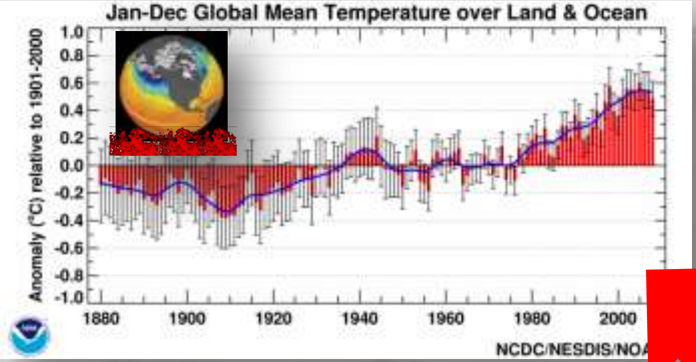
Stream Climate Trends and Aquatic Resource Vulnerability on the Nez Perce-Clearwater National Forests

Dan Isaak, US Forest Service

Rocky Mountain Research Station



?

Clearwater-Nez is a Special Fishy Place

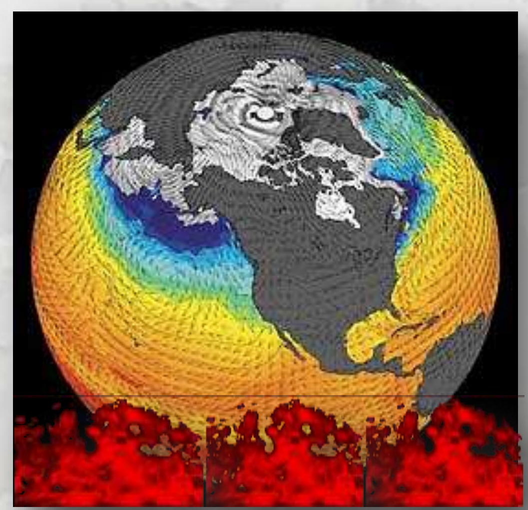
The Kelly Creek Chronicles

A Fly Fisherman's Reminiscence of a Stream

Colbert E. Cushing

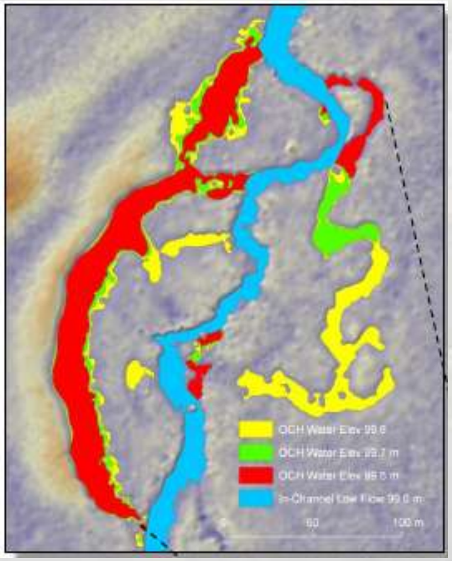
How Will Global Climate Change Affect My Streams & Favorite Fishes?

Global climate

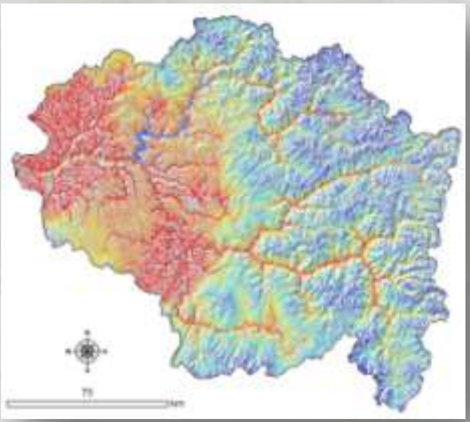


Regional climate

Stream reach

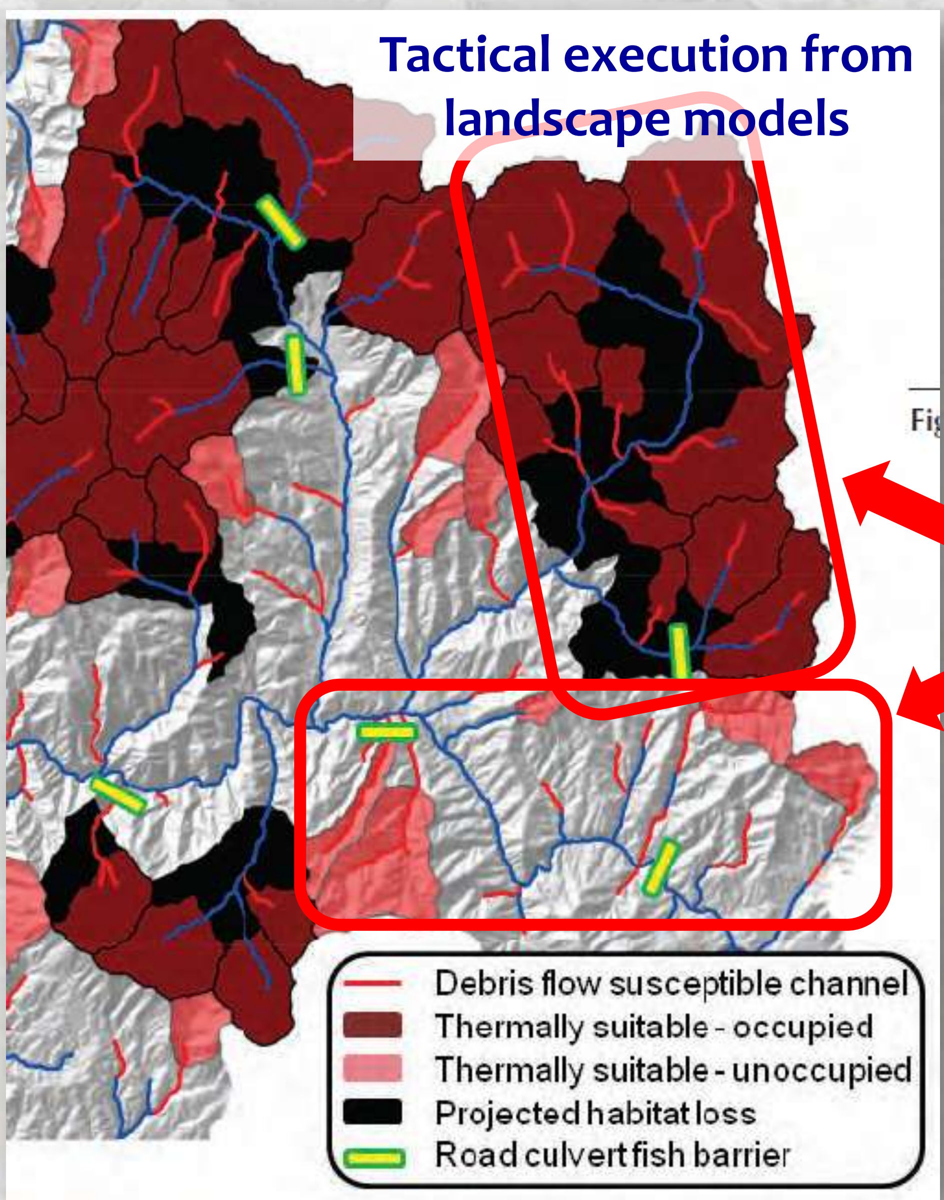


River network temperatures

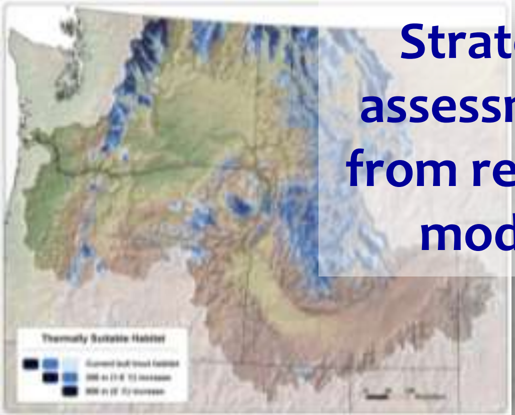


Accurate Local Information Needed to Empower Local Decision Makers

Tactical execution from landscape models



Strategic assessments from regional models

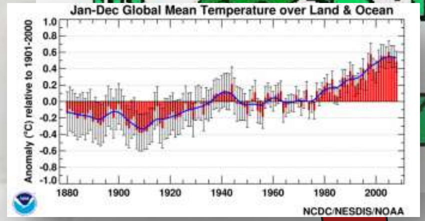


I'm going to invest here…

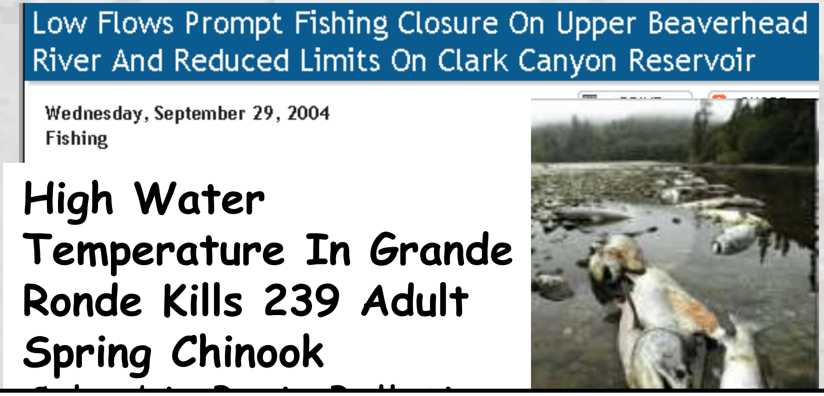
…instead of here

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

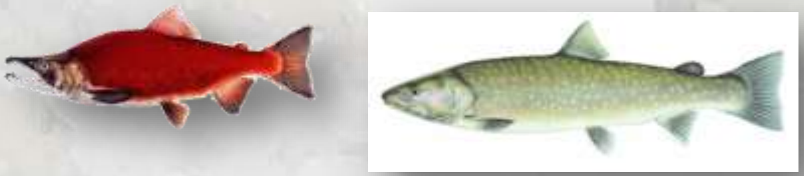
Wednesday, September 29, 2004
Fishing

High Water Temperature In Grande Ronde Kills 239 Adult Spring Chinook

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

Land Use & Water Development

ESA Listed Species



Green Team has Huge Potential Synergies for Information Development & Application

Large land-base (190 Million Acres)

+

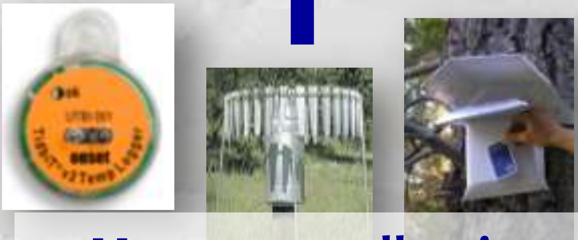
"Boots-on-the-Ground"

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

+

Research branch develops information & connects people

+



Managers collecting mountains of useful data

General outline:

1) Historical trends & future predictions for streams (flow, temperature, sediment regimes) western U.S. & Clearwater/Nez Perce NF

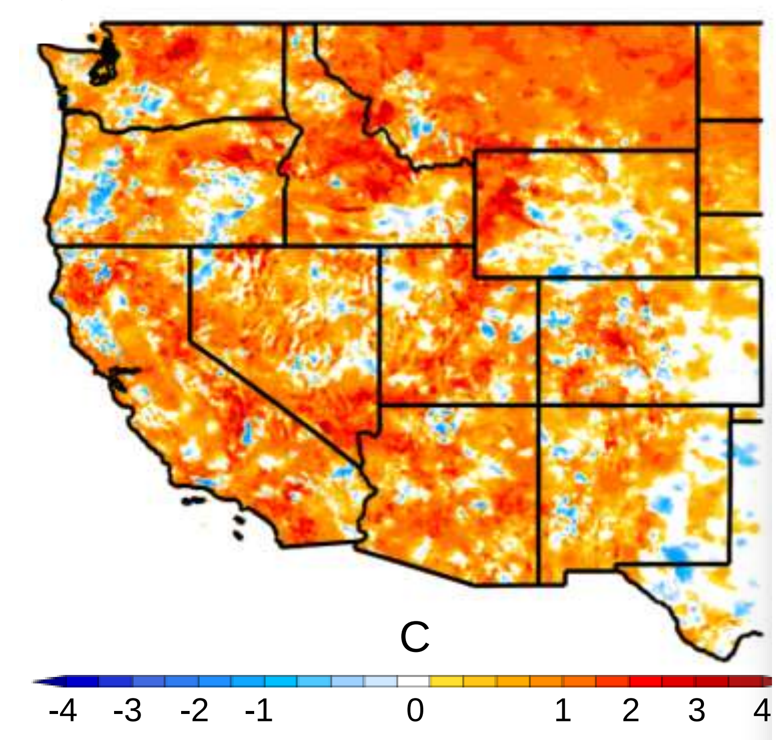
2) How could aquatic resources be affected?

3) Tools & monitoring systems for climate-smart prioritization. What are our goals?

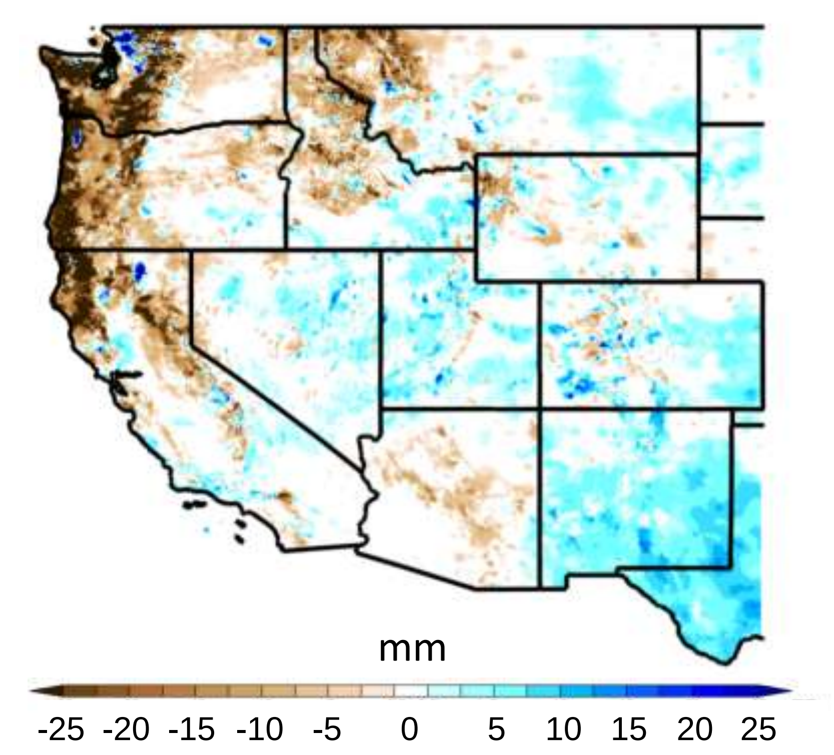
4) Key uncertainties (some resolvable, some not)

Western US Observed Climate Trends (1950 – 2009)

Air temperatures



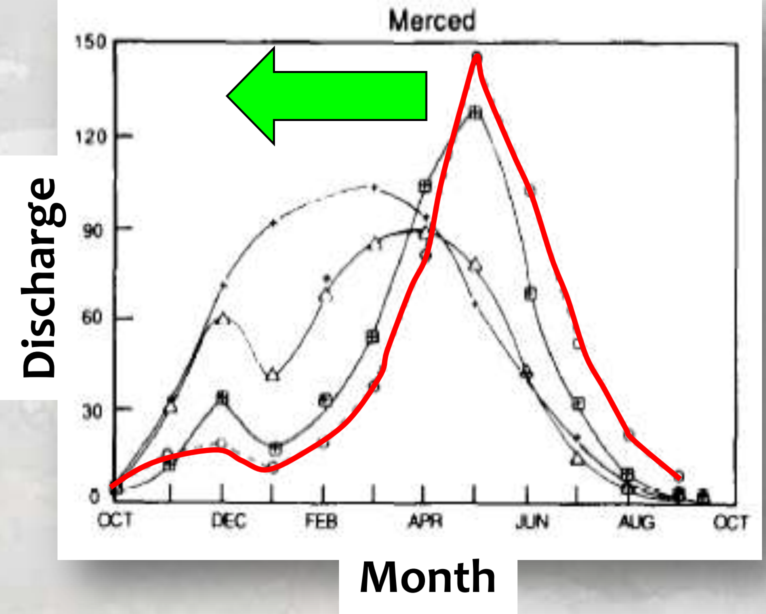
Total Annual Precipitation



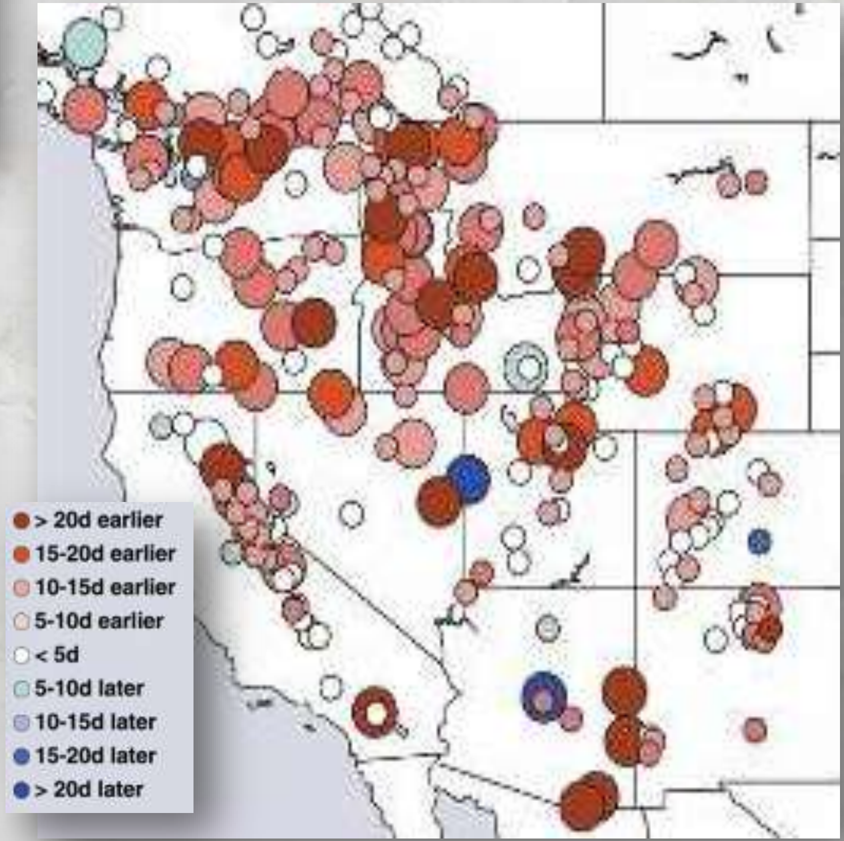
What does it mean for streams and stream critters?

Trends in Stream Runoff Timing

(1948-2000)

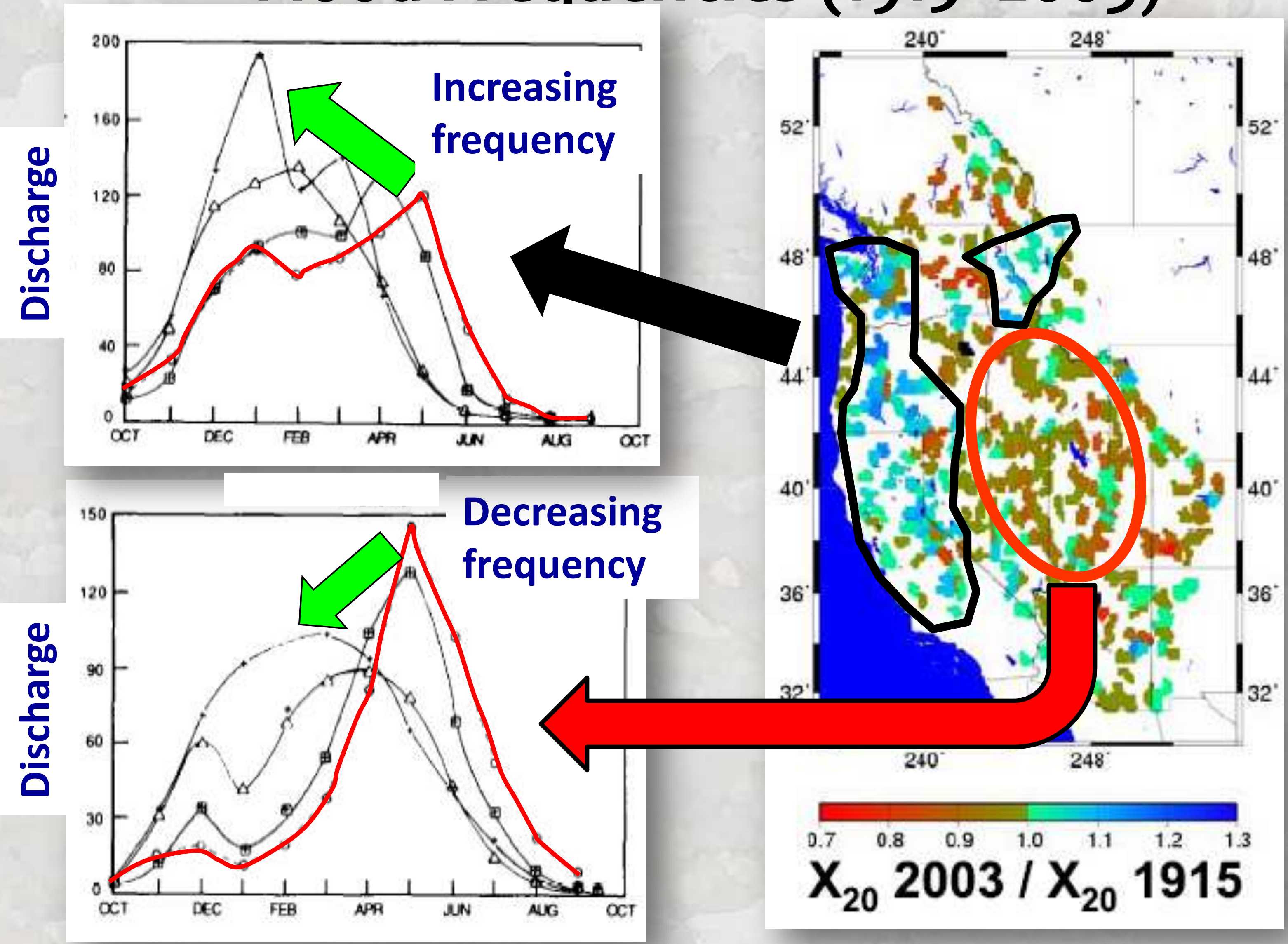


Earlier snowmelt & river runoff



Stewart et al. 2005

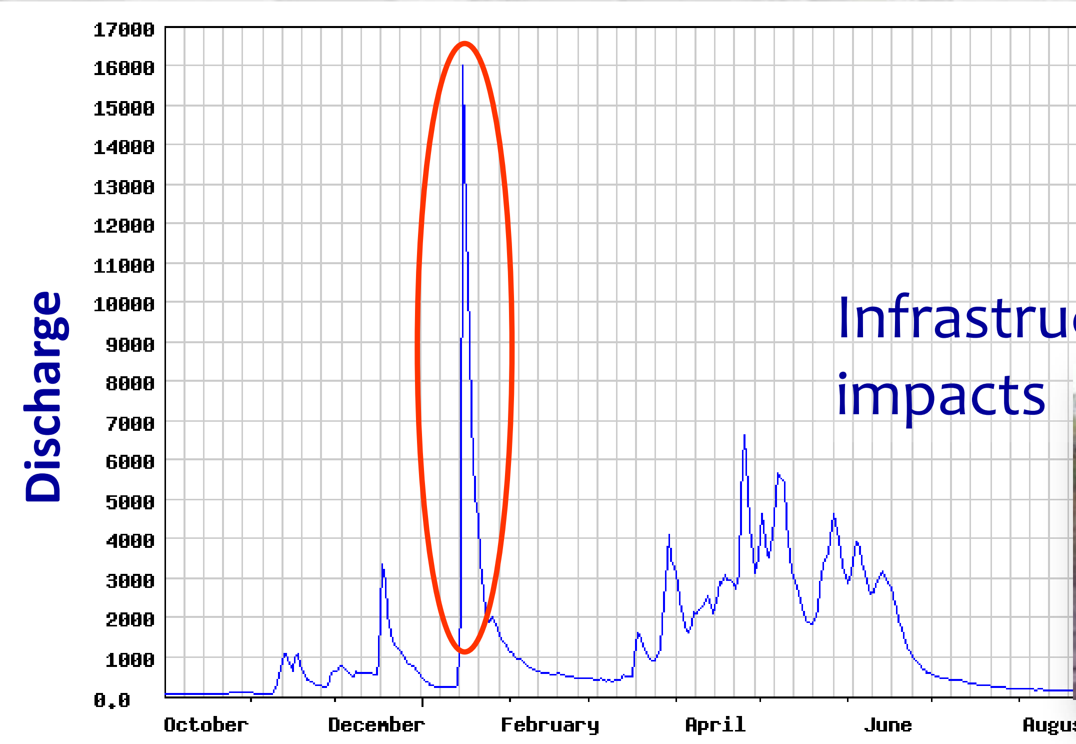
20th Century Trends in 20-Year Flood Frequencies (1915–2003)



