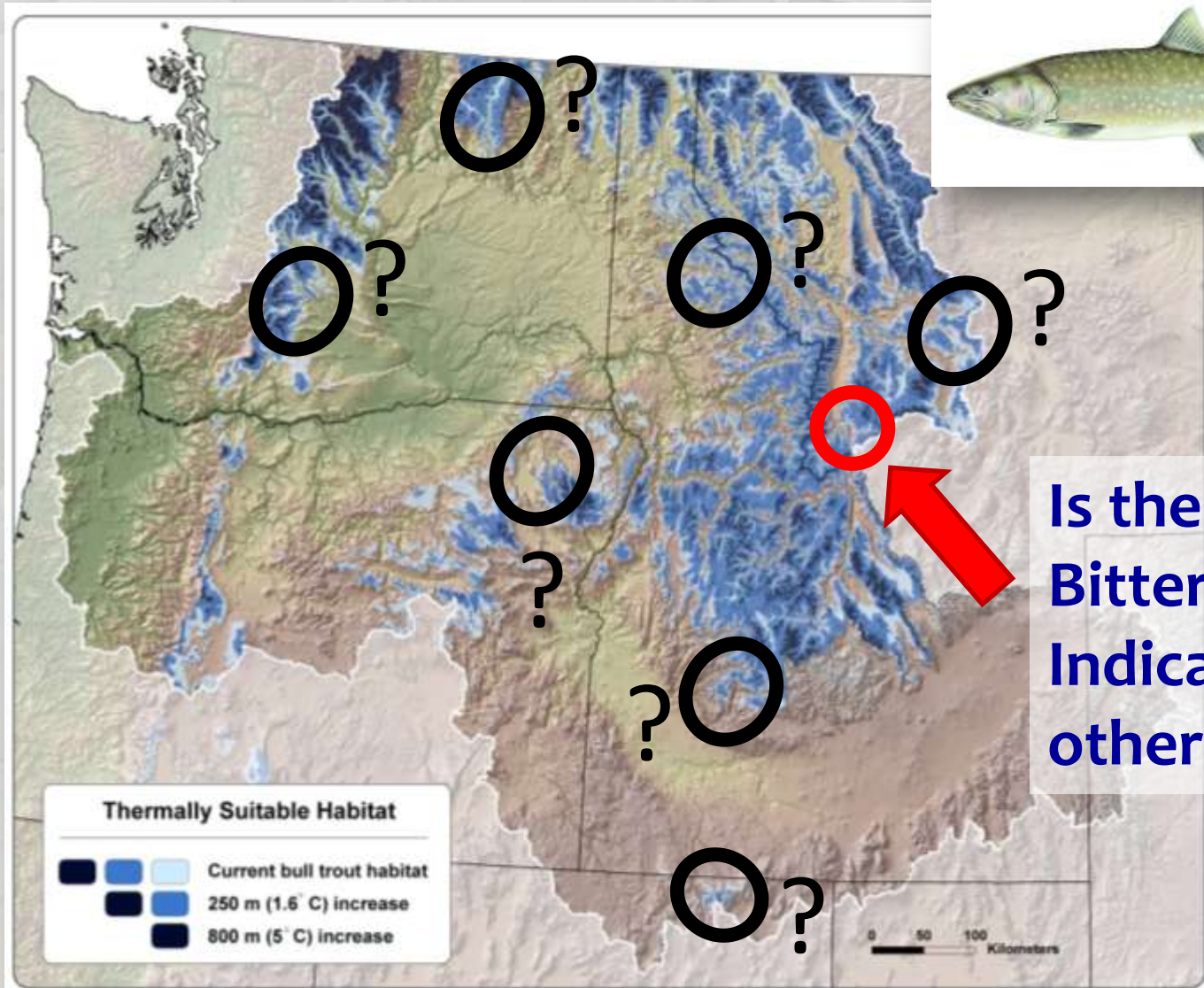
Probability (95%CI)



Extirpations (15)

Colonizations (5)

More Resurveys Needed to Understand Potential Breadth of Declines



Is the Bitterroot Indicative of other Areas?

Do “Climate-Proof” Habitats Exist for Key Species in Some Areas? If Not, Can Targeted Restoration Create Them?

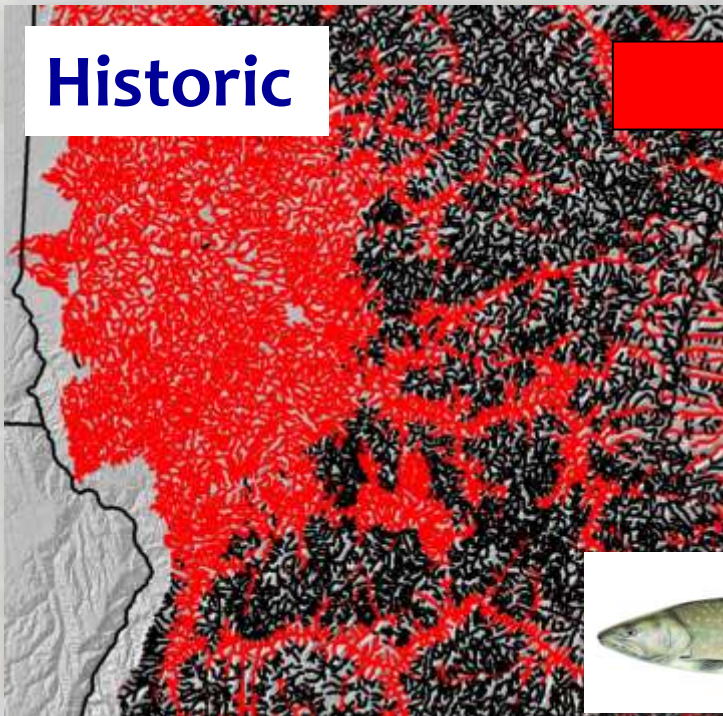
Feature:
FISHERIES MANAGEMENT



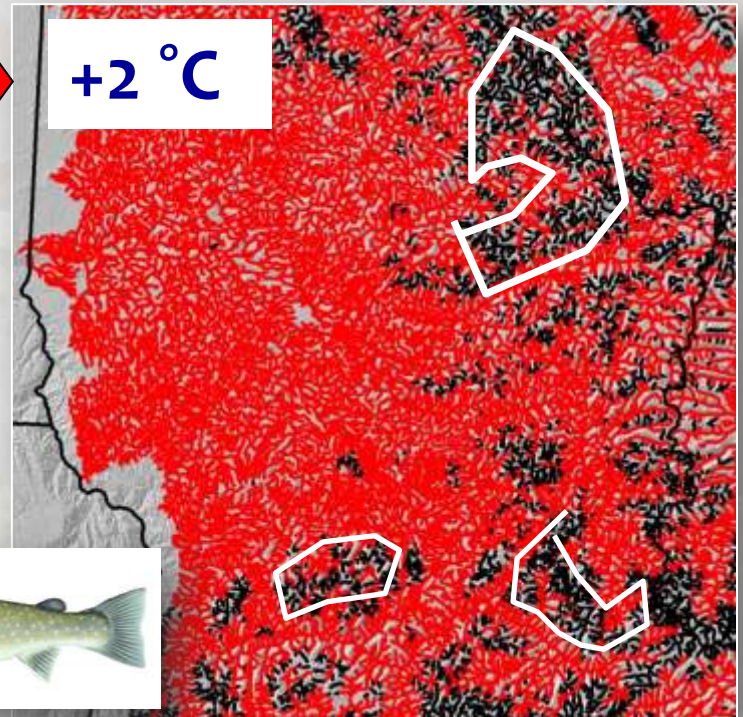
Native Fish Conservation Areas: A Vision for Large-Scale Conservation of Native Fish Communities

Williams et al. 2011. *Fisheries* 36: 267-277.