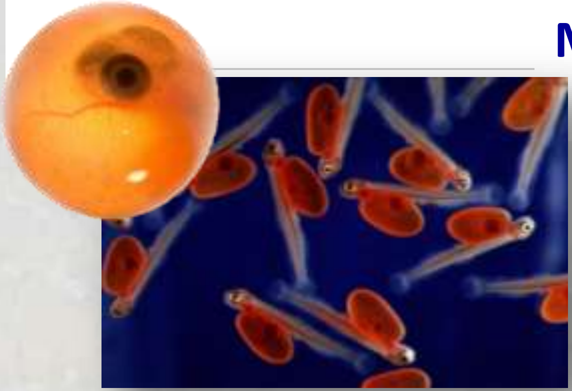
Hamlet and Lettenmaier. 2007. *Water Resources Research* 43, W06427, doi:10.1029/2006WR005099

Increases in Winter Floods

Rain-on-snow events



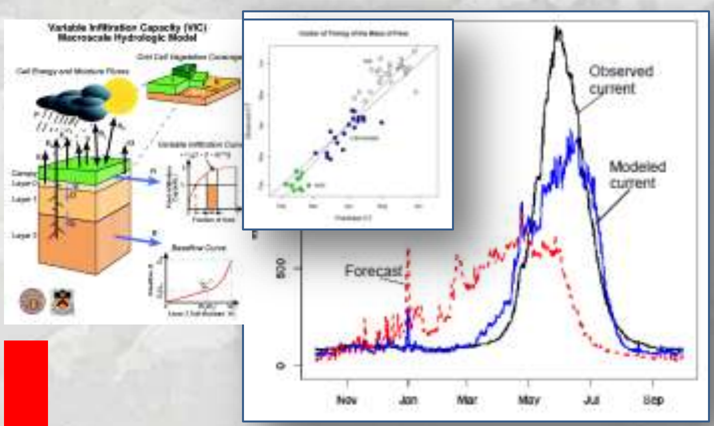
Infrastructure impacts



Fish egg/embryo mortality

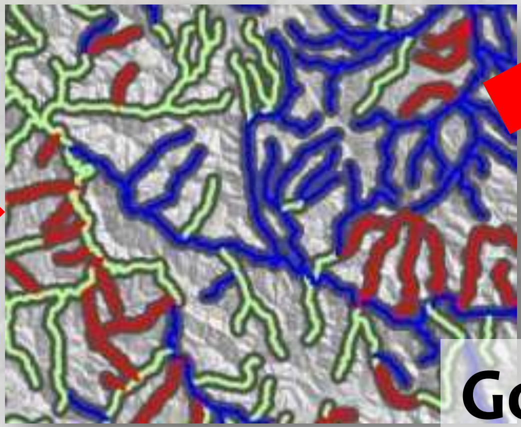
VIC Streamflow Scenarios

Ecological Flow Metrics



A1B IPCC Scenarios for the western U.S.

NHD+ stream segment resolution



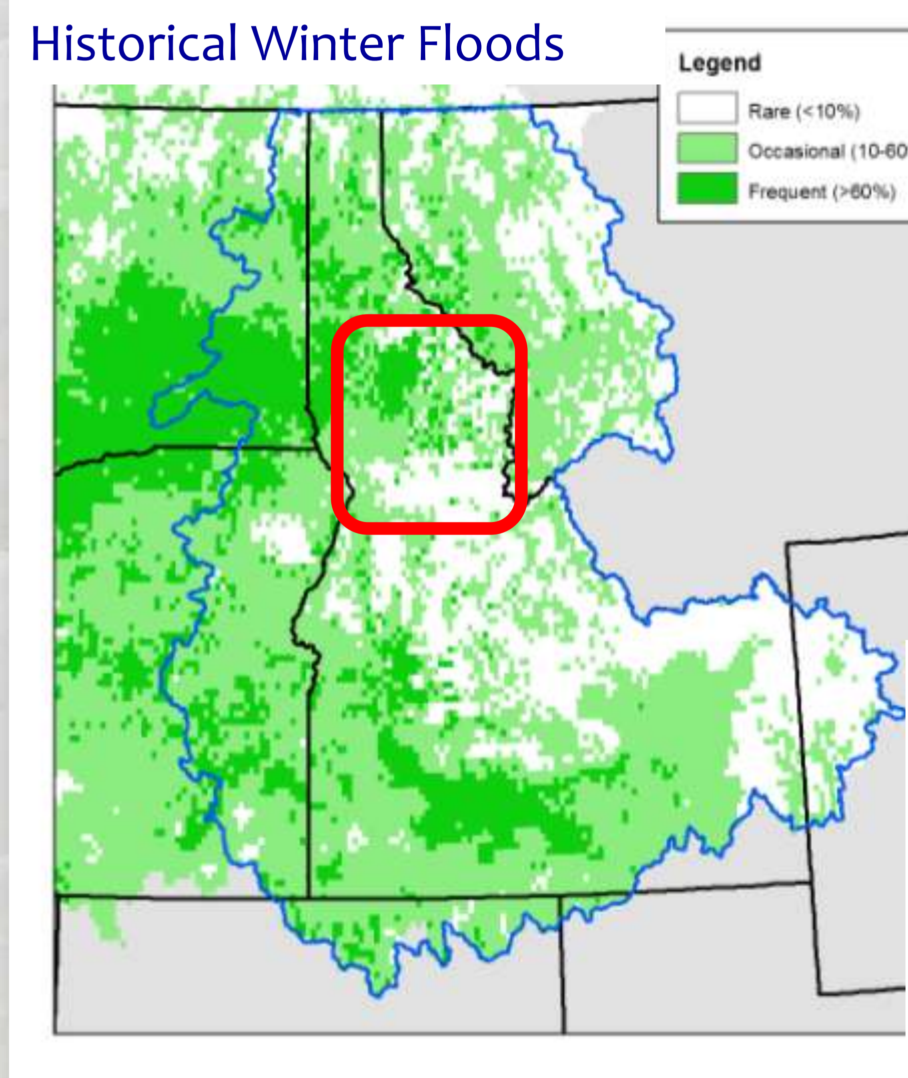
Google "Stream flow Metrics"

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)

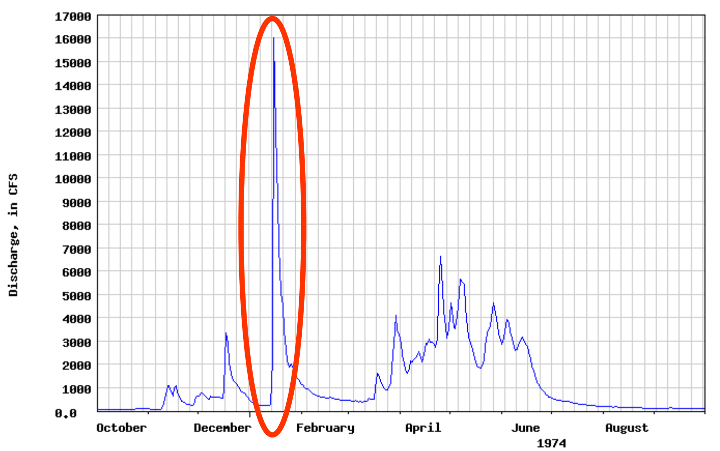


Historical Winter Floods

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

- Scenarios:

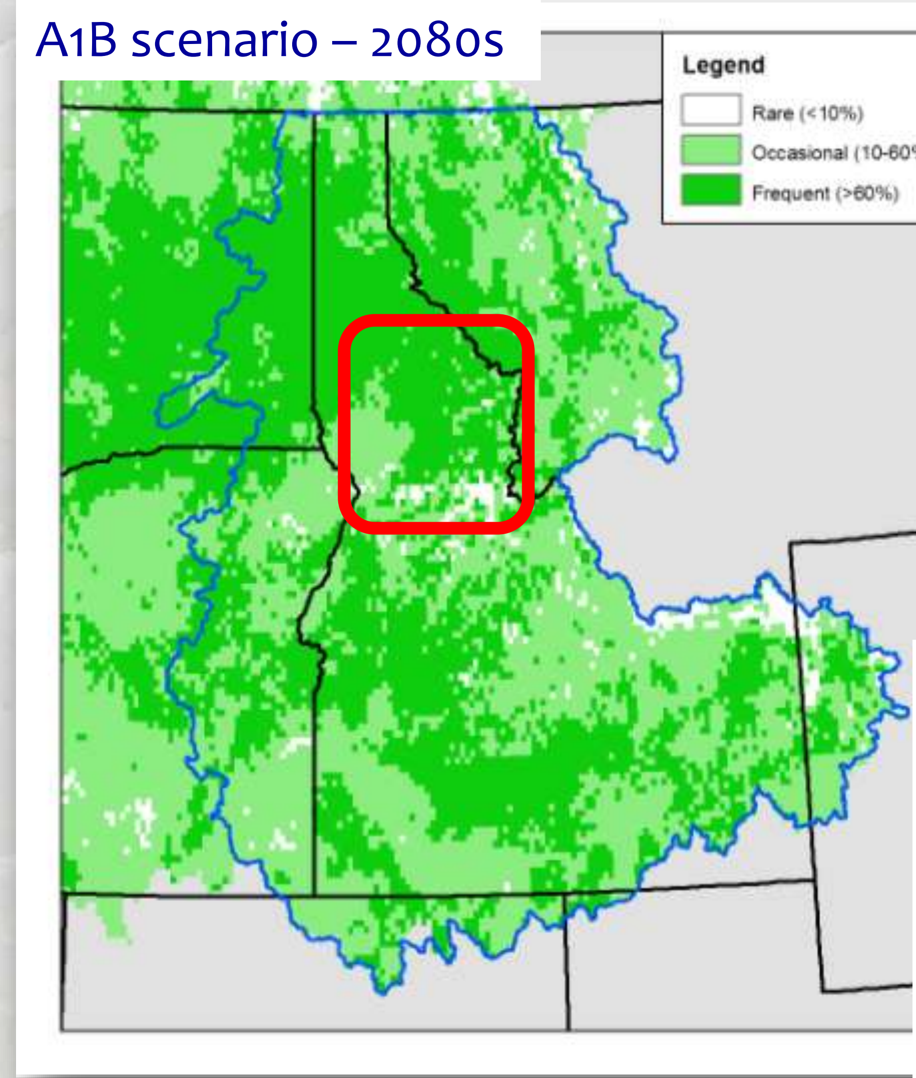
1) historical (1980s);
2) A1B mid-century (2040s – ensemble GCMs);
3) A1B late-century (2080s – ensemble GCMs)



Wenger et al. 2010. *WRR* **46**, W09513; Wenger et al. 2011. *PNAS* **108**:14175-14180

VIC Streamflow Scenario

Winter flood frequency (95% event)

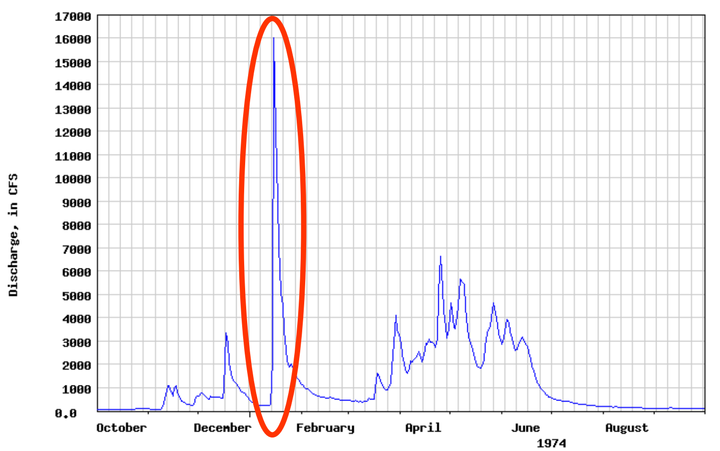


A1B scenario – 2080s

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

- Scenarios:

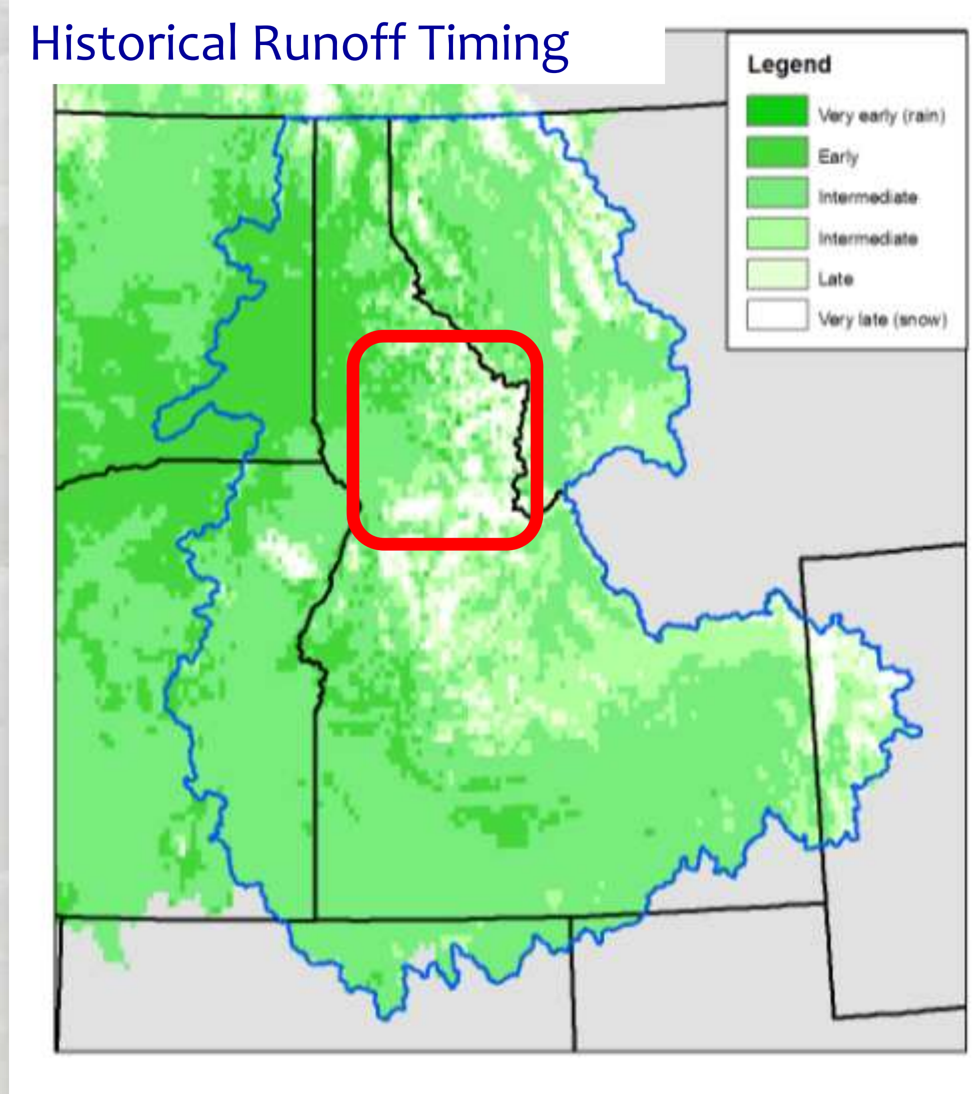
1) historical (1980s);
2) A1B mid-century (2040s – ensemble GCMs);
3) A1B late-century (2080s – ensemble GCMs)



Wenger et al. 2010. *WRR* **46**, W09513; Wenger et al. 2011. *PNAS* **108**:14175-14180

VIC Streamflow Scenario

Runoff timing (Center of annual flow mass)

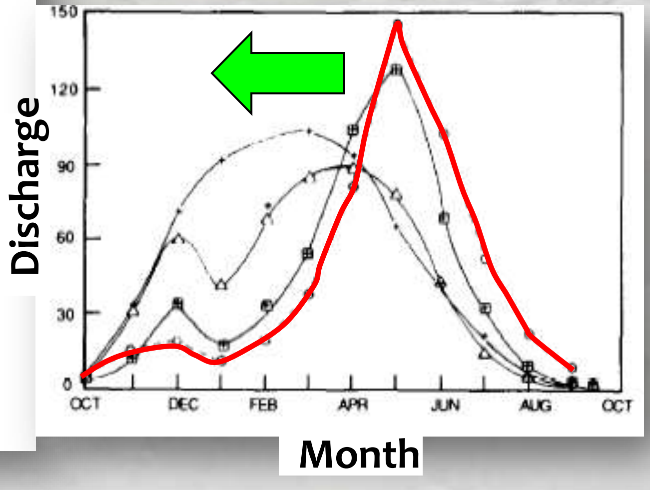


Historical Runoff Timing

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

- <u>Scenarios:</u>

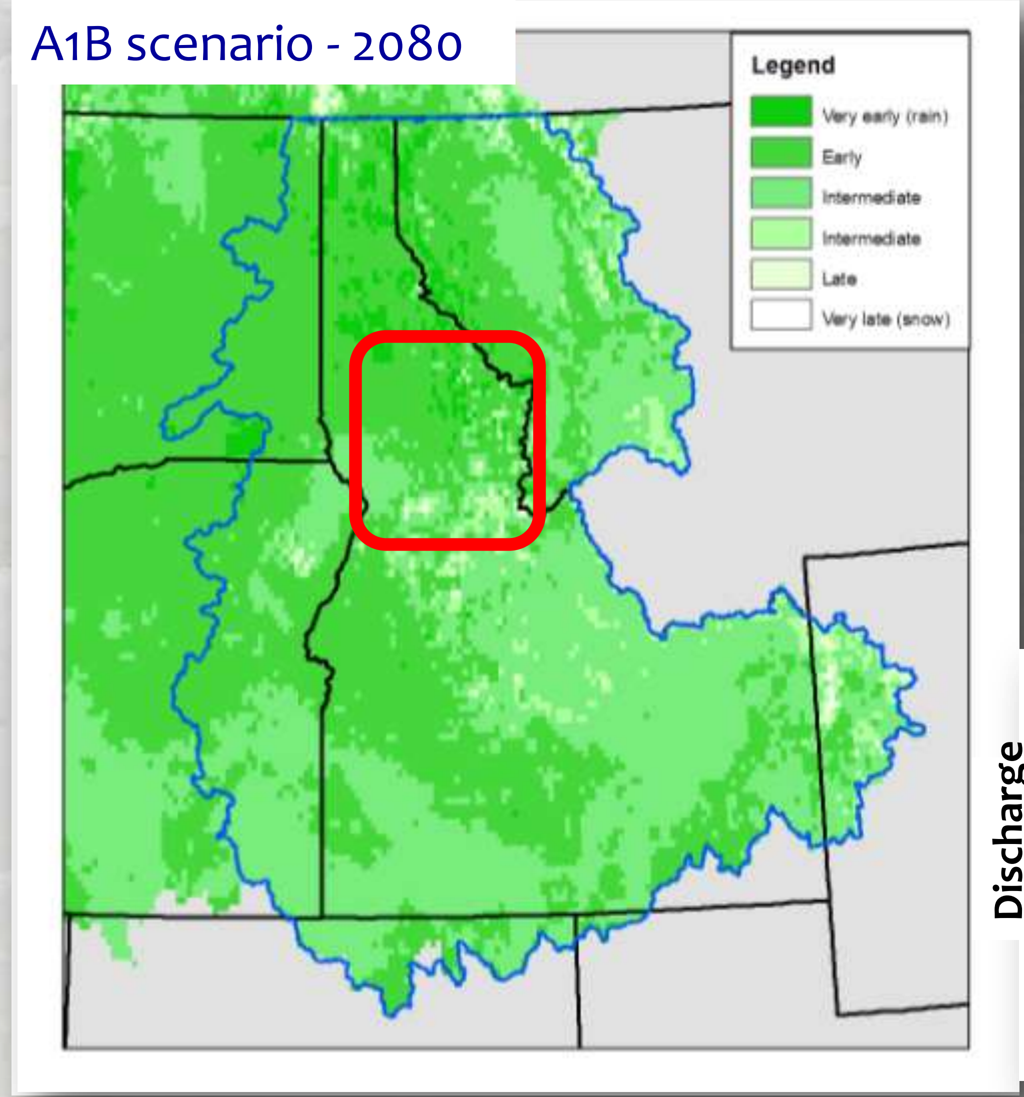
1) historical (1980s);
2) A1B mid-century (2040s – ensemble GCMs);
3) A1B late-century (2080s – ensemble GCMs)



Wenger et al. 2010. *WRR* **46**, W09513; Wenger et al. 2011. *PNAS* **108**:14175-14180

VIC Streamflow Scenario

Runoff timing (Center of annual flow mass)