Historic

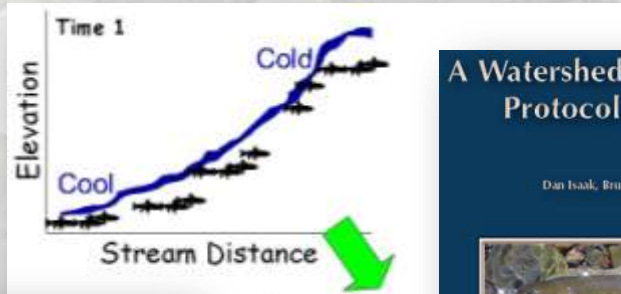


+2 °C




Monitoring Data are Key to Reducing Uncertainty

Temperature, streamflow, species distributions

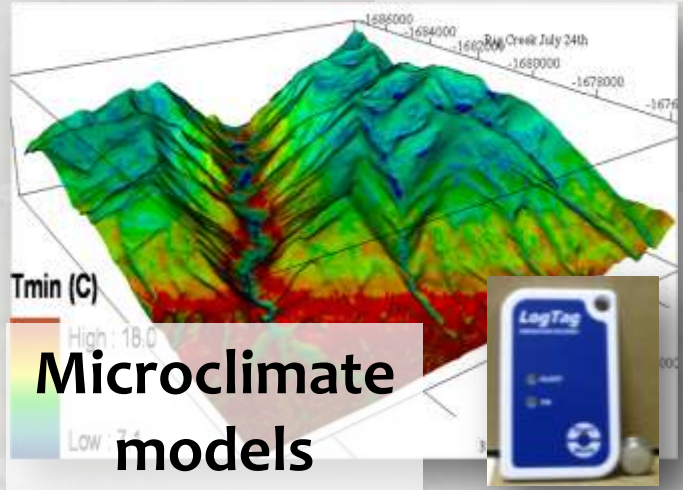


A Watershed-Scale Monitoring Protocol for Bull Trout

Dan Isaak, Bruce Rieman, and Dona Horan



Inexpensive sensors, bioassays & standardized protocols



Short communication

Design and evaluation of an inexpensive radiation shield for monitoring surface air temperatures

Zachary A. Holden^{a,*}, Anna E. Klene^b, Robert F. Keefe^c, Gretchen G. Moisen^d



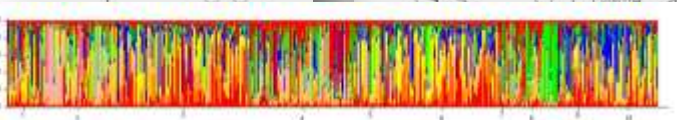
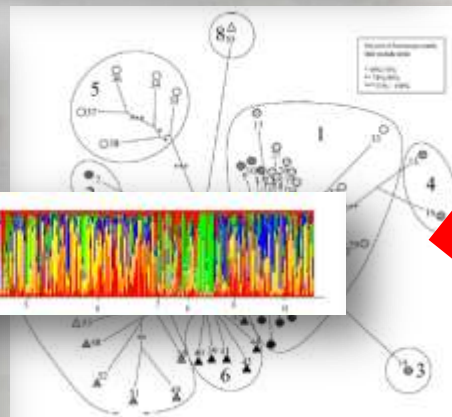
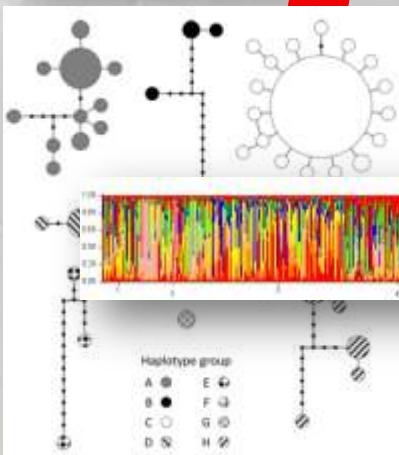
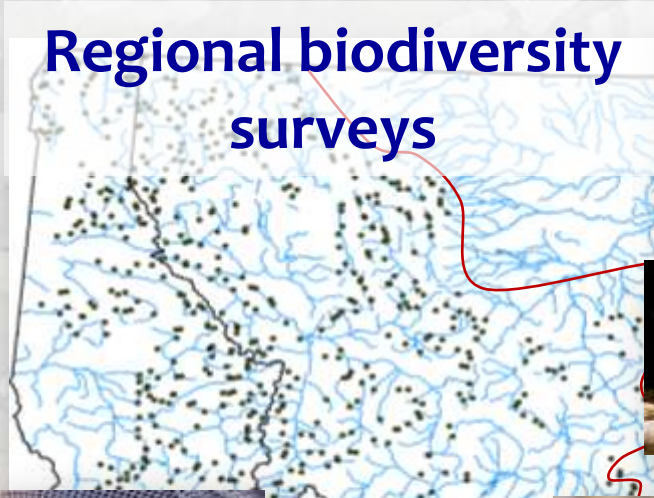
A Simple Protocol Using Underwater Epoxy to Install Annual Temperature Monitoring Sites in Rivers and Streams

Daniel J. Isaak
Dona L. Horan
Sherry P. Wollrab



Genetic Monitoring... Fun, Easy & Powerful

Regional biodiversity surveys



Nov 7/23/09
Sample ID: Cr 2008 (118)

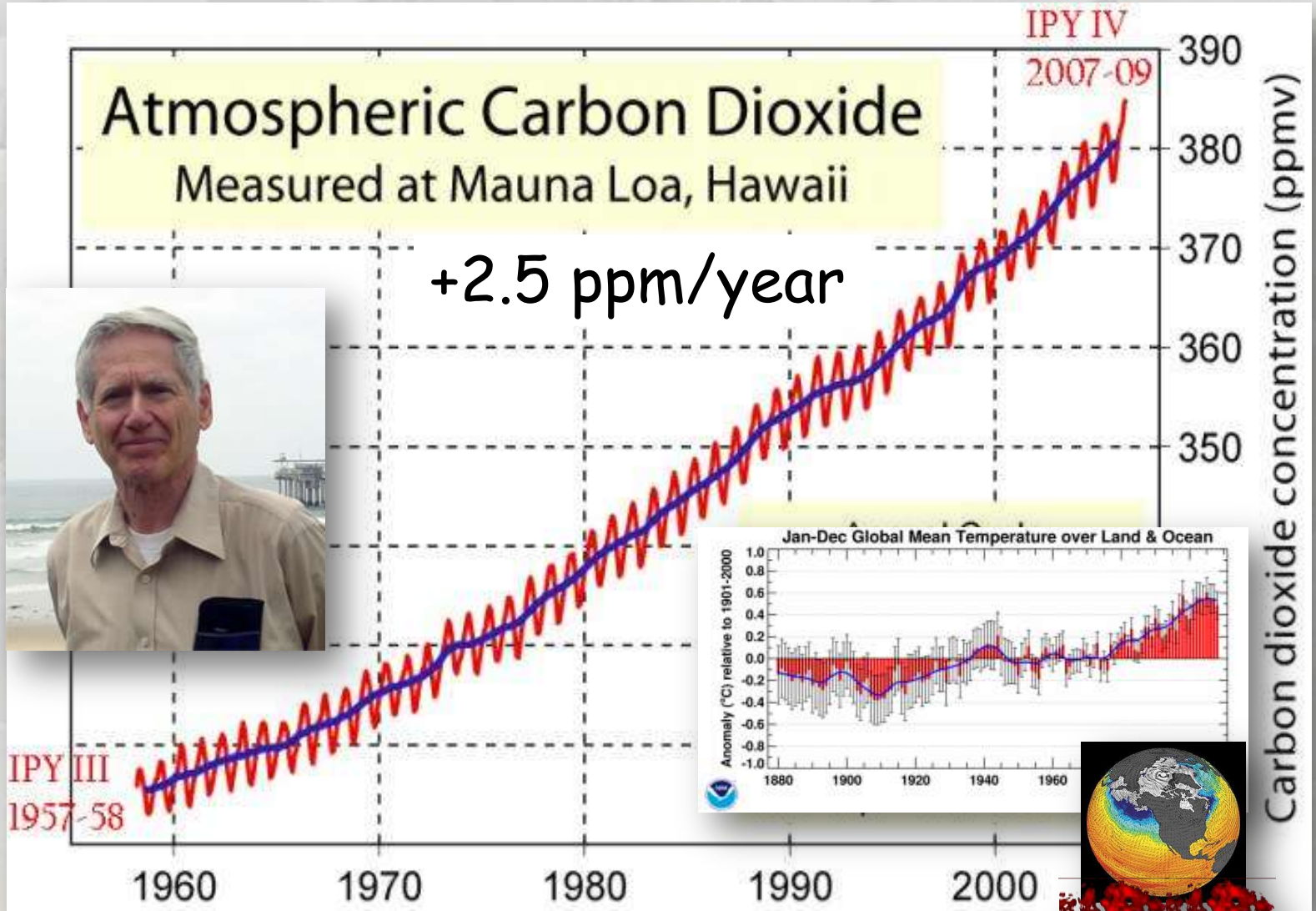
Sample ID	Cr 2008 (118)	Cr 2008 (119)	Cr 2008 (120)	Cr 2008 (121)	Cr 2008 (122)
111	140	120			
113	142	121			
126	152	101			
117					
210					
111					
142	121	112			
123	114				
96	89				