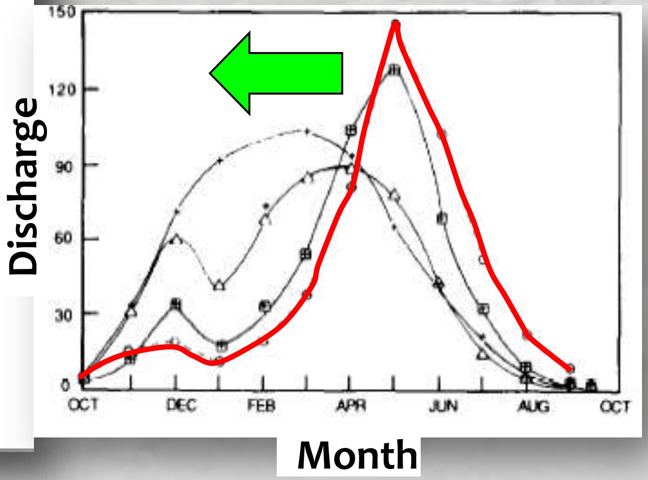


A1B scenario - 2080

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

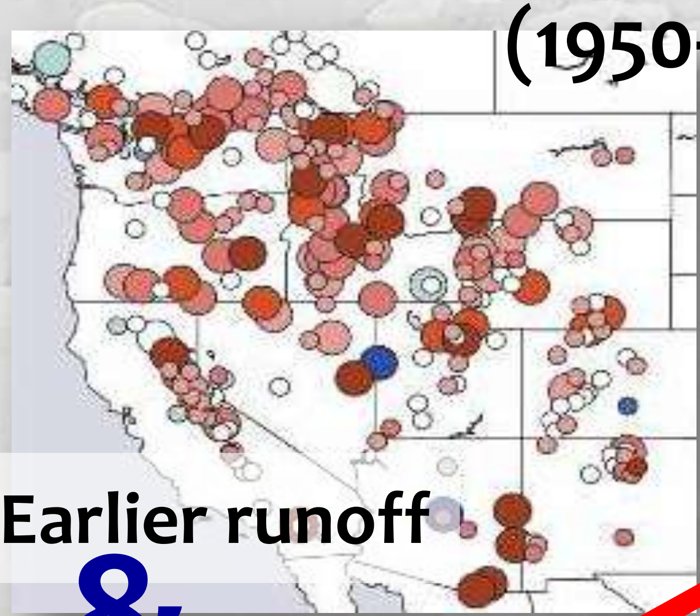
- <u>Scenarios:</u>

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



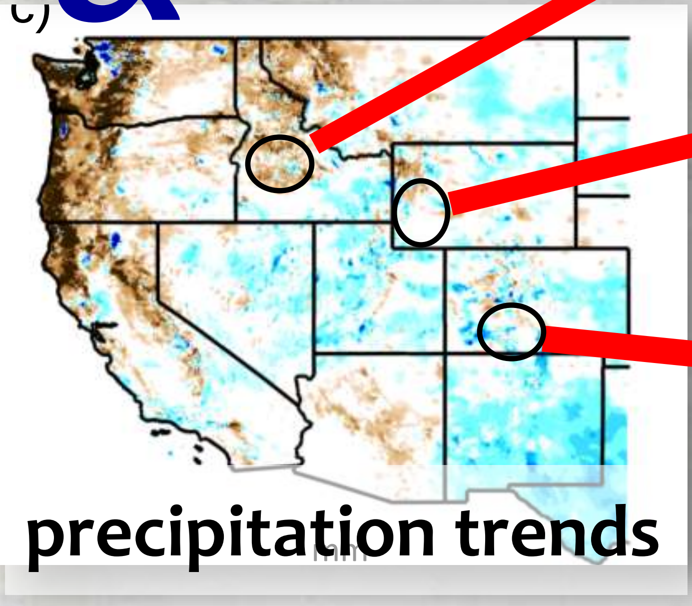
Wenger et al. 2010. *WRR* **46**, W09513; Wenger et al. 2011. *PNAS* **108**:14175-14180

Summer Flow Trends (1950–2009)

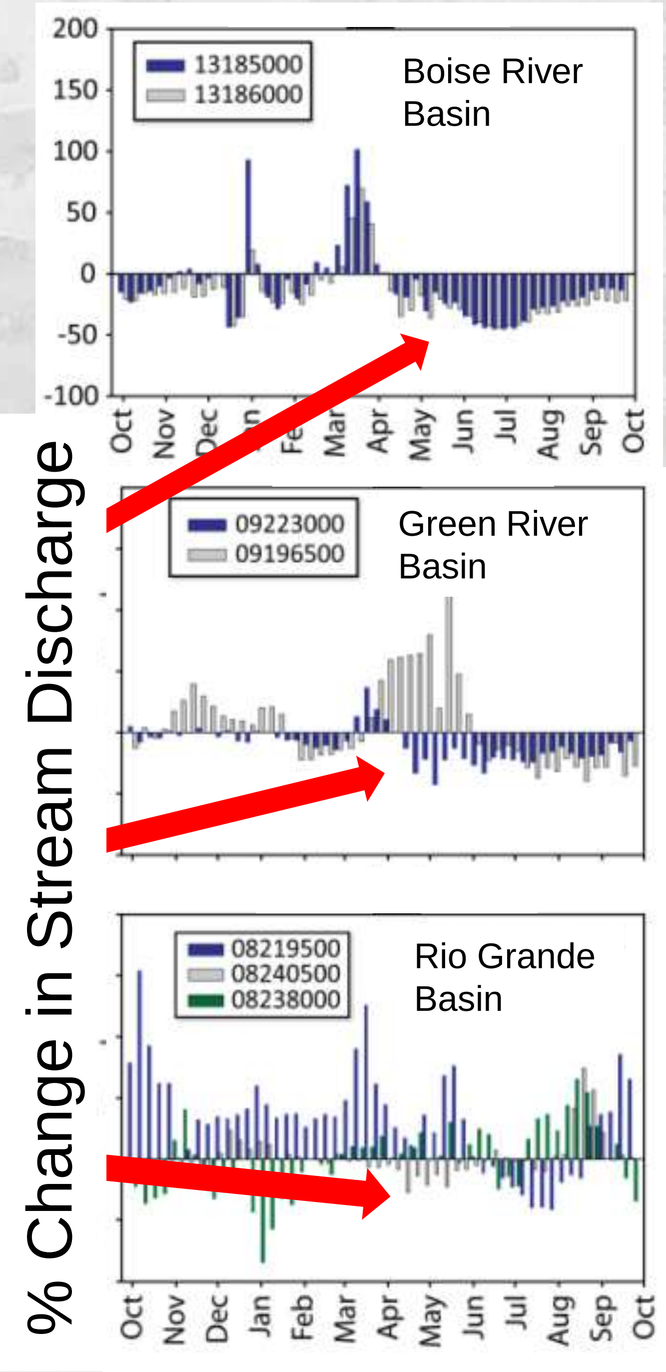


Earlier runoff

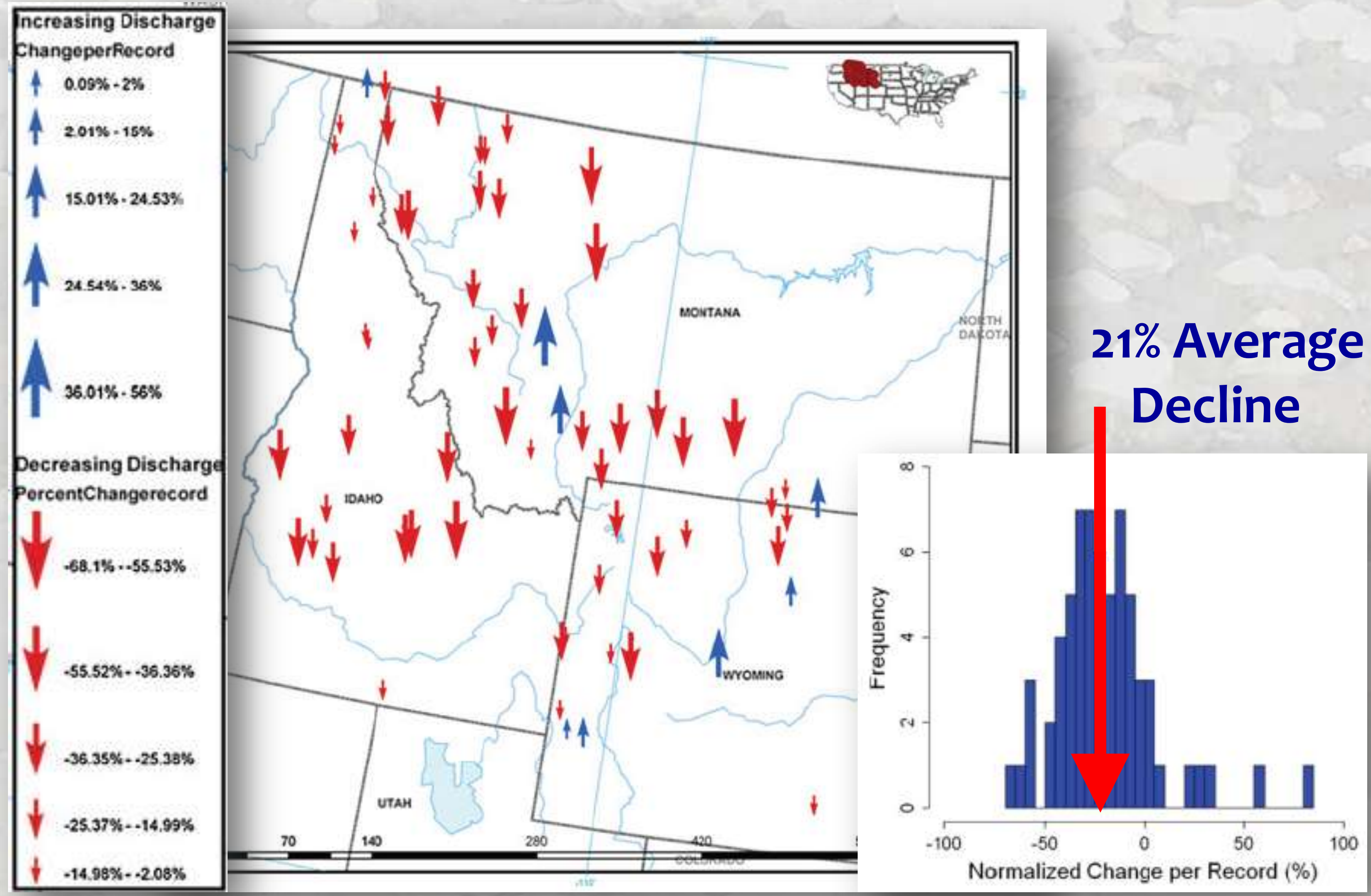
&



precipitation trends



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

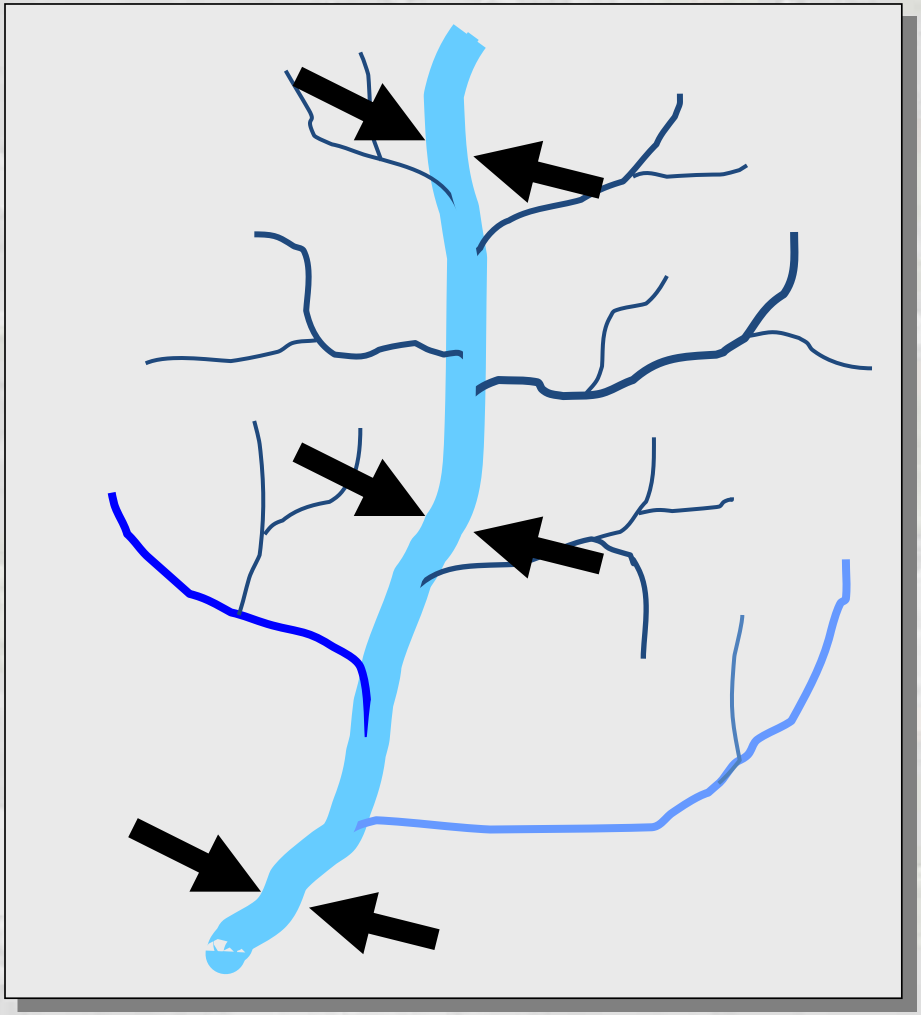


21% Average Decline

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

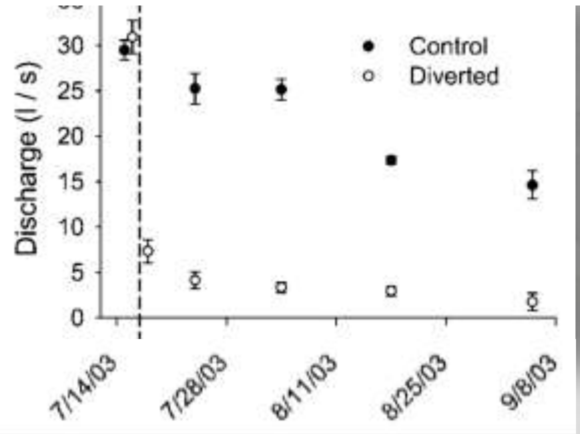
C. Nalder



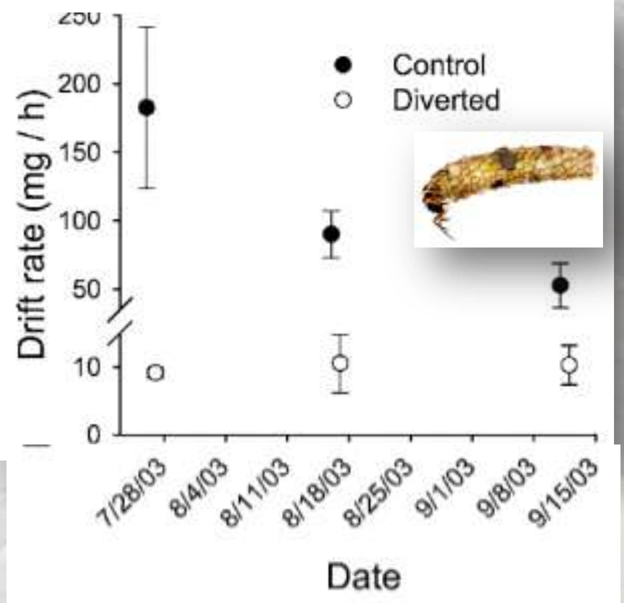
Fish passage issues exacerbated

Flow Declines ~ Less Productive Habitats

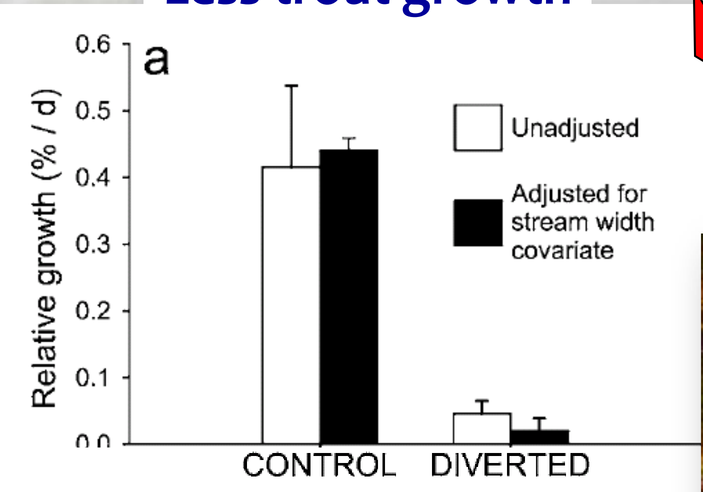
Less water & velocity



Less aquatic insect drift



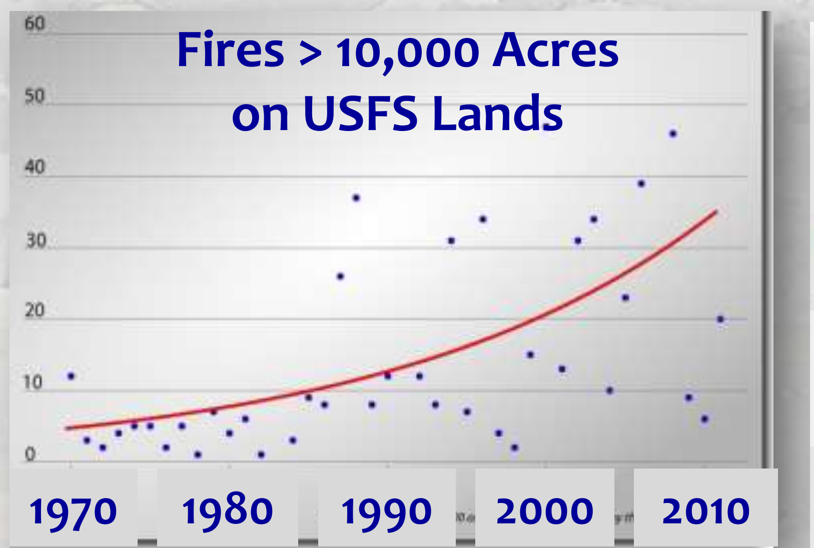
Less trout growth



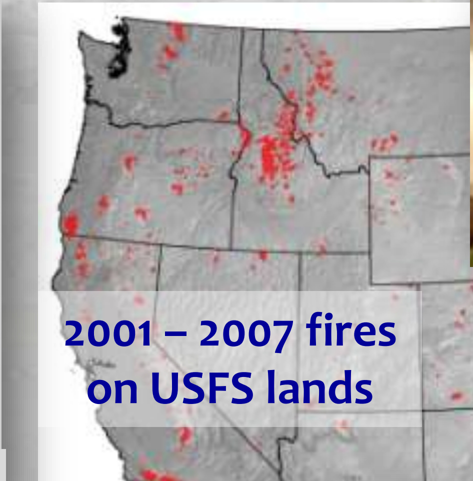
You are a bug.
I will eat you

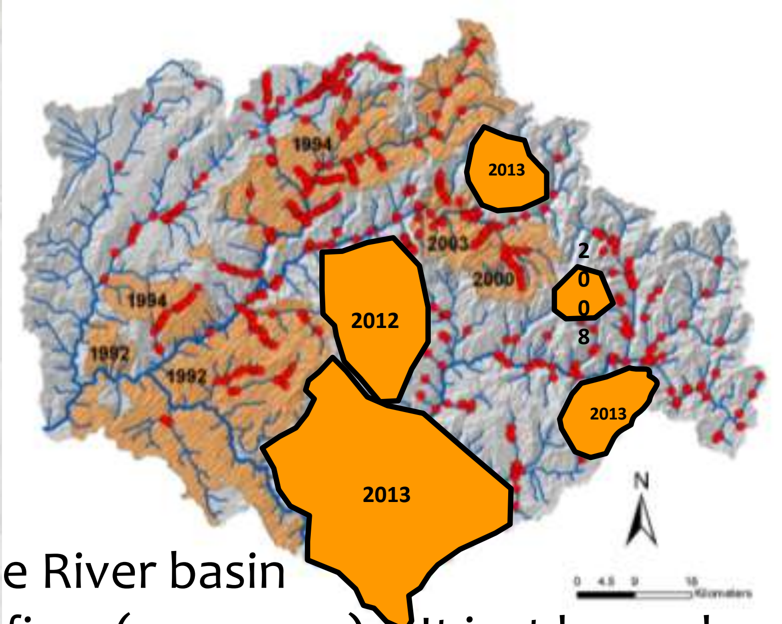
Harvey et al. 2006. Reduced streamflow lowers dry-season growth of rainbow trout in a small stream. *Transactions of the American Fisheries Society* **135**:998-1005.

Wildfires Increasing Westwide



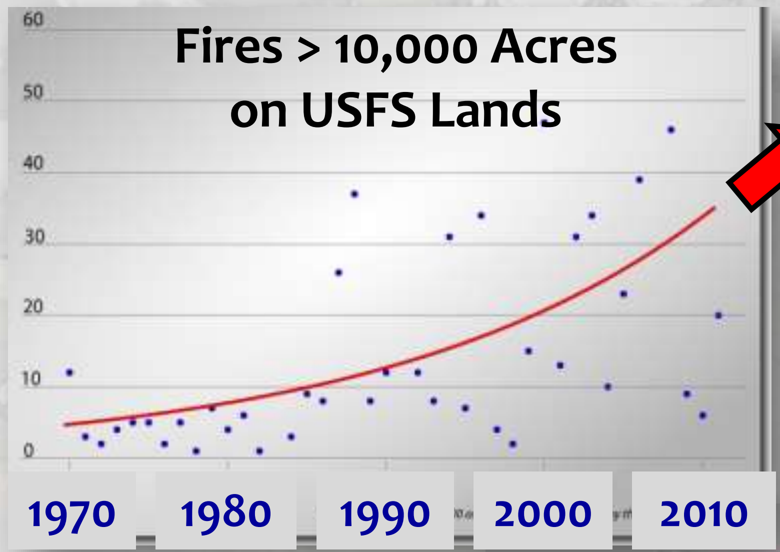
National Research Council. 2011





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

Future Means More & Bigger Fires



If +1.0 °C…

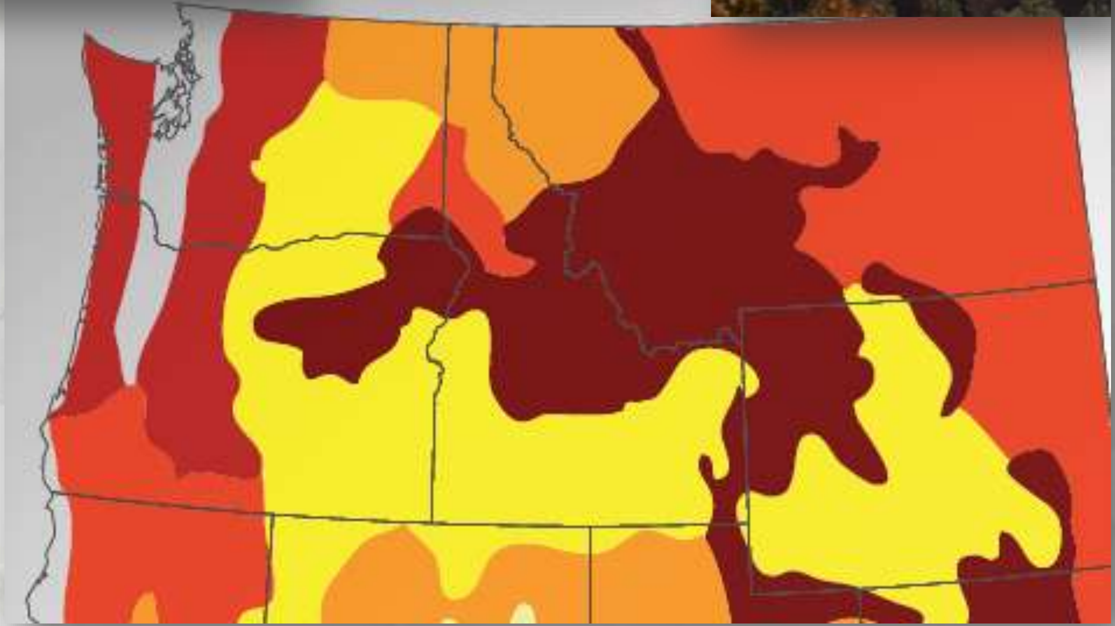
- 🟫 at least 6 times more
- 🟥 5-6 times more
- 🟥 4-5 times more
- 🟧 3-4 times more
- 🟨 2 - 3 times more
- ⬜ up to 2 times more

TIMOTHY EGAN

Winner of the National Book Award

The BIG BURN

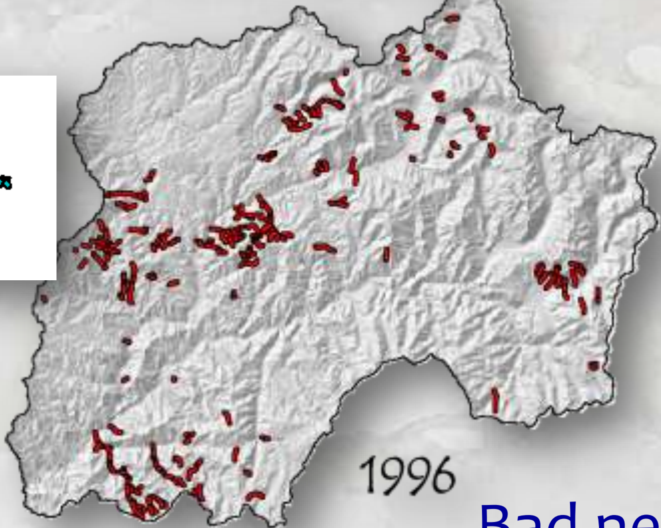
Teddy Roosevelt & the Fire that Saved America



National Research Council 2011

Sediment Loading to Stream Channels

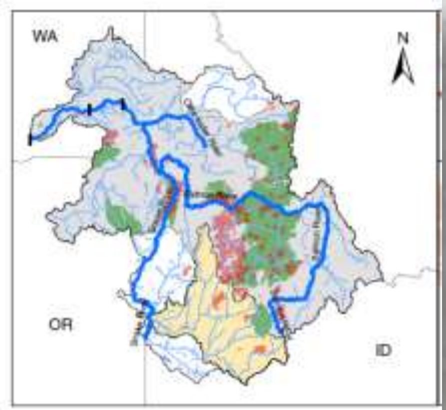
Thunderstorms & debris flow torrents

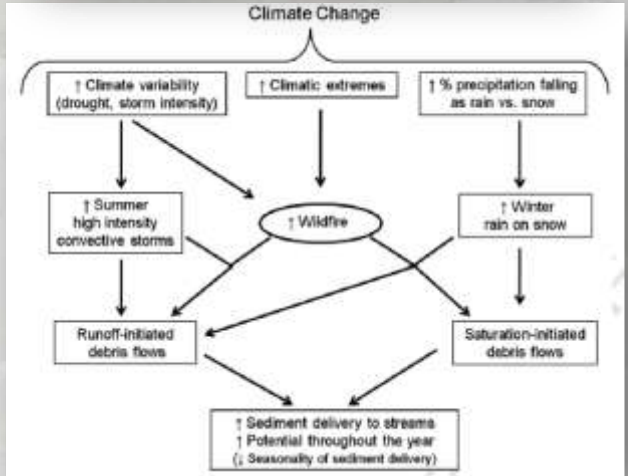


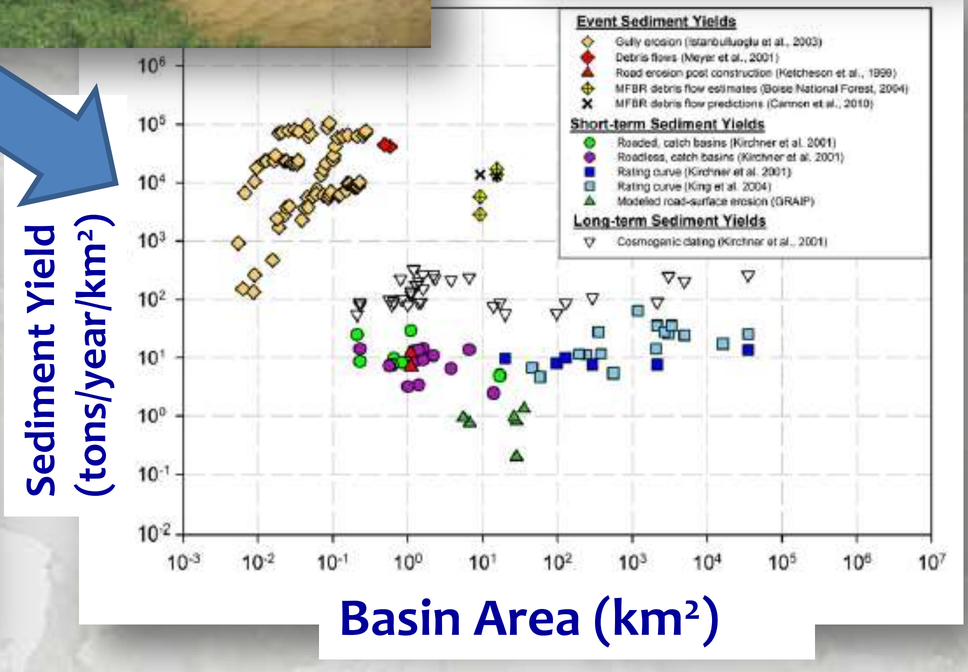
Bad news if you’re a fish living here

Sediment Loading to Stream Channels

Channel form & habitats will evolve



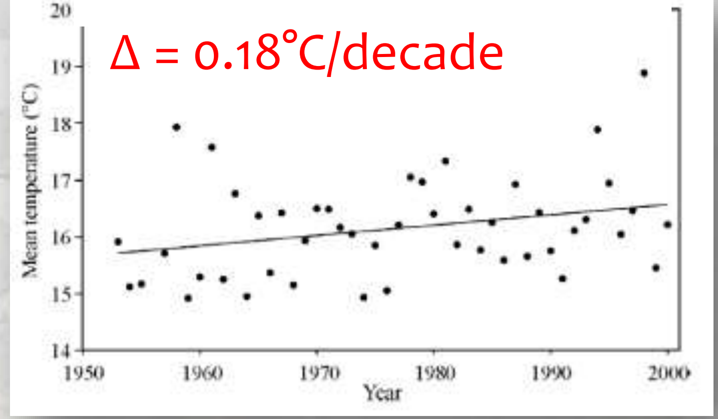




Goode et al. 2011. Enhanced sediment delivery in a changing climate in semi-arid mountain basins: Implications for water resource management and aquatic habitat in the northern Rocky Mountains. *Geomorphology* **139/140**:1-15.

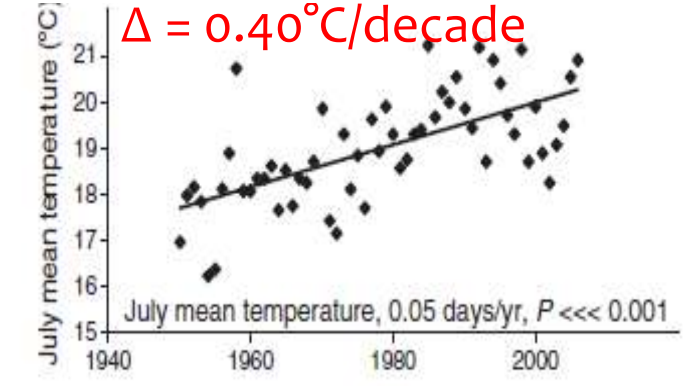
Temperature Trends In Northwest Rivers

Fraser River - Annual



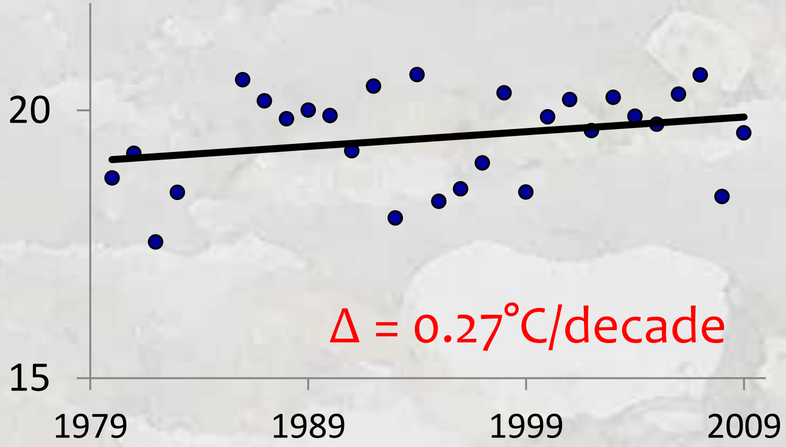
Δ = 0.18°C/decade

Columbia River - Summer



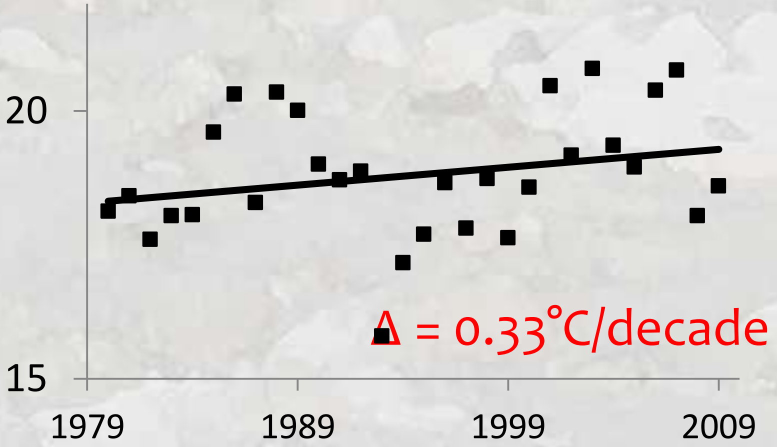
Δ = 0.40°C/decade

Snake River, ID - Summer



Δ = 0.27°C/decade

Missouri River, MT - Summer

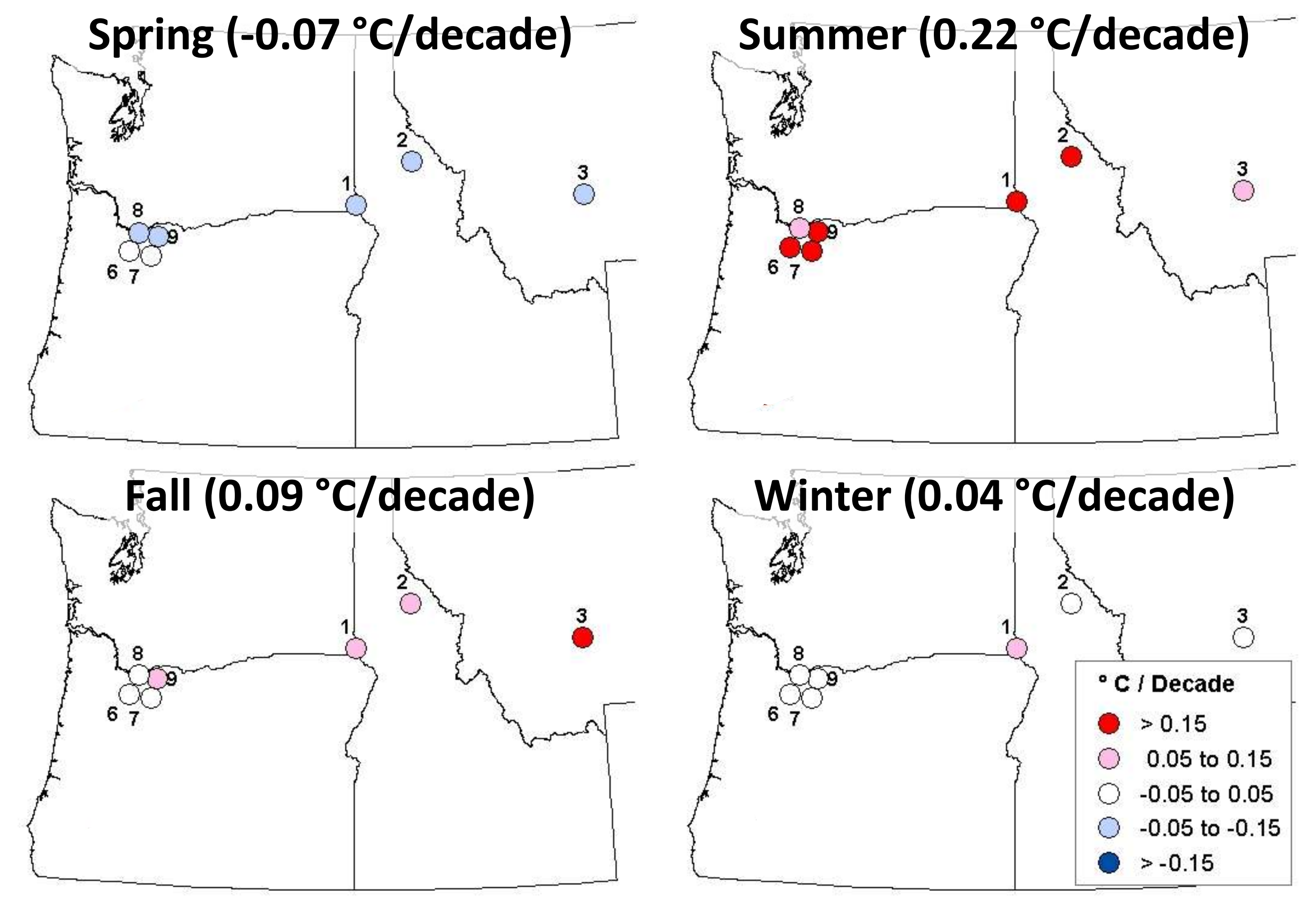


Δ = 0.33°C/decade

Isaak et al. 2012. *Climatic Change* **113**:499-524.

Seasonal Trends In Temperatures (1980-2009)

Unregulated sites (7) with 30 years of annual data



Spring (-0.07 °C/decade)

Summer (0.22 °C/decade)

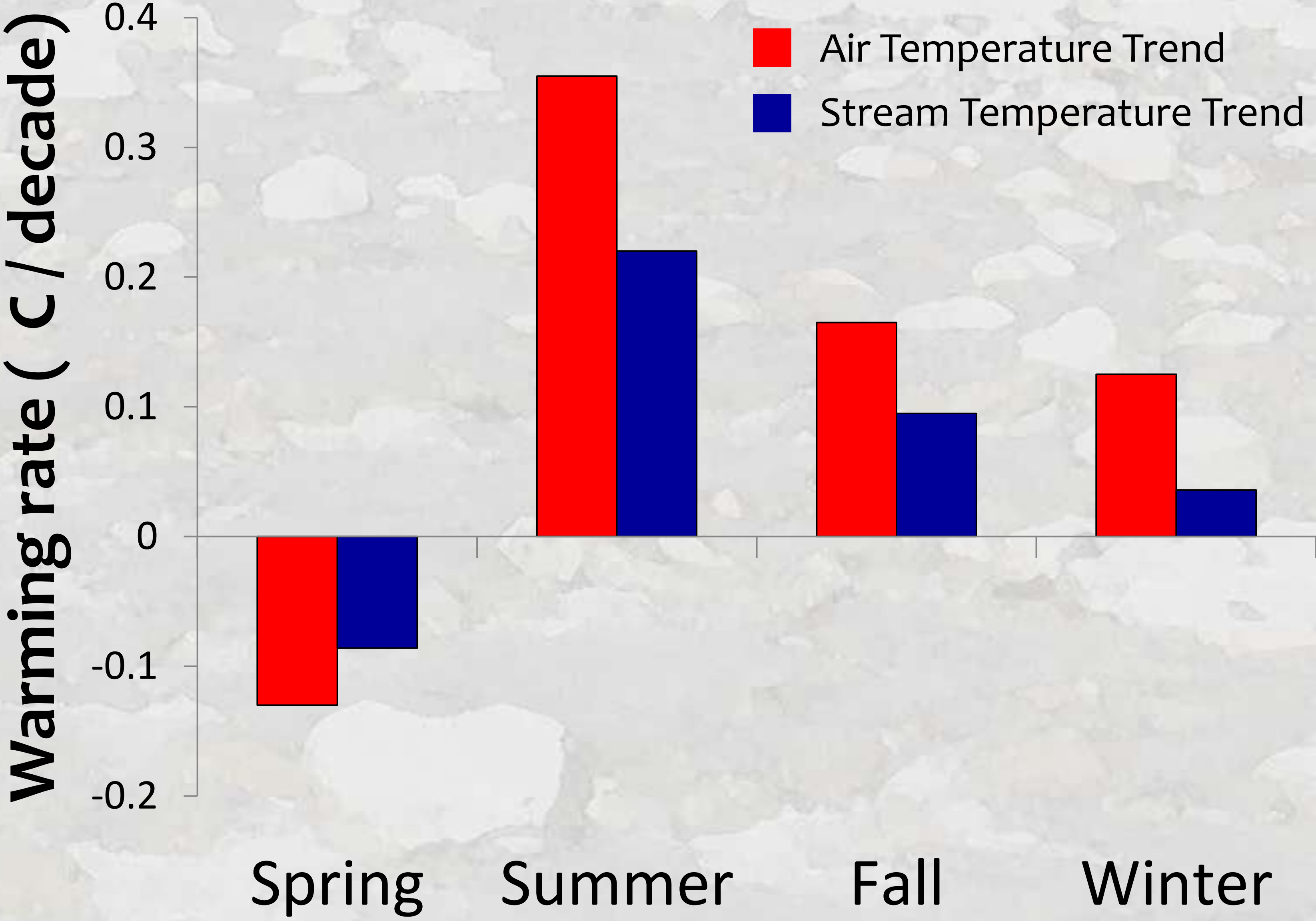
Fall (0.09 °C/decade)

Winter (0.04 °C/decade)

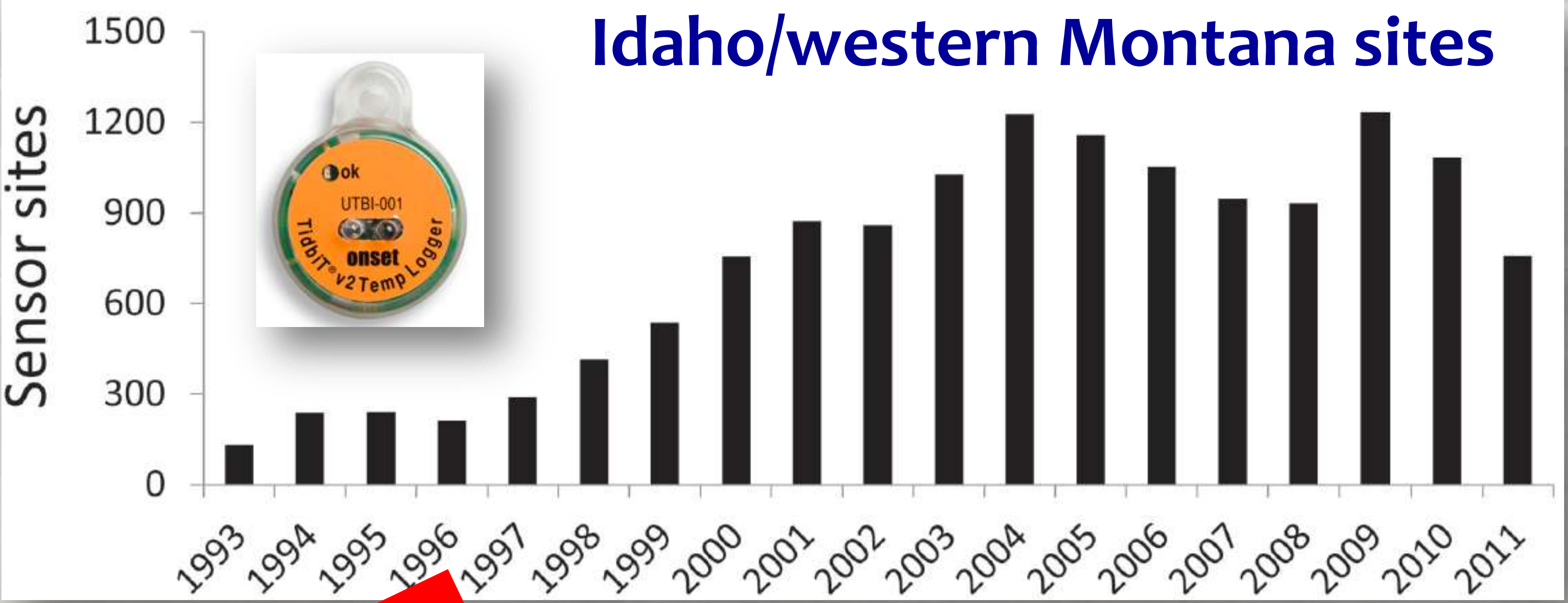
Isaak et al. 2012. *Climatic Change* **113**:499-524.