Tissue Samples

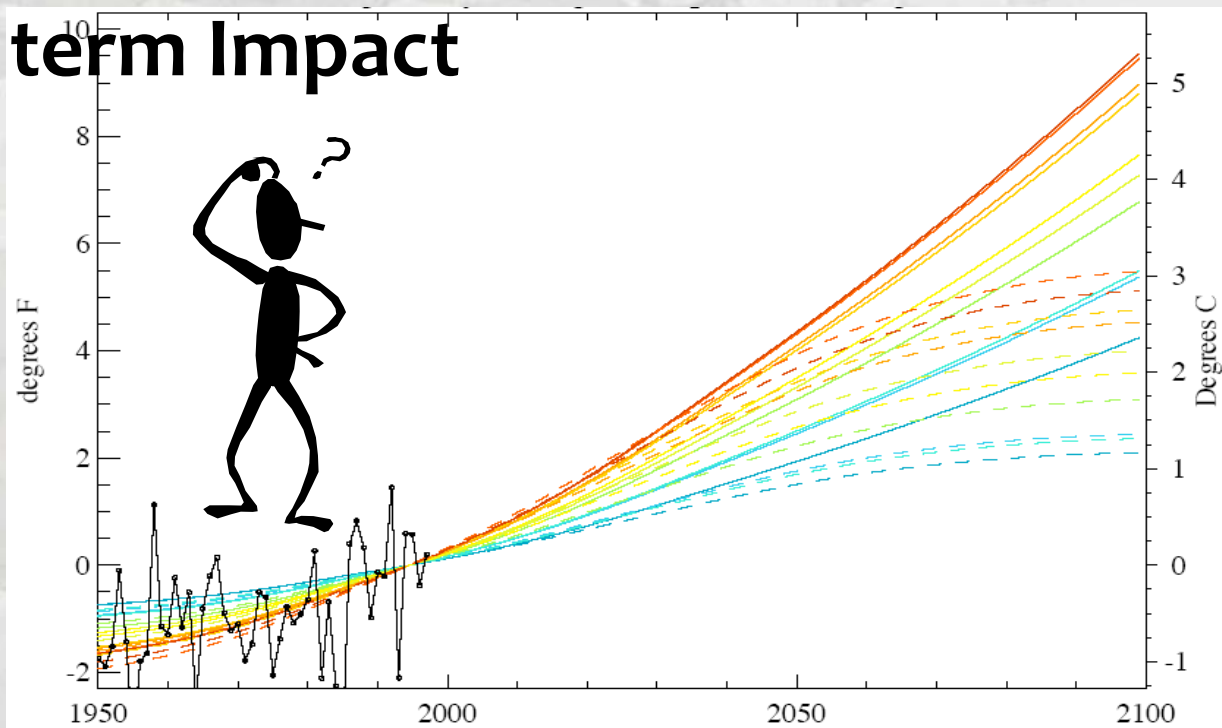
Young et al. 2013; Schwartz et al. 2007; Campbell et al. 2012

A Rather Important Monitoring Record

The Keeling Curve



The Better Information we Have, The Better we can Manage, Conserve, & Have a Long-term Impact



USFS Lands Are Steep, Which Provides a Buffer Important 21st Century Biodiversity Reserves



Slow
Climate
“Velocities”





The End