Stream Temperatures Track Air Temps

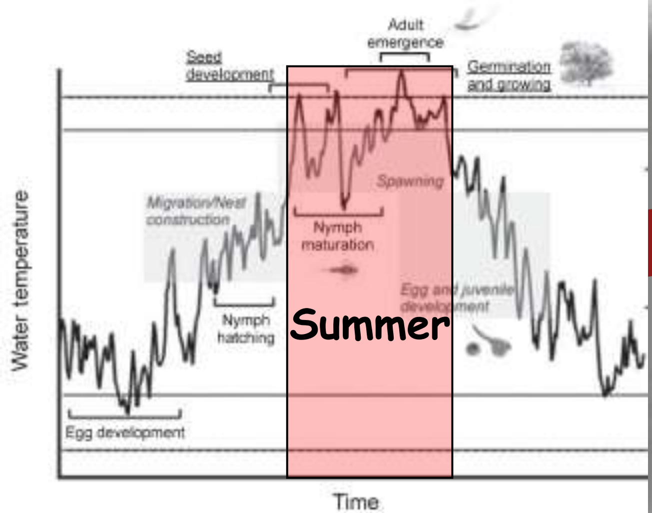
Streams warm about 60% as fast

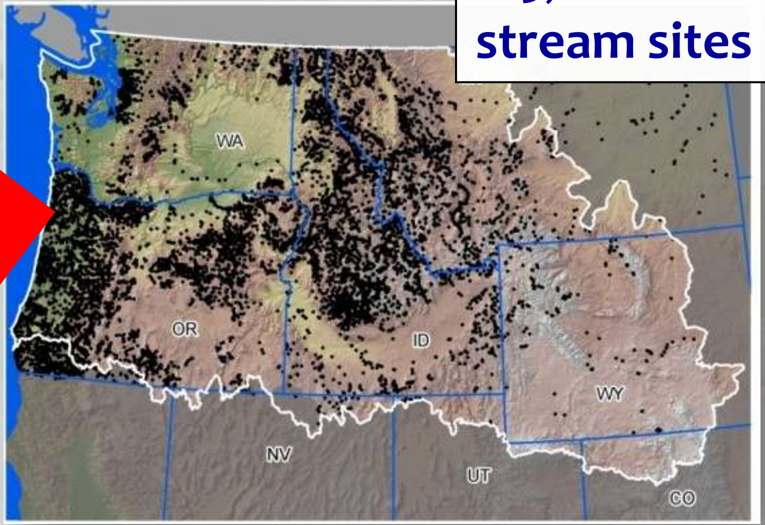


Lots of Summer Temp Data Out There…



Idaho/western Montana sites

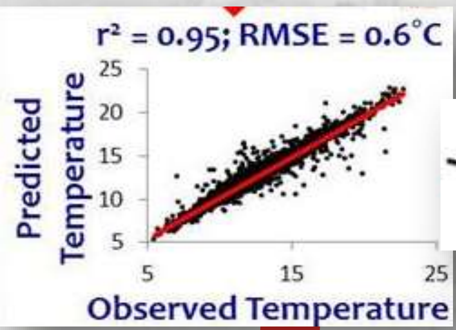


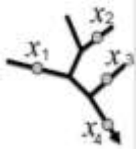


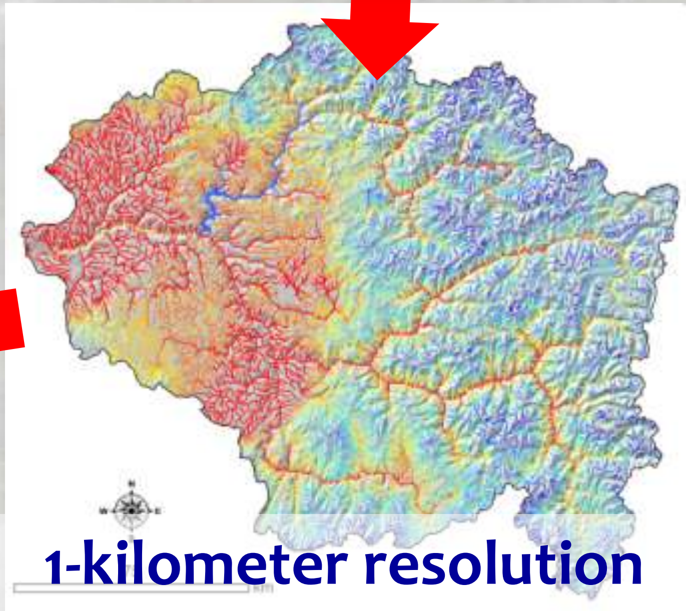
~15,000 stream sites

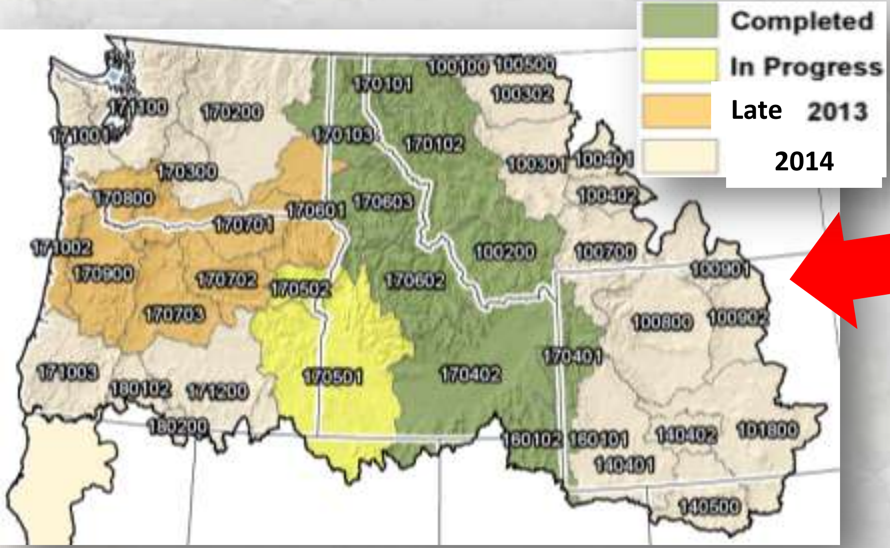
NorWeST Stream Temp Scenarios

>60 agencies
>15,000 stream sites
>45,000,000 hourly recordings


r² = 0.95; RMSE = 0.6°C

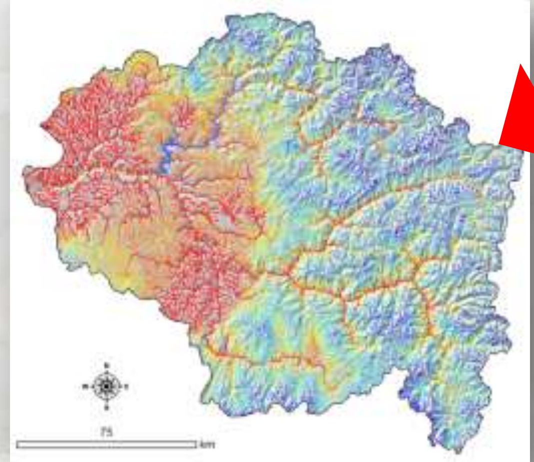



1-kilometer resolution

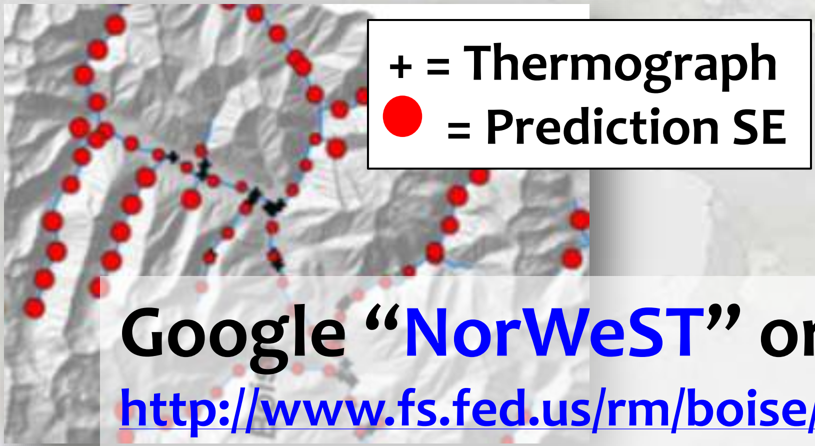


Website Distributes Scenarios & Temperature Data as GIS Layers

1) GIS shapefiles of stream temperature scenarios



2) GIS shapefiles of stream temperature model prediction precision

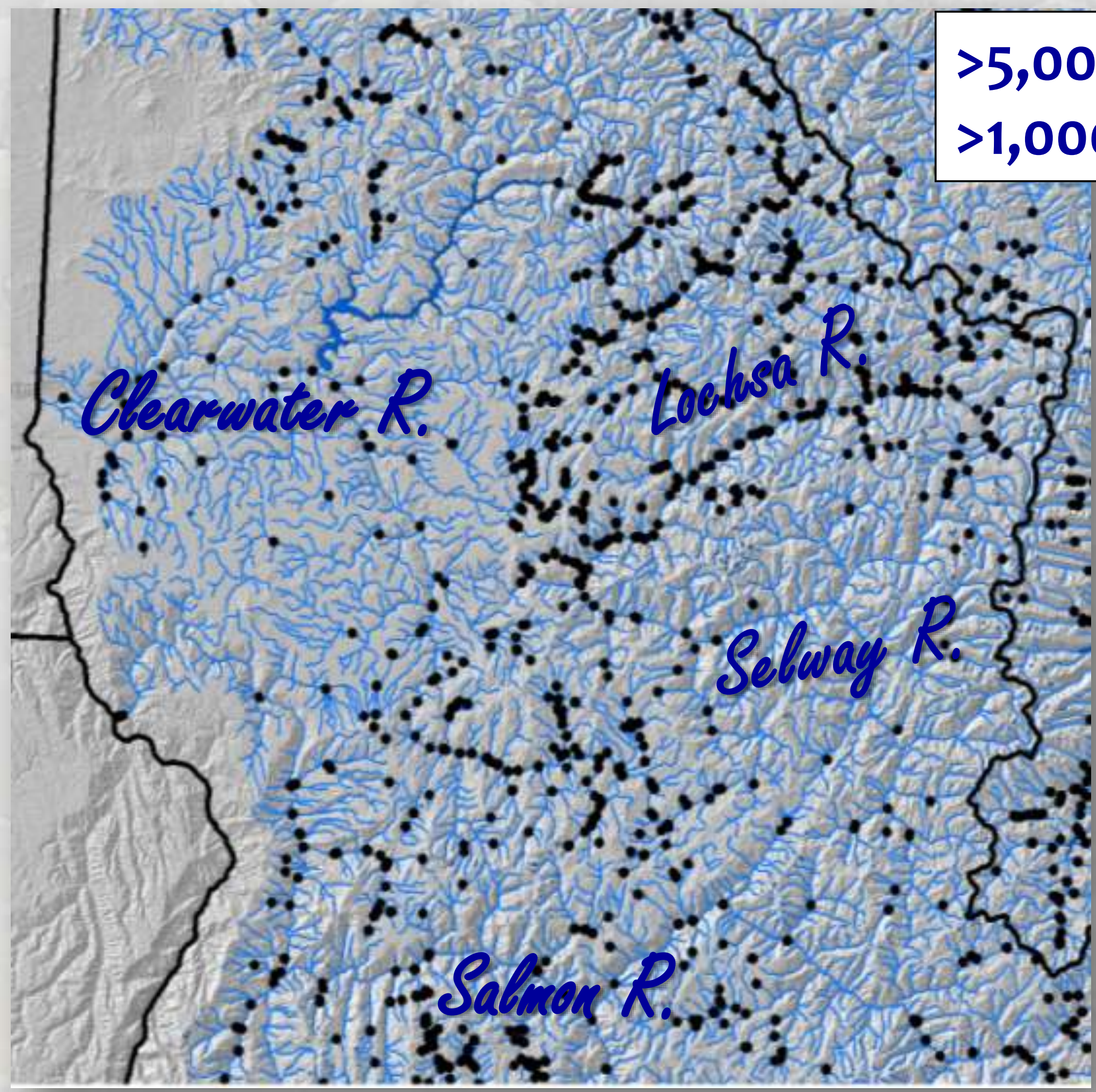


3) Temperature data summaries

Google “**NorWeST**” or go here…

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

Clearwater-Nez Temperature Dataset is *World Class!*

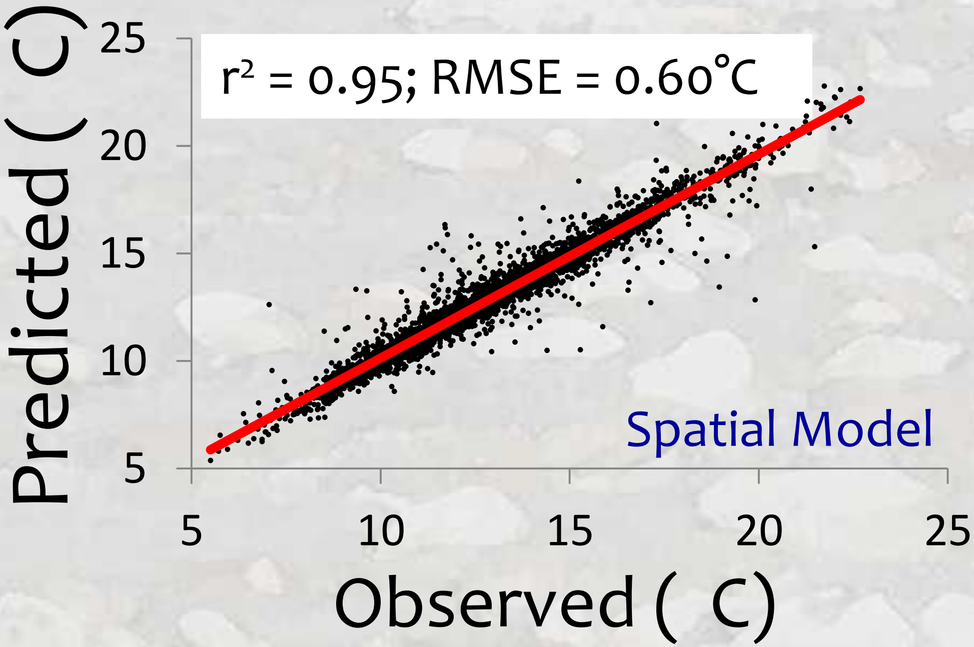


>5,000 August means
>1,000 stream sites

•Temperature site

Clearwater-Nez River Temp Model

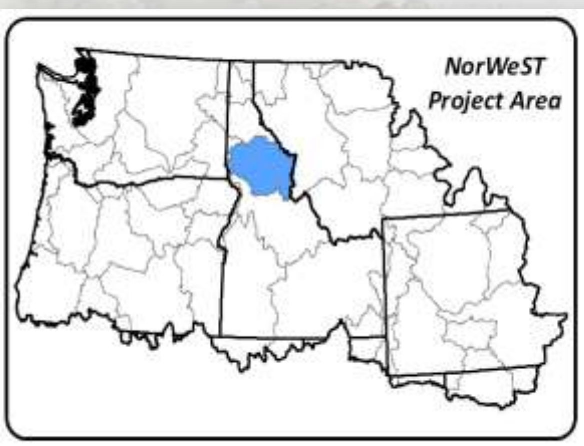
Mean August Temperature



Covariate Predictors

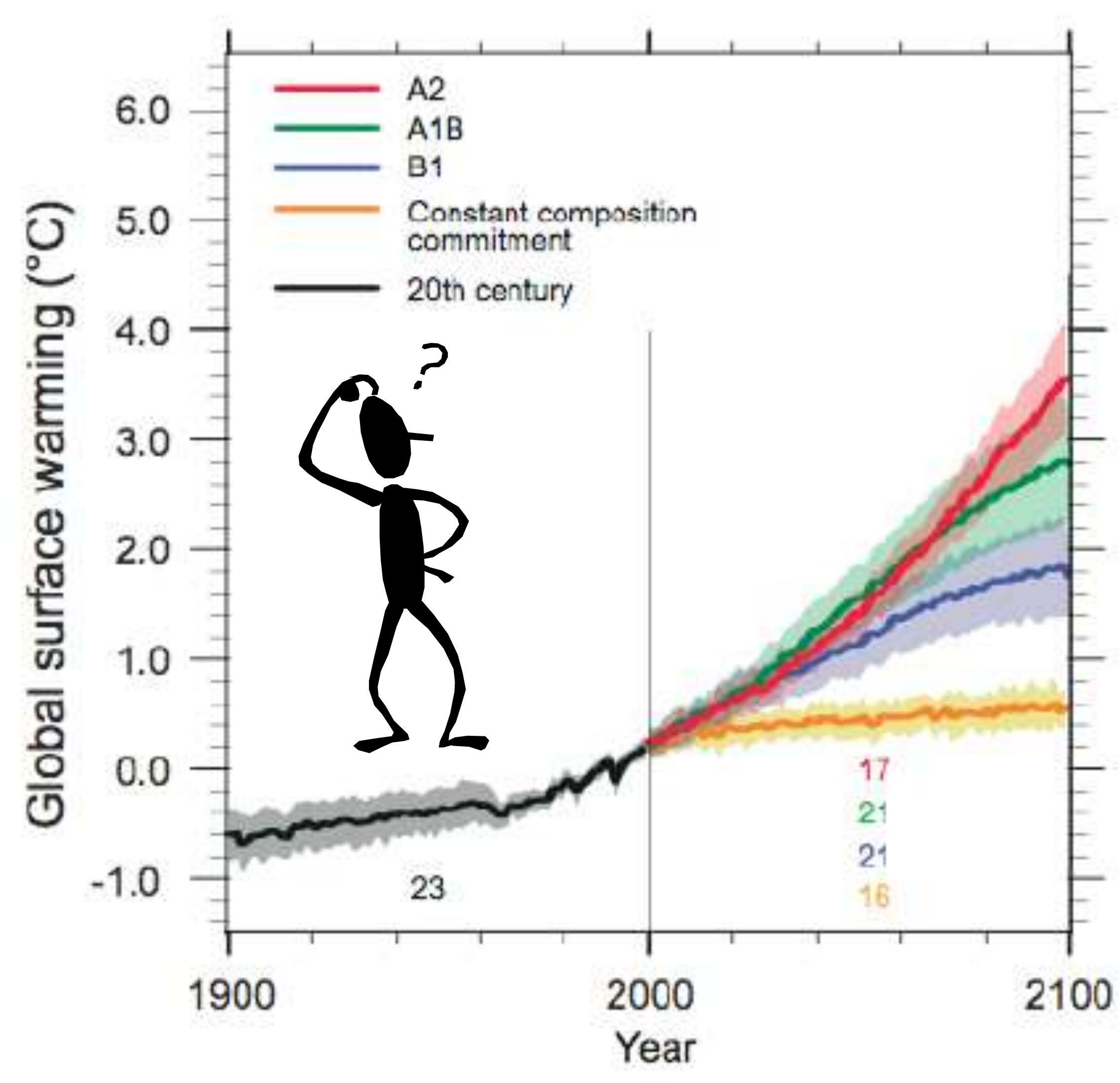
1. Elevation (m)
2. Canopy (%)
3. Stream slope (%)
4. Ave Precipitation (mm)
5. Latitude (km)
6. Lakes upstream (%)
7. Baseflow Index
8. Watershed size (km²)

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…



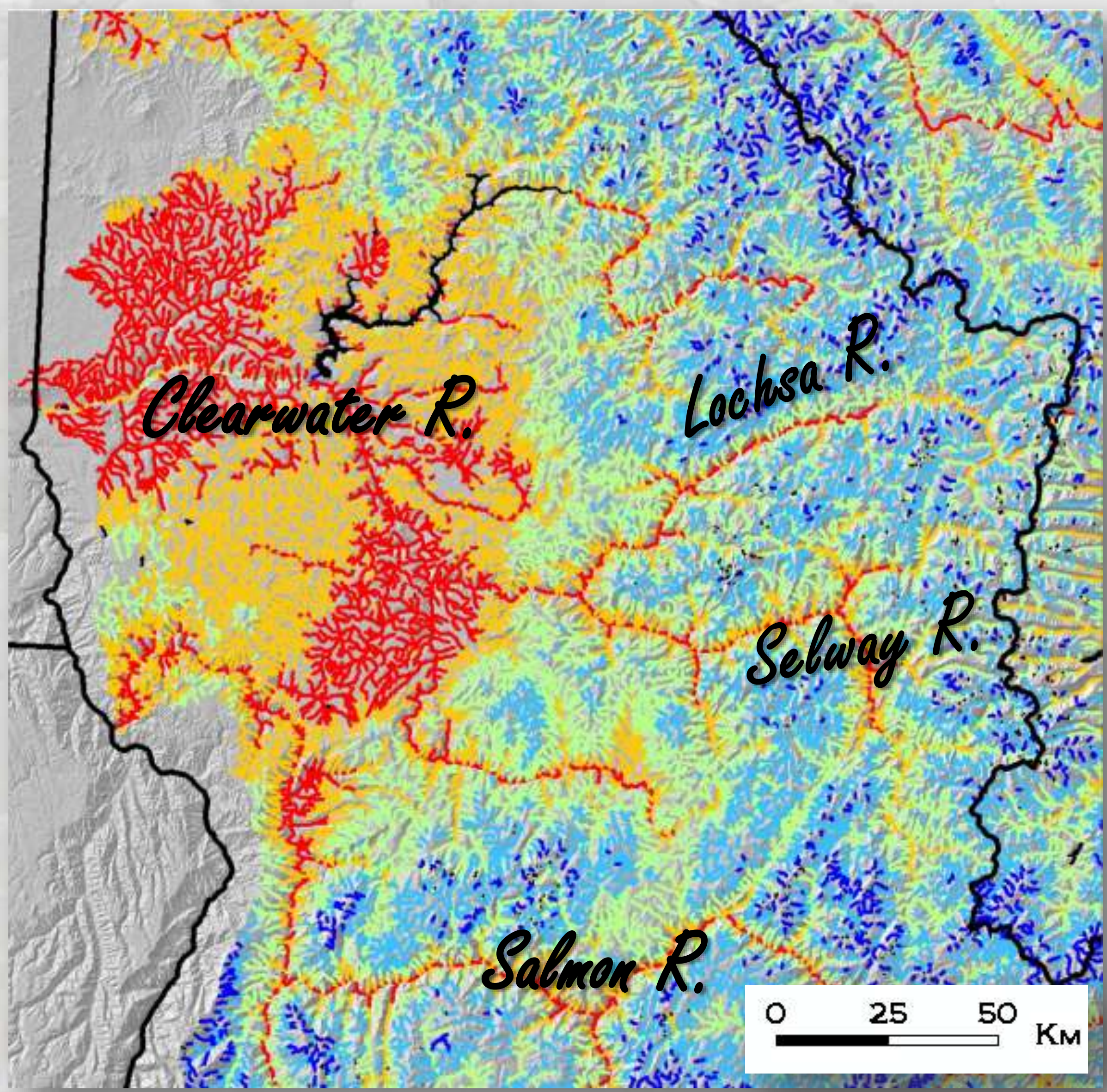
Adjust…

- Air
- Discharge
- %Canopy

…values to create scenarios

Clearwater-Nez Stream Temp Scenarios

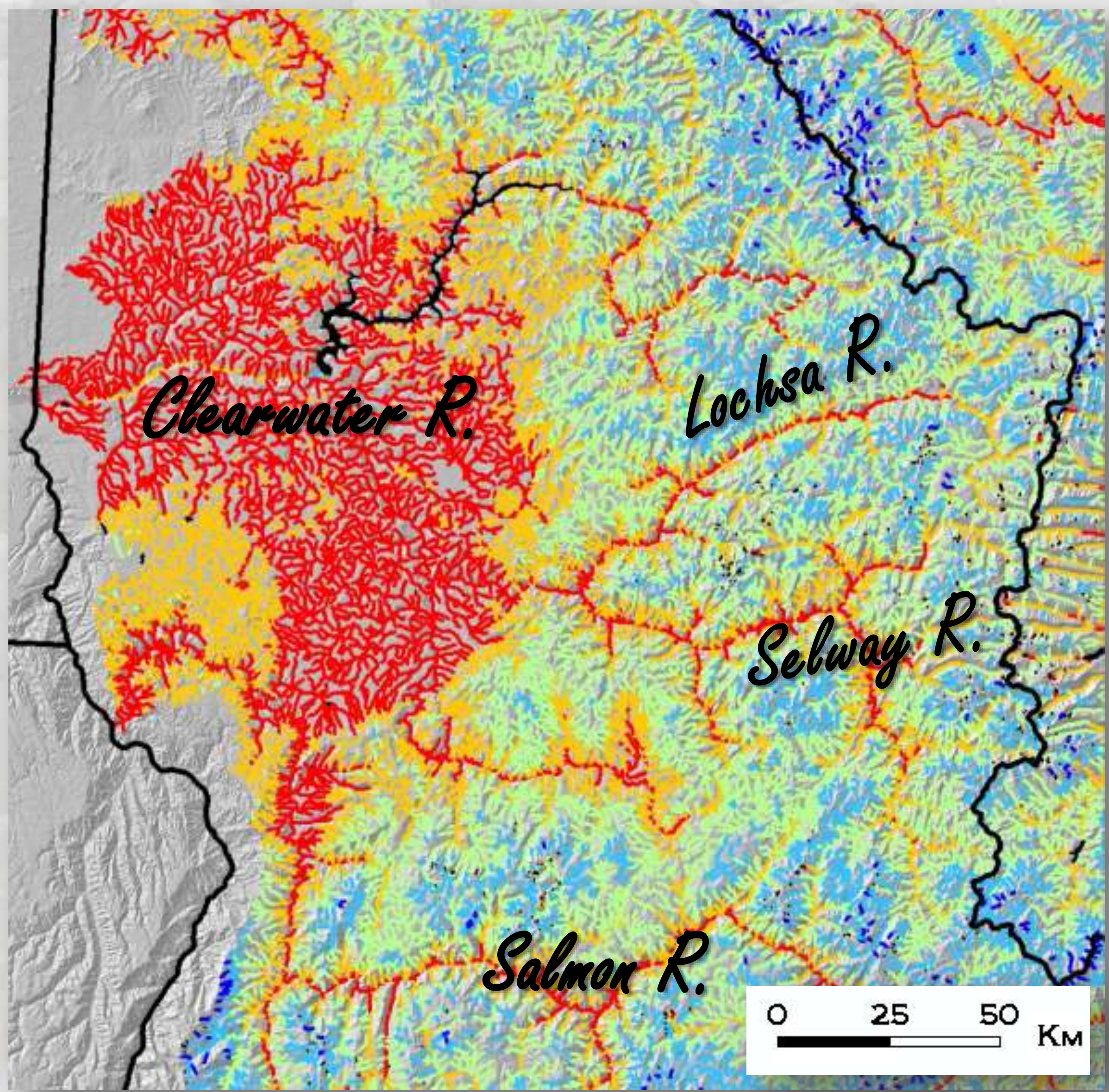
Historic (1993-2011 Average August)



1 kilometer model resolution

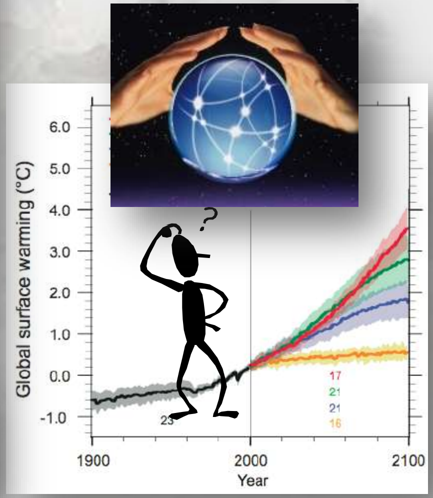
Clearwater-Nez Stream Temp Scenarios

+1.00°C Stream Temp (~2040s)



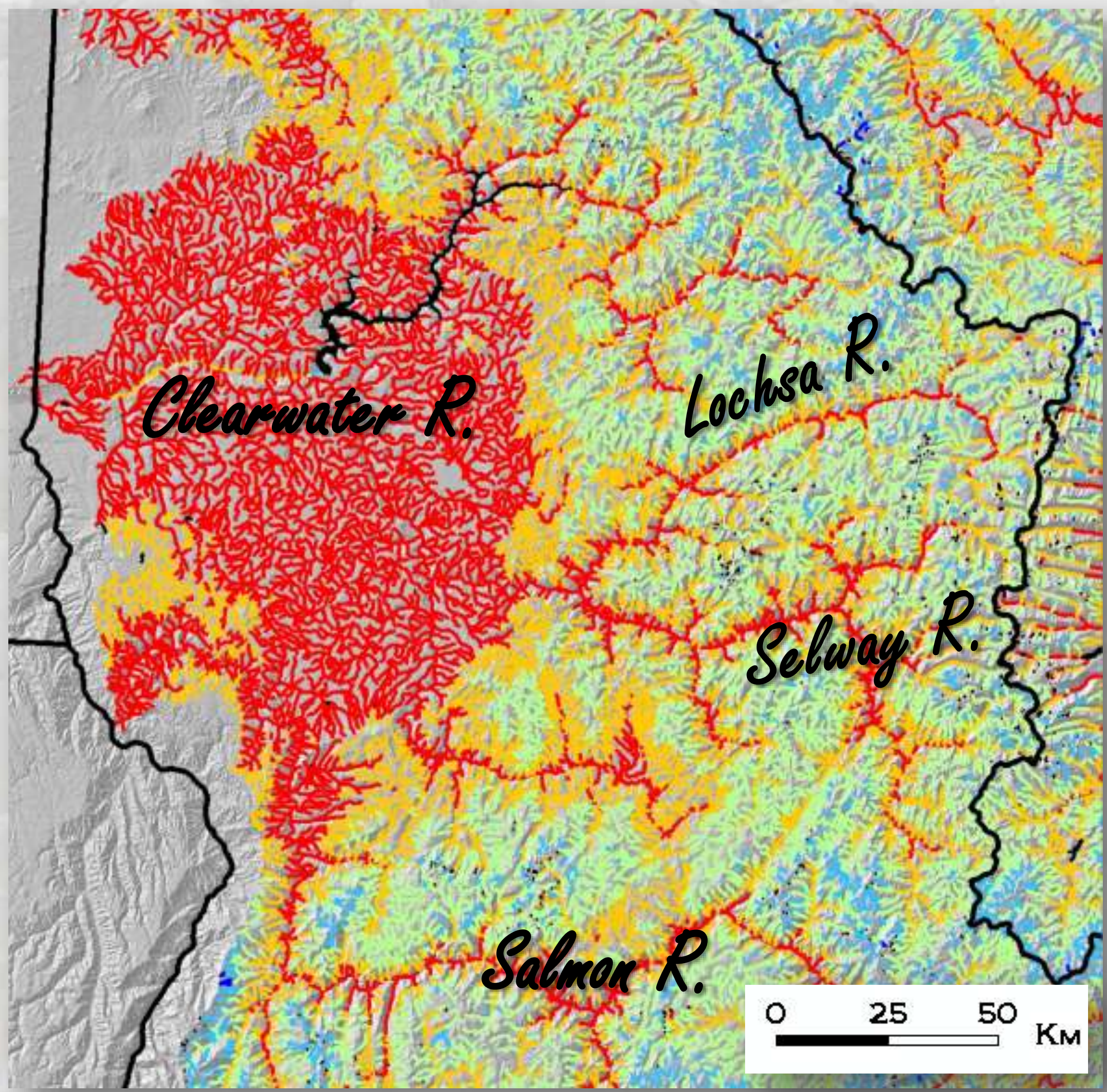
Temperature (C)

- 0.0 - 8.0
- 8.1 - 10.0
- 10.1 - 12.5
- 12.6 - 15.0
- > 15



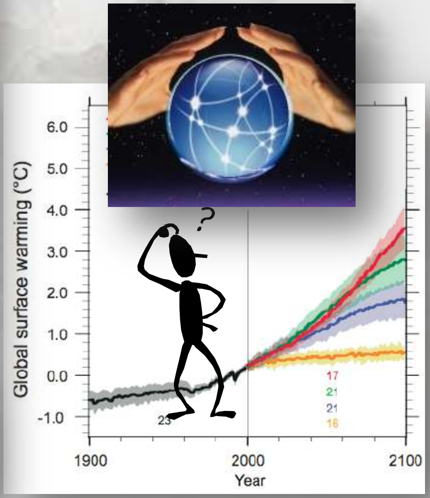
Clearwater-Nez Stream Temp Scenarios

+2.00°C Stream Temp (~2080s)



Temperature (C)

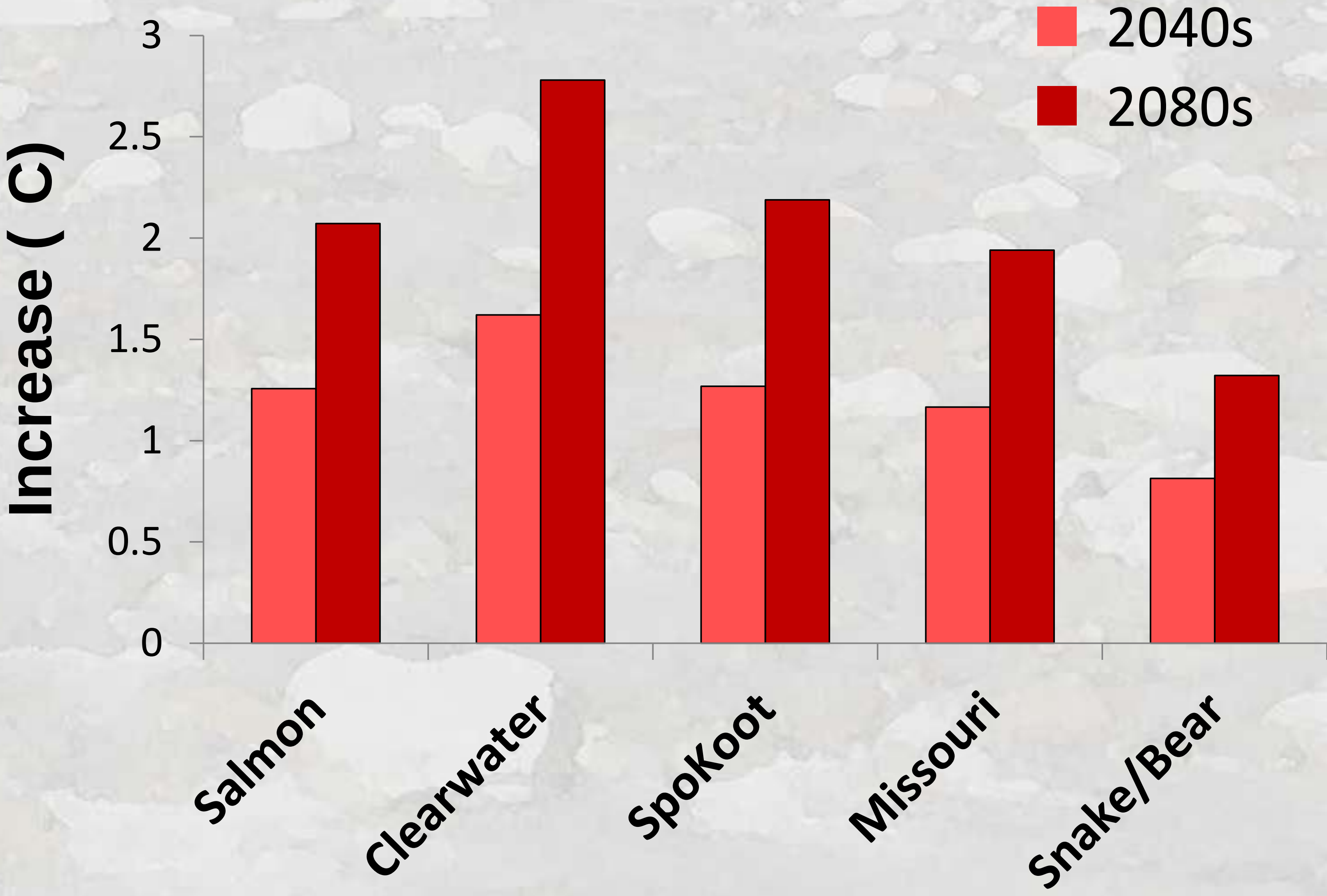
- 0.0 - 8.0
- 8.1 - 10.0
- 10.1 - 12.5
- 12.6 - 15.0
- > 15



Future Stream Temperature Increases

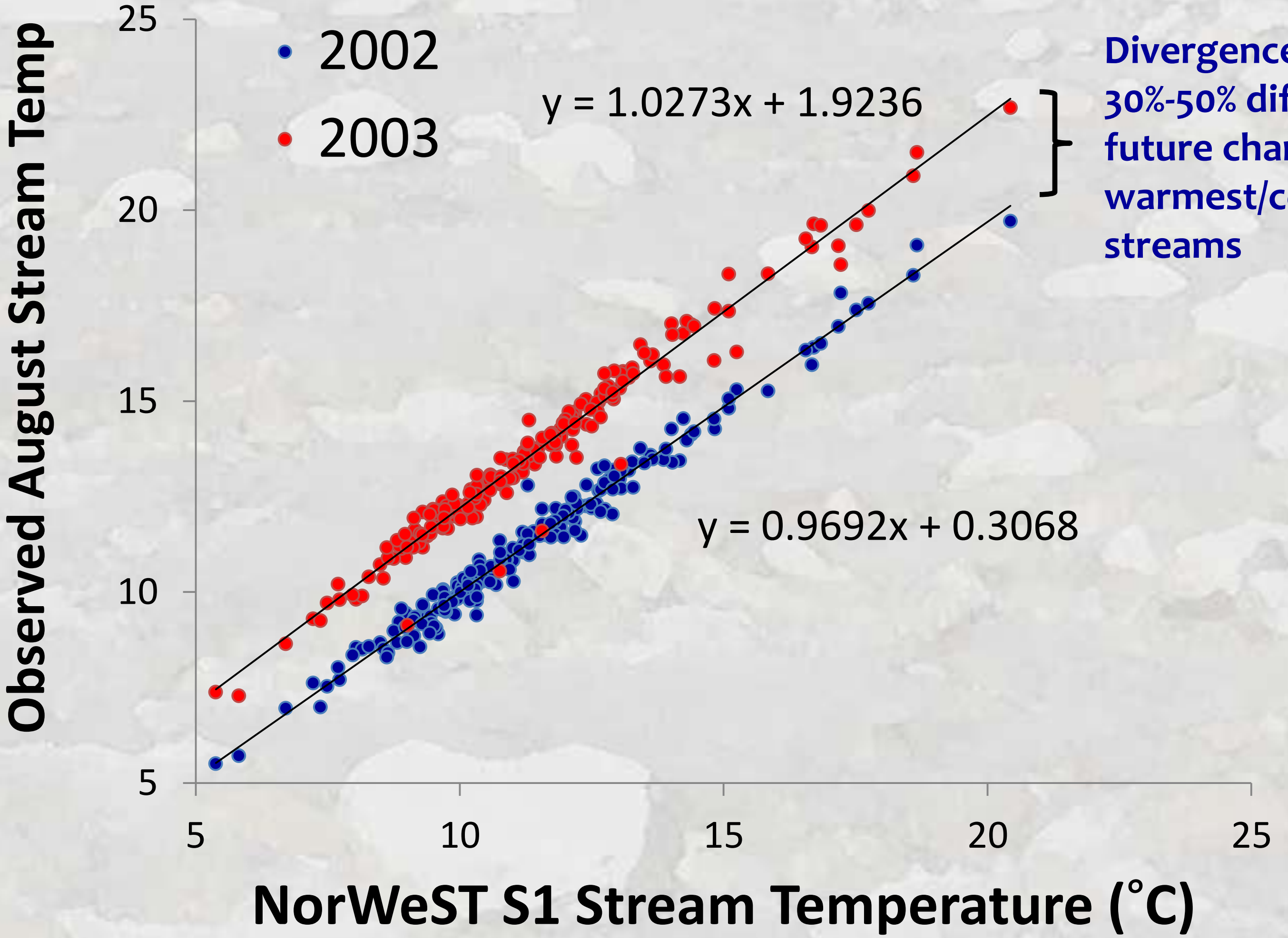
Scenario: A1B ensemble averages from CIG (delta-hybrid)

Baseline: 1980s (1970-1999) period



Differential Stream Temperature Warming

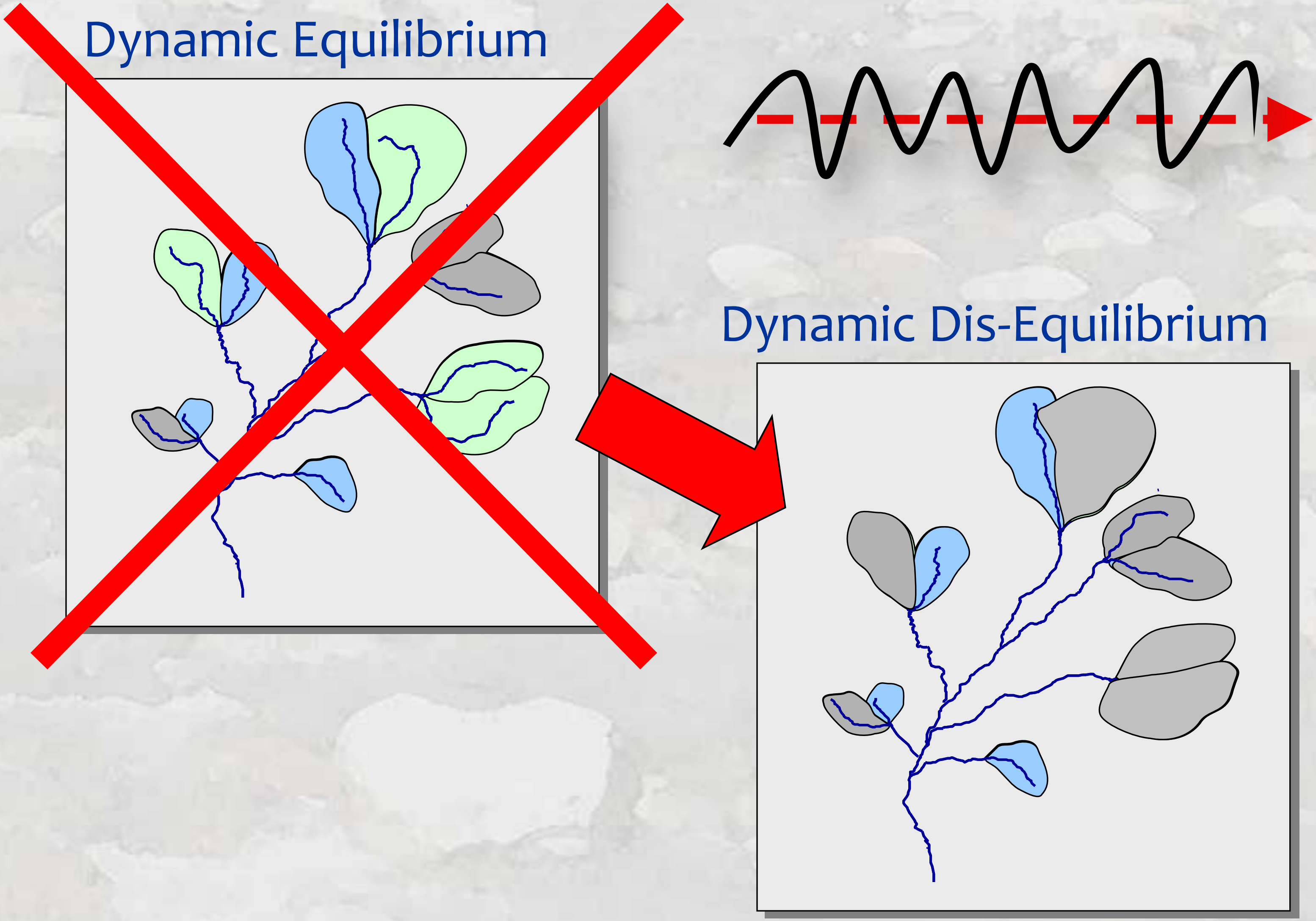
Cold streams warm slower (data are Clearwater monitoring data referenced to NorWeST predictions)



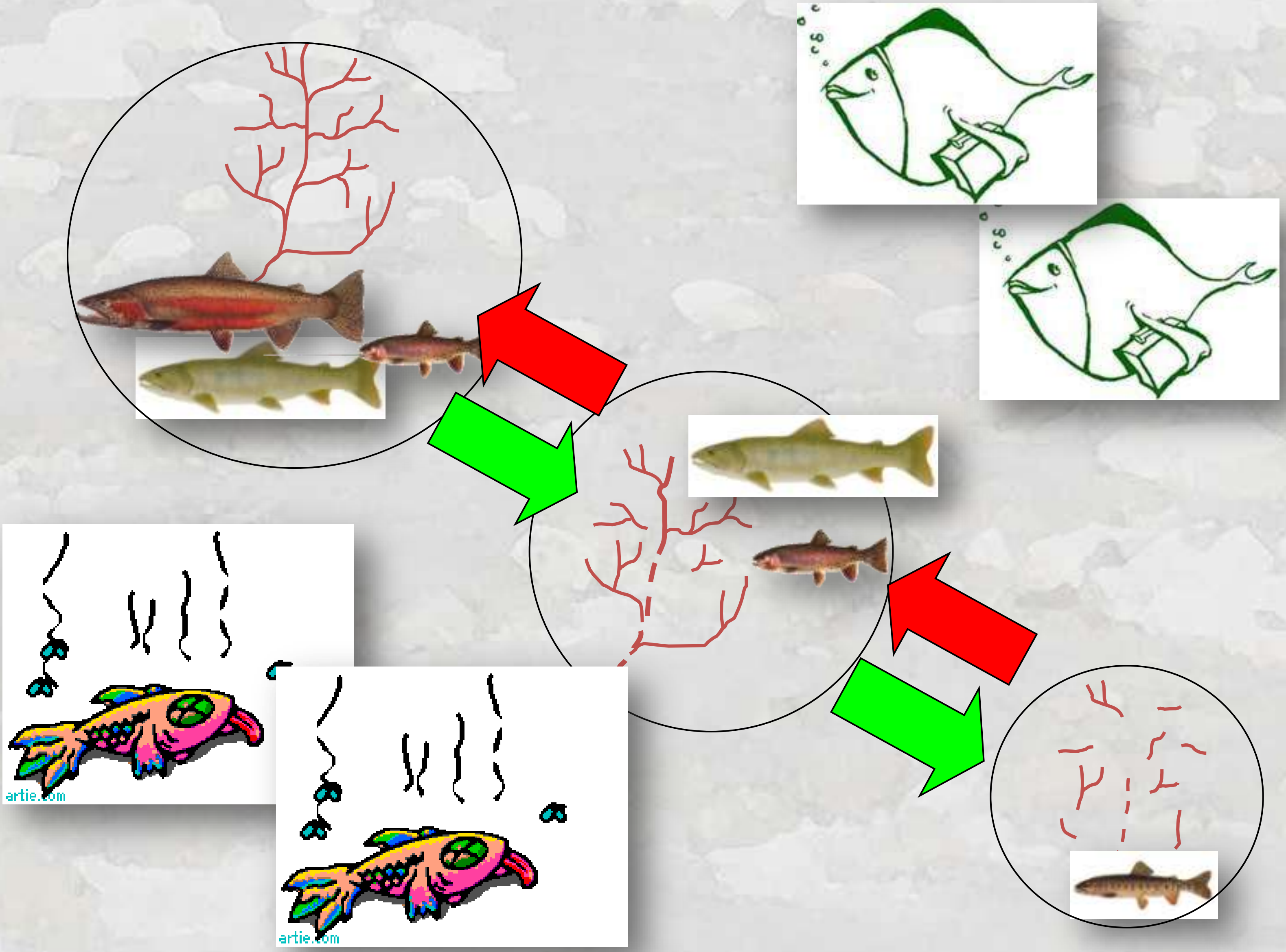
Divergence suggests 30%-50% difference in future changes between warmest/coldest streams

Luce et al. In Review. Water Resources Research

"Balance of Nature" Paradigm no Longer Valid

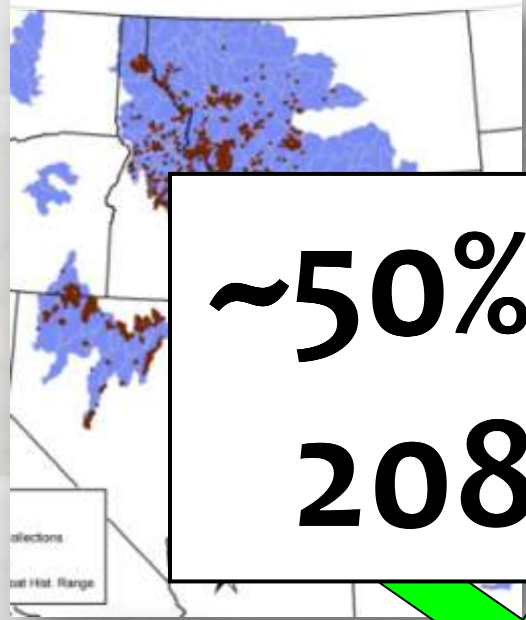


There Will be Winners & Losers

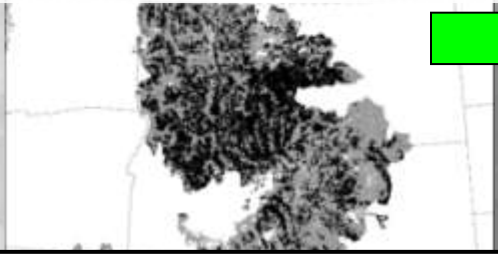


Western US Trout Climate Assessment

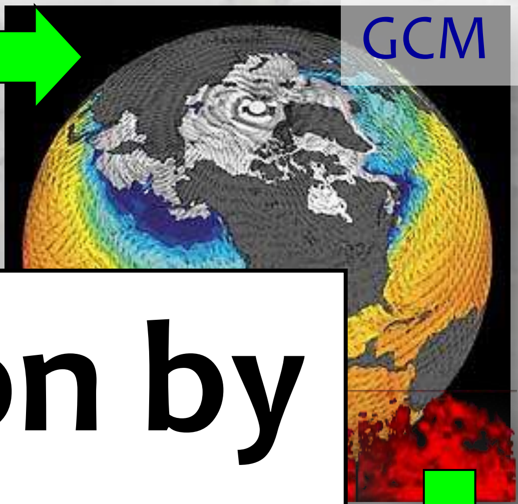
Fish survey database
~10,000 sites



Historic Distributions

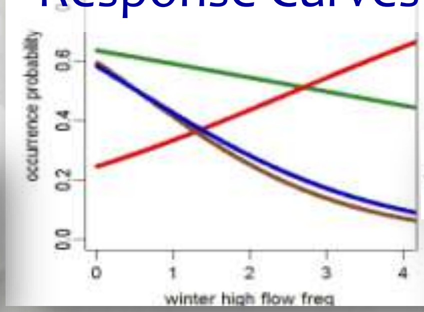


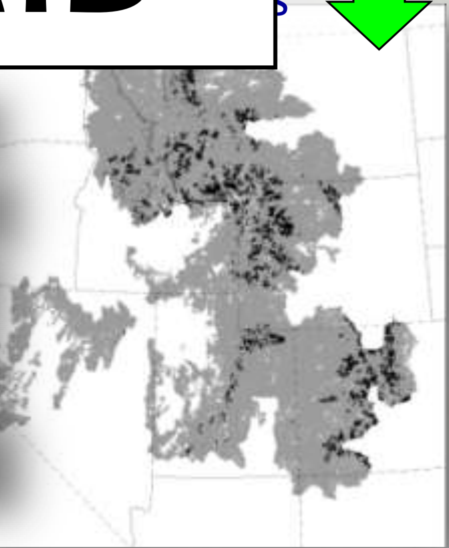
GCM



~50% reduction by 2080 under A1B

Habitat
Response Curves





TROUT UNLIMITED

National Fish and Wildlife Foundation

USGS science for a changing world

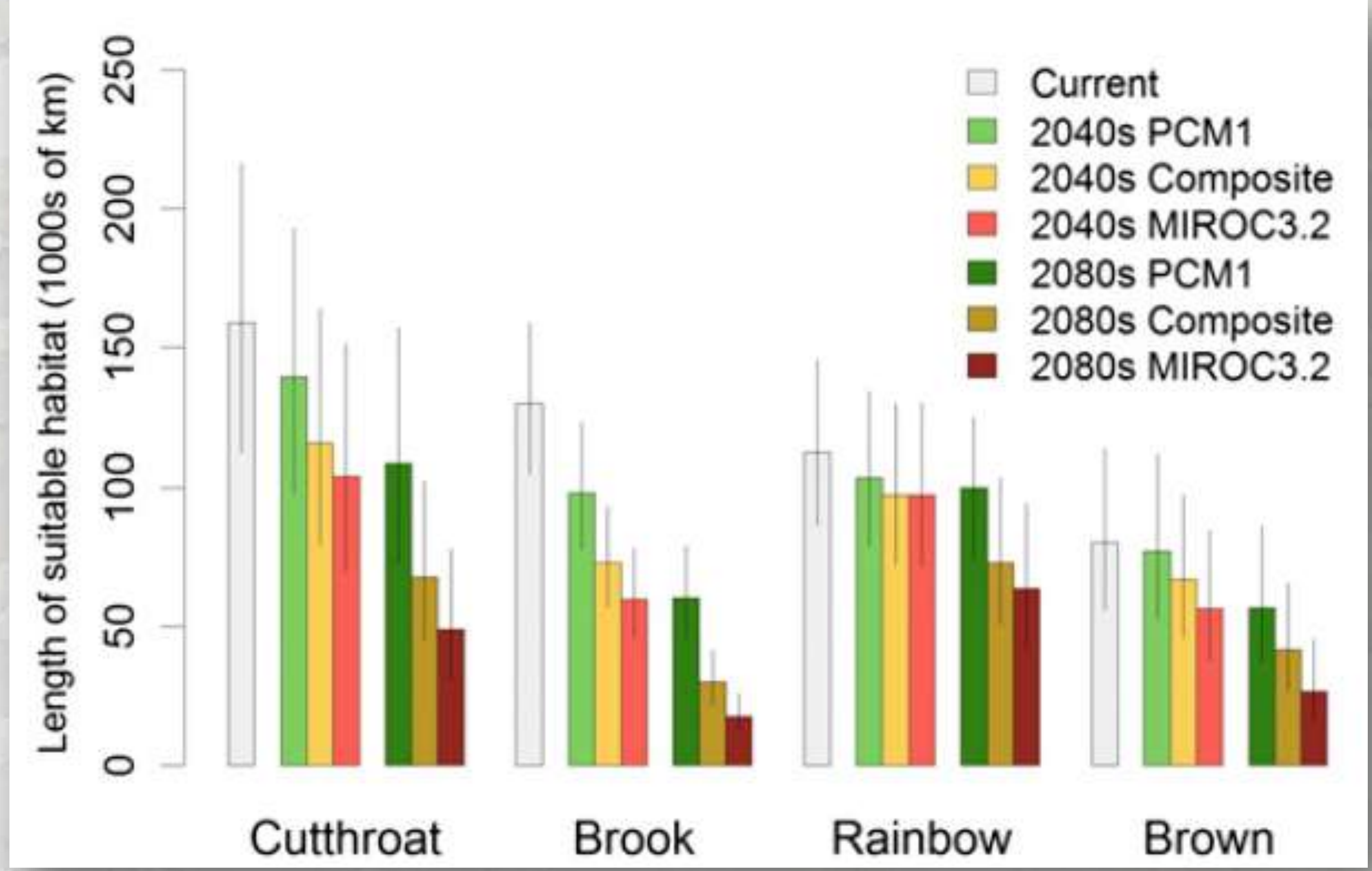
Colorado State University

Rocky Mountain Research Station

CLIMATE IMPACTS GROUP

Wenger et al. 2011. *PNAS* **108:**14175-14180

Species Vary in Climate Response



Predicted reduction (2080) =

57%

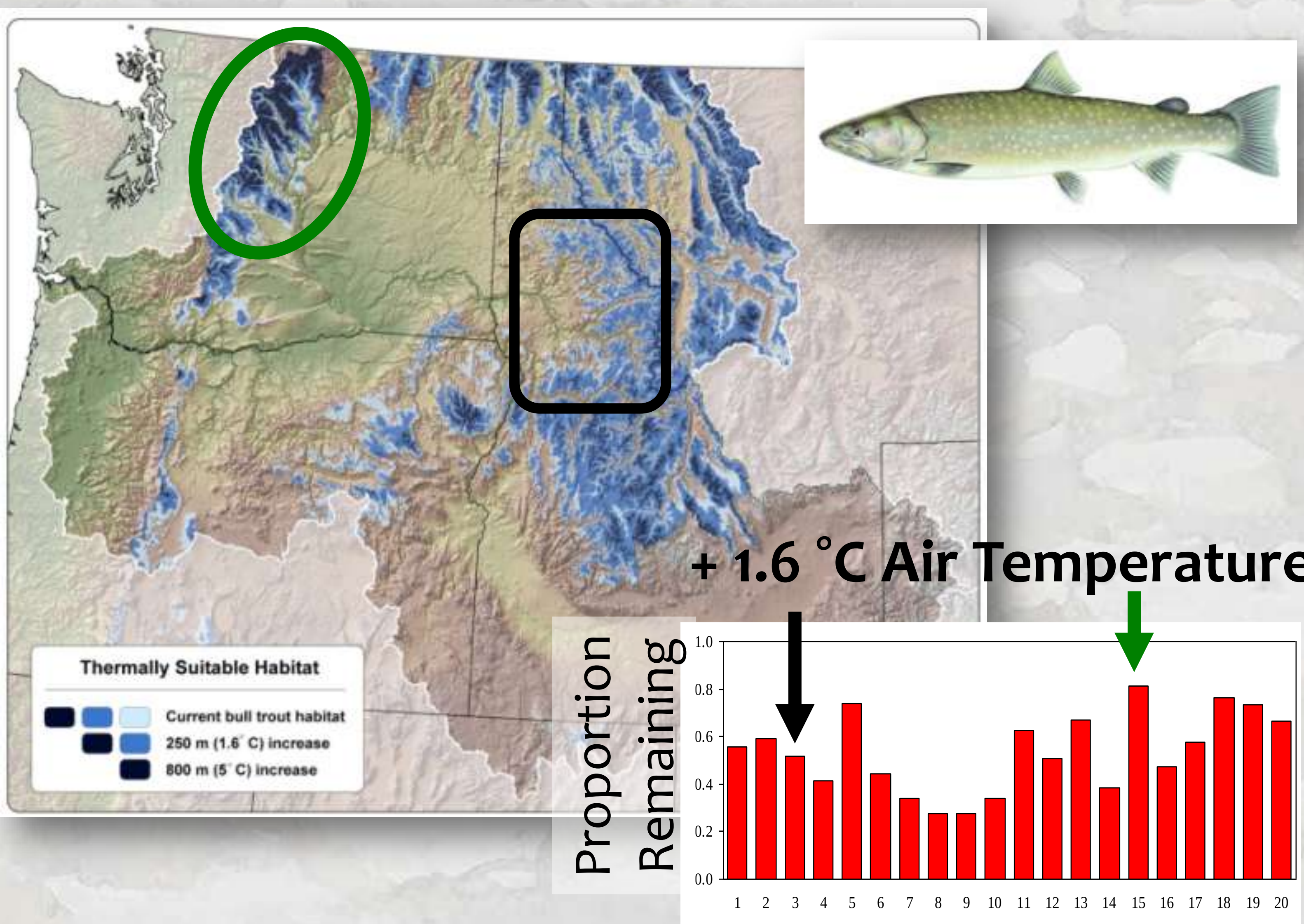
77%

35%

48%

Wenger et al. 2011. *PNAS* **108:**14175-14180

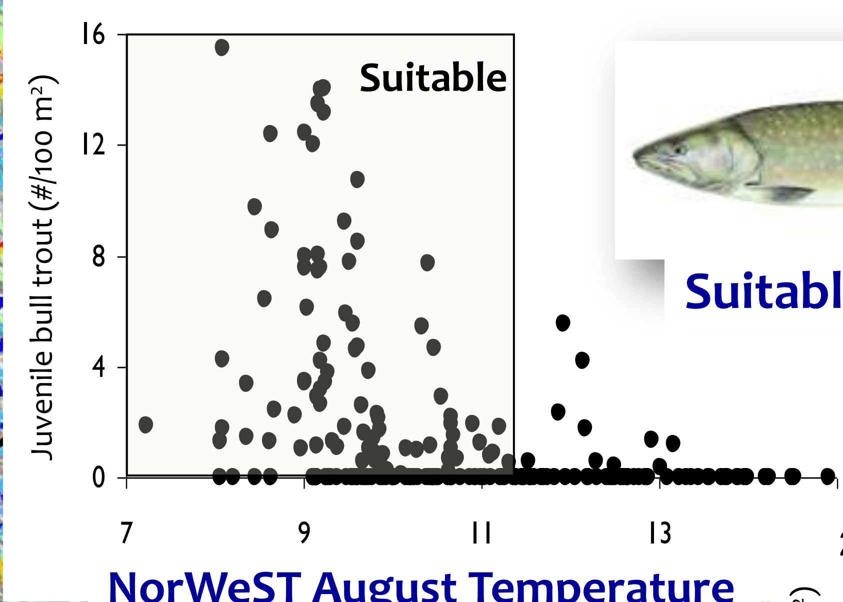
Spatial Variation in Habitat Loss



Rieman et al. 2007. *TAFS* **136**:1552-1565

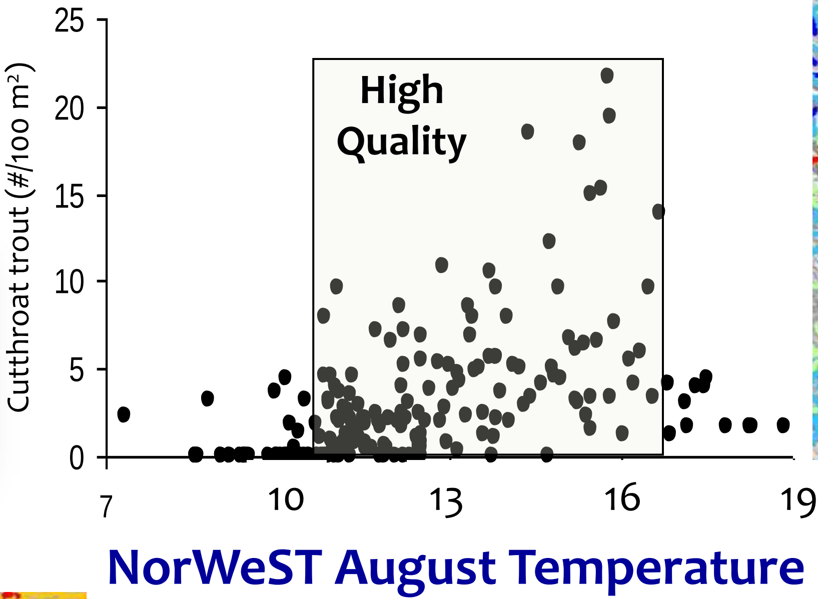
NorWeST Scenarios Increase Accuracy

Species-Specific Thermal Criteria



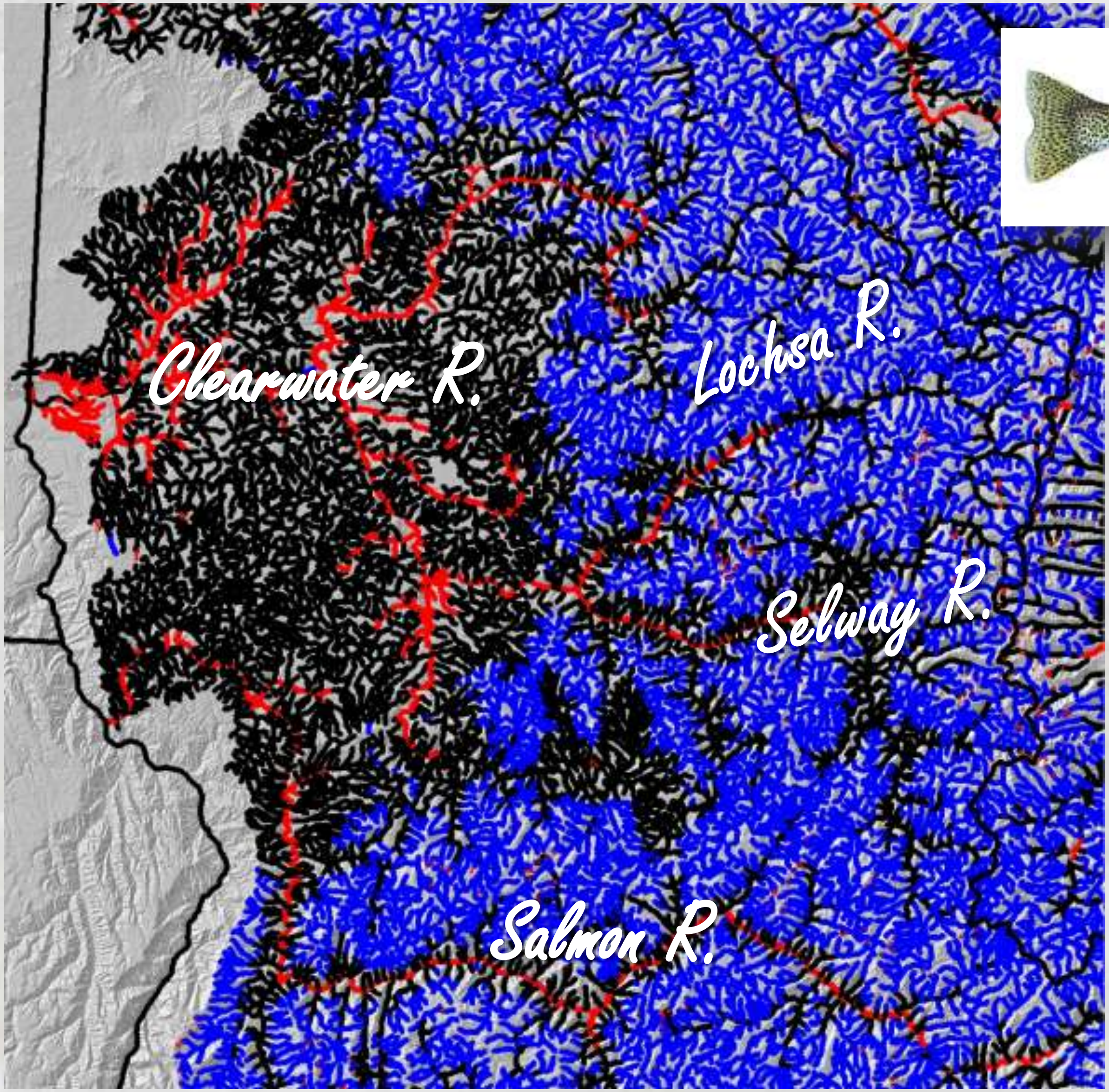
Suitable habitat < 11.2°C

High-quality habitat = 11.0-17.0°C



Climate Effects on Cutthroat Thermal Habitat

Historic (1993-2011 Average August)



⬛ Suitable

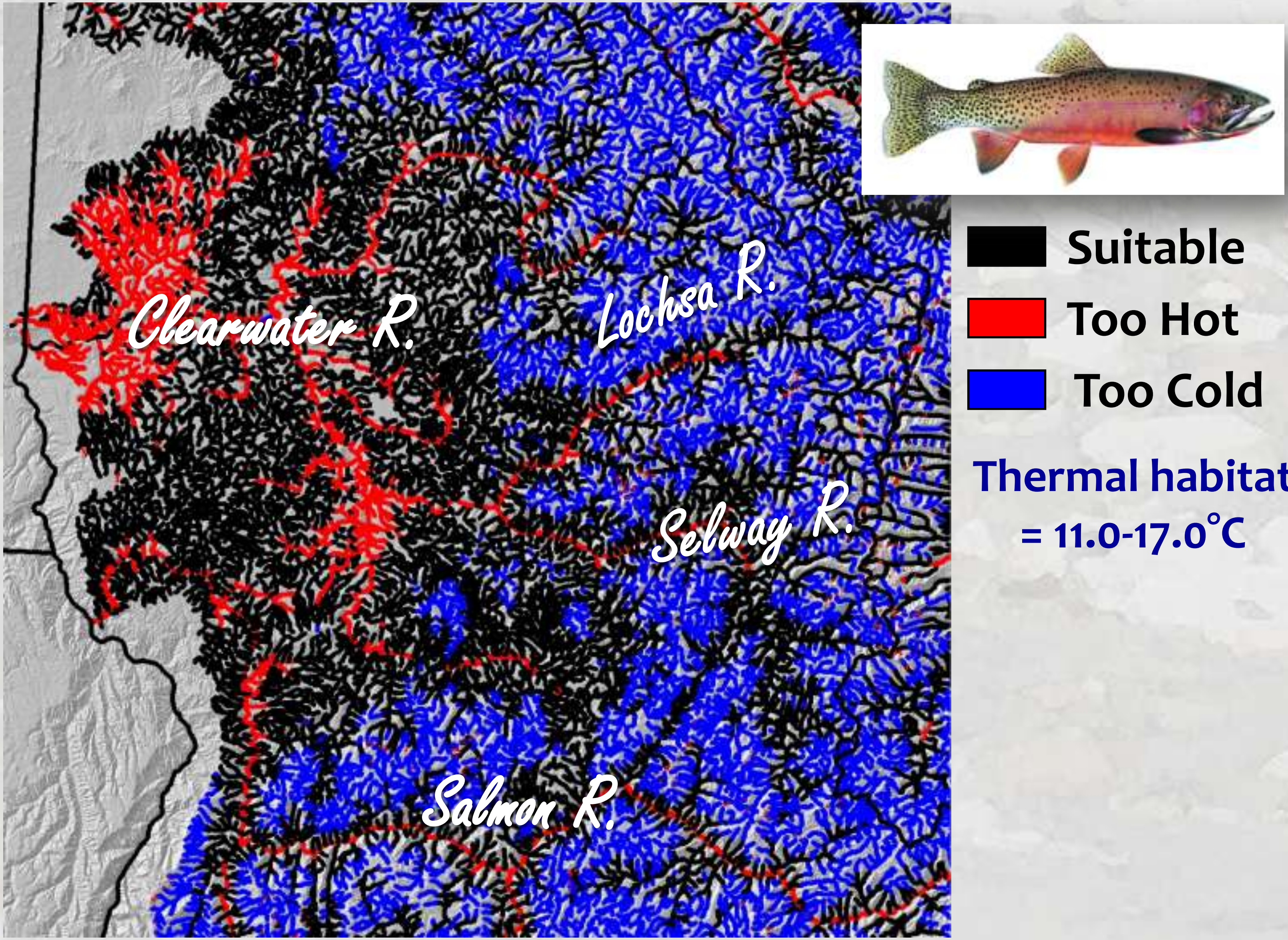
🟥 Too Hot

🟦 Too Cold

Thermal habitat = 11.0-17.0°C

Climate Effects on Cutthroat Thermal Habitat

+1.00°C Stream Temp (~2040s)



⬛ Suitable

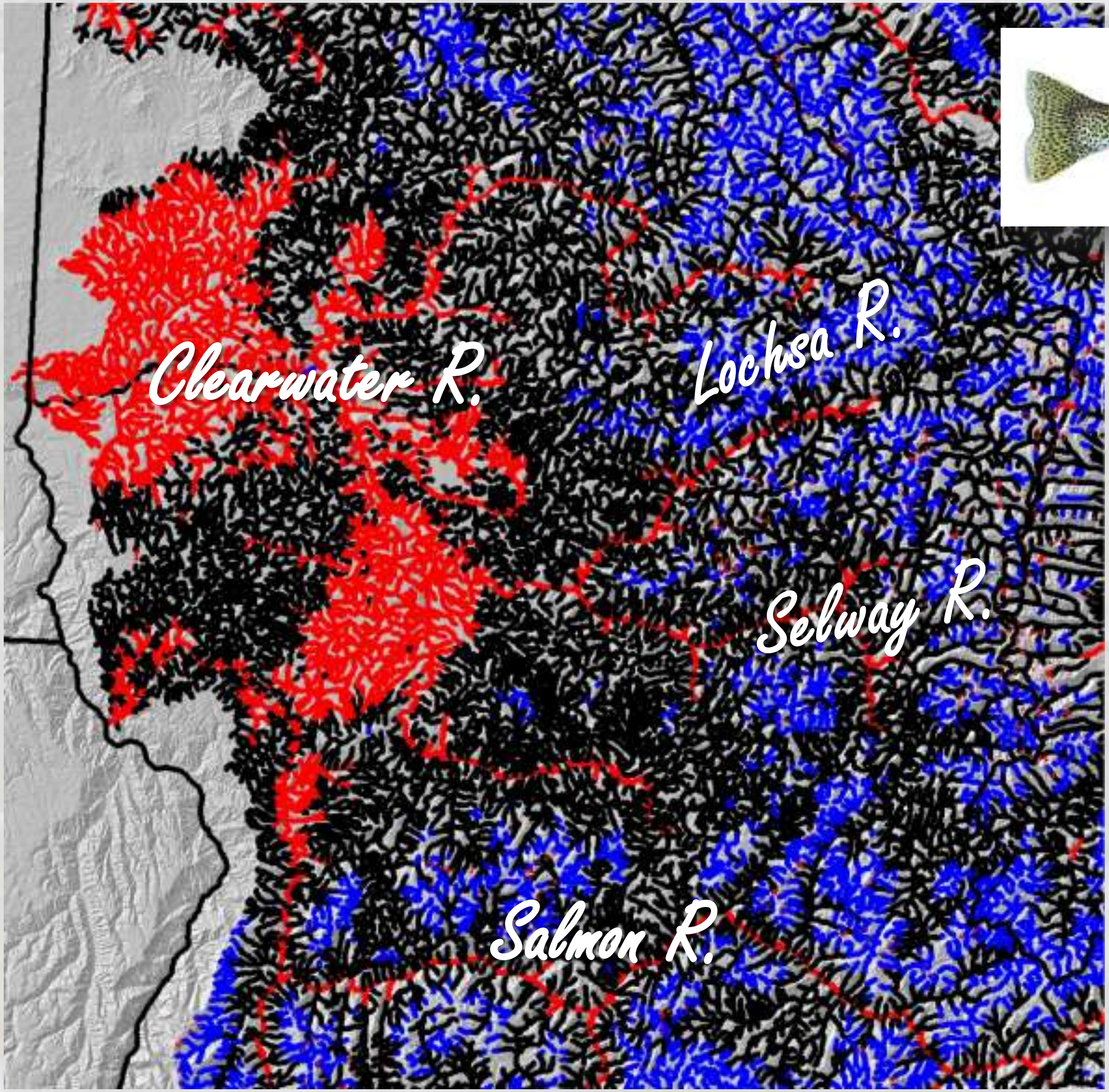
🟥 Too Hot

🟦 Too Cold

Thermal habitat = 11.0-17.0°C

Climate Effects on Cutthroat Thermal Habitat

+2.00°C Stream Temp (~2080s)



⬛ Suitable

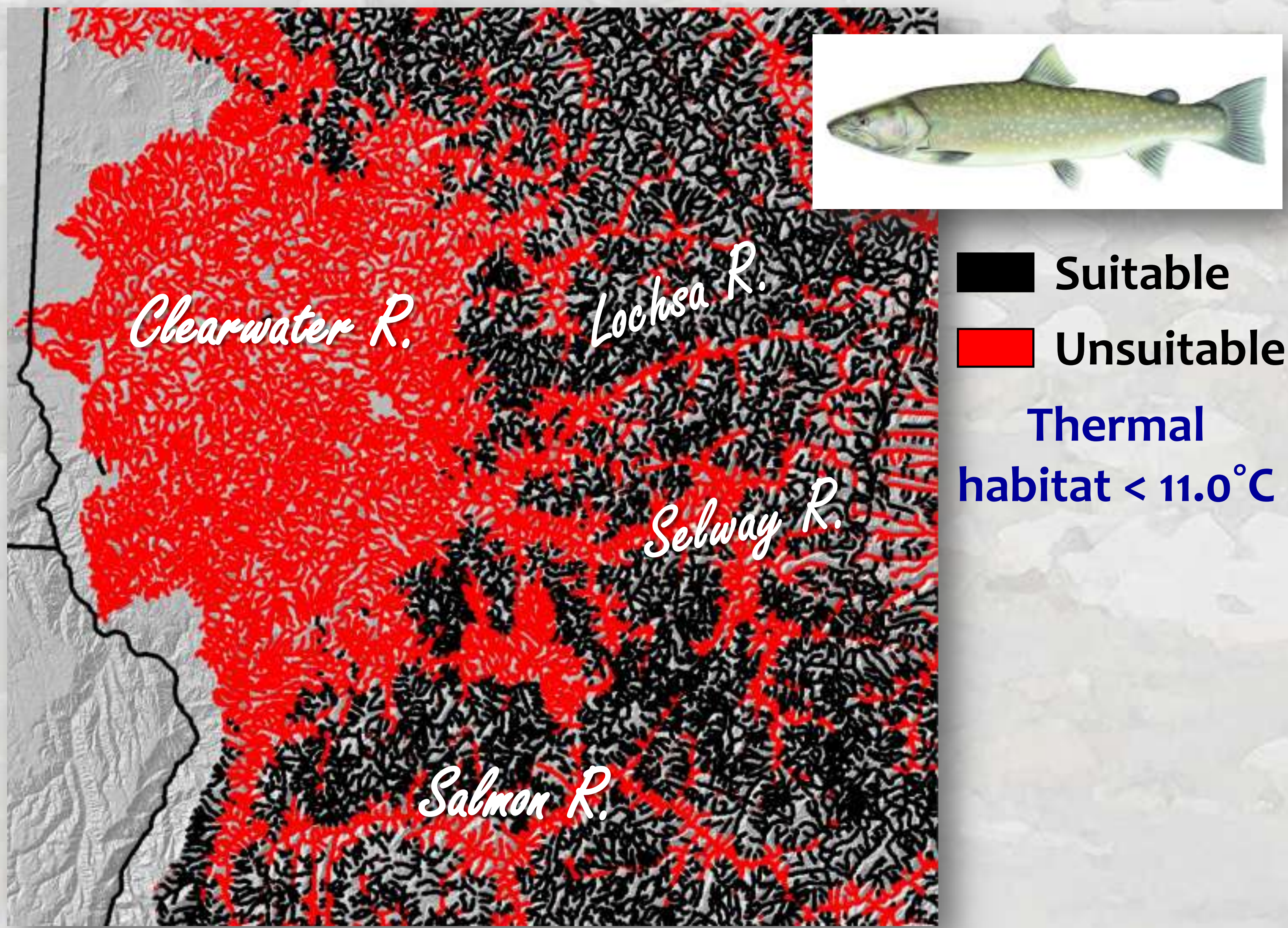
🟥 Too Hot

🟦 Too Cold

Thermal habitat
= 11.0-17.0°C

Climate Effects on Bull Trout Thermal Habitat

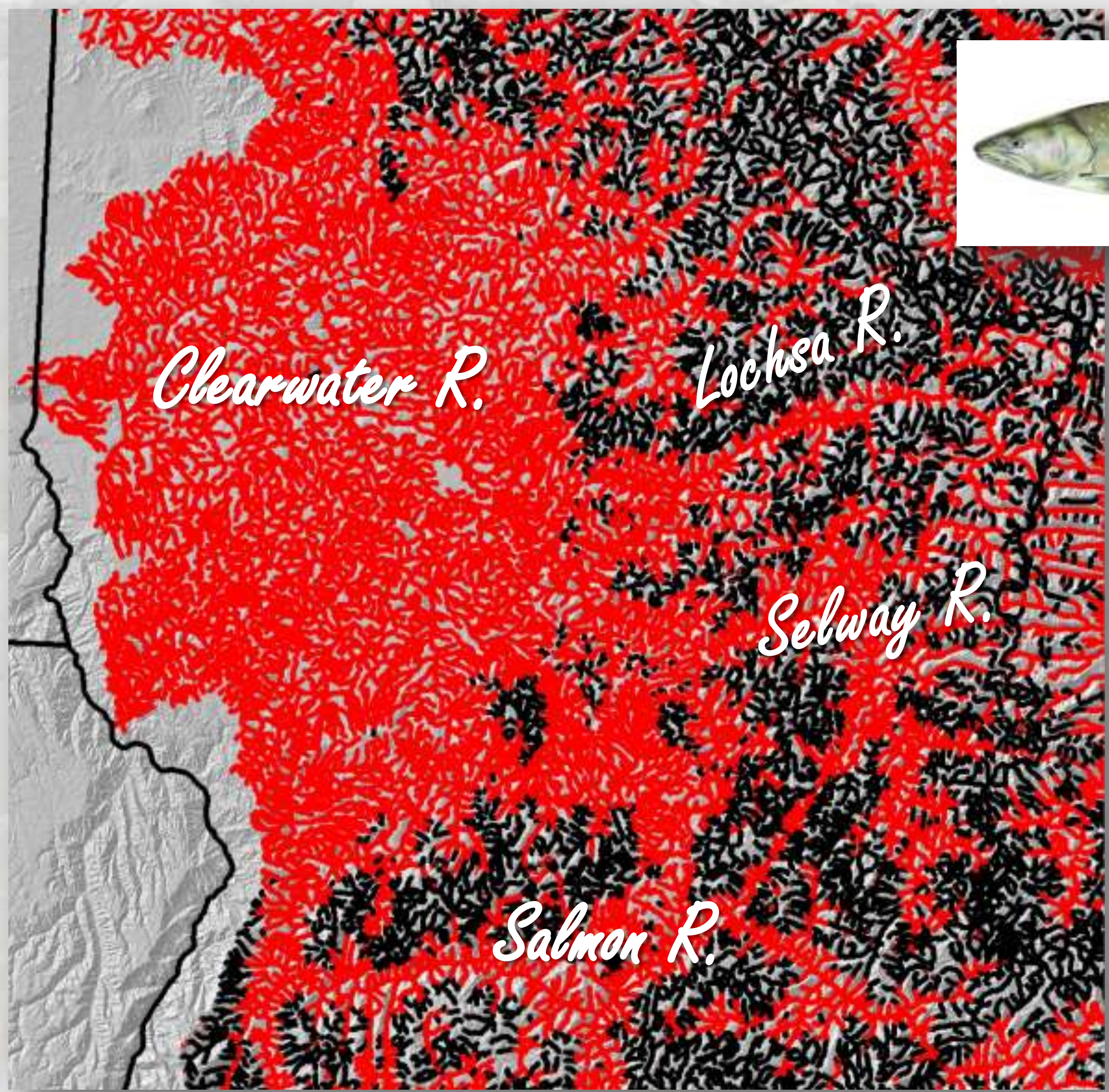
Historic (1993-2011 Average August)



Thermal habitat < 11.0°C

Climate Effects on Bull Trout Thermal Habitat

+1.00°C Stream Temp (~2040s)



⬛ Suitable

🟥 Unsuitable

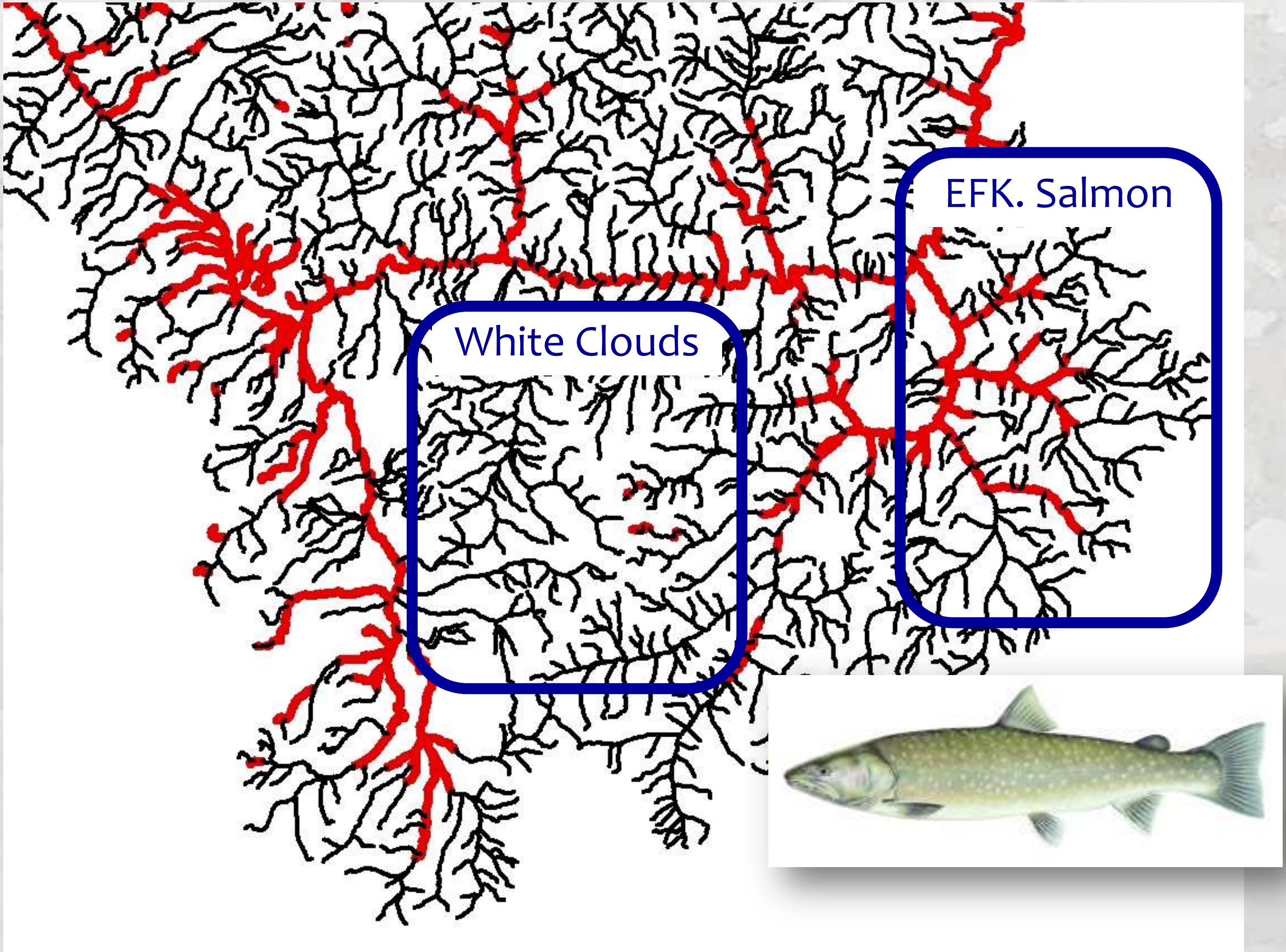
Thermal habitat < 11.0°C

Climate Effects on Bull Trout Thermal Habitat

+2.00°C Stream Temp (~2080s)

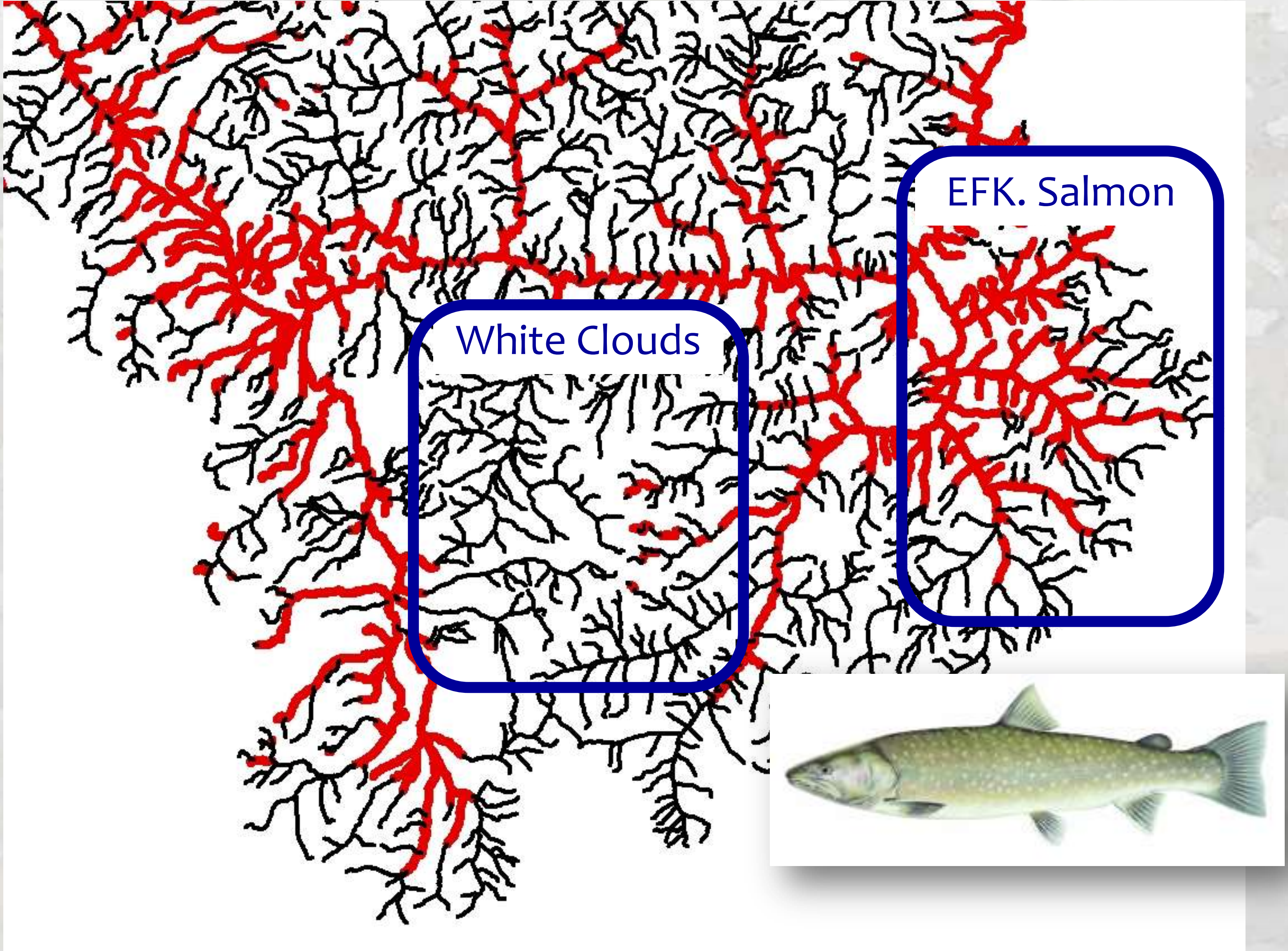
Spatial Variation in Habitat Loss

Historical scenario



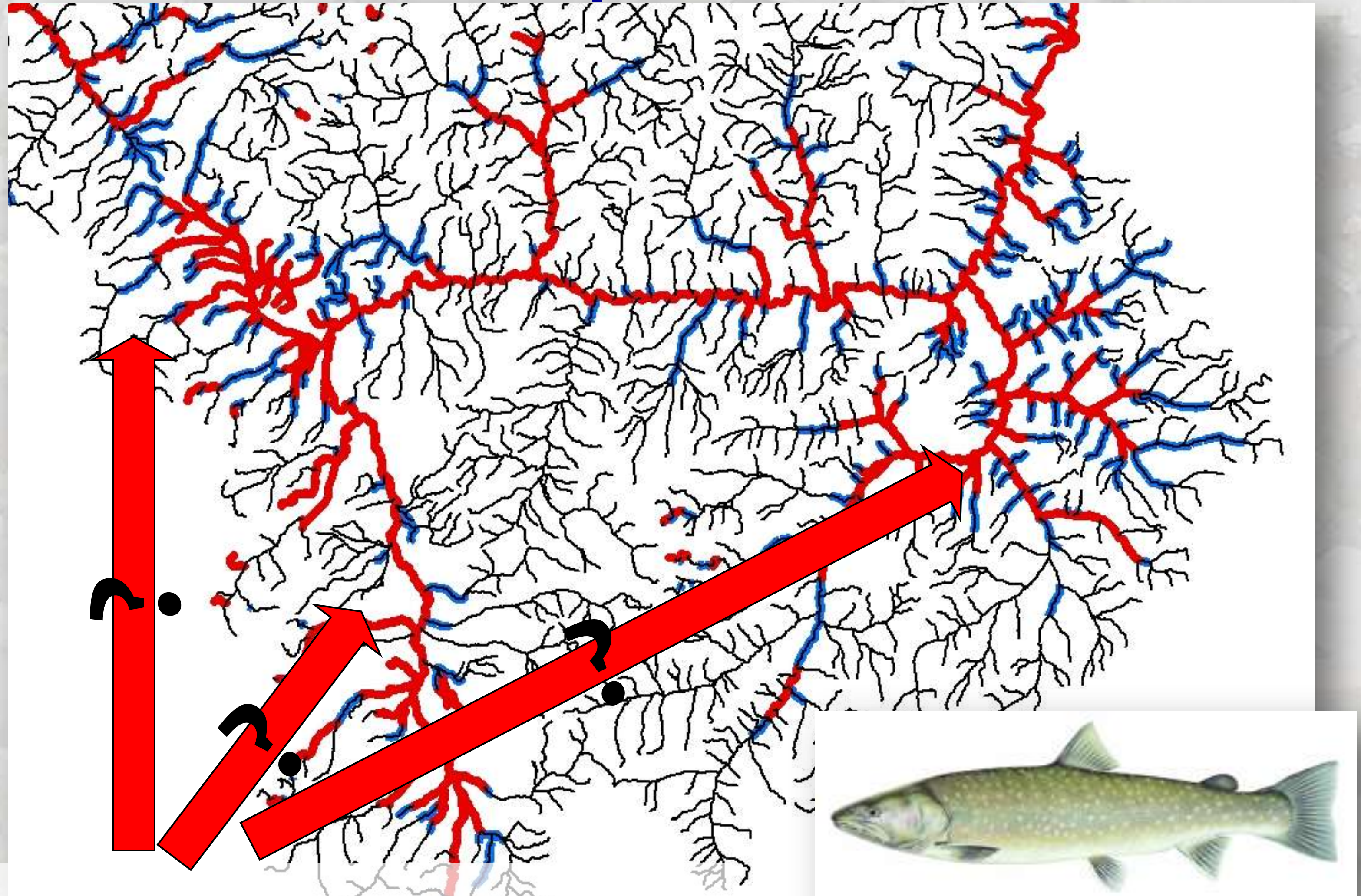
Spatial Variation in Habitat Loss

+1°C stream temperature scenario



Difference Map Shows Vulnerable Habitats

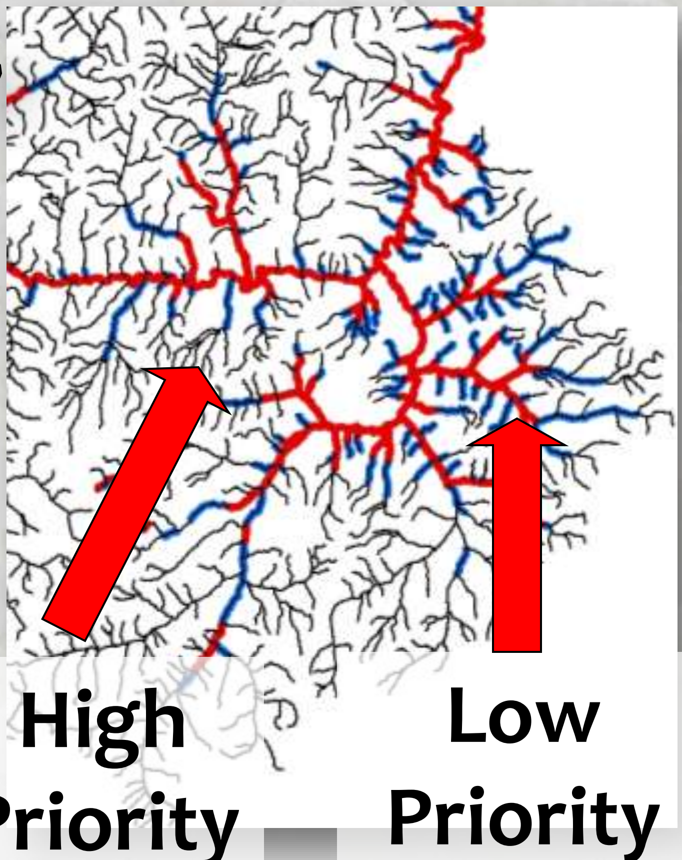
+1°C stream temperature scenario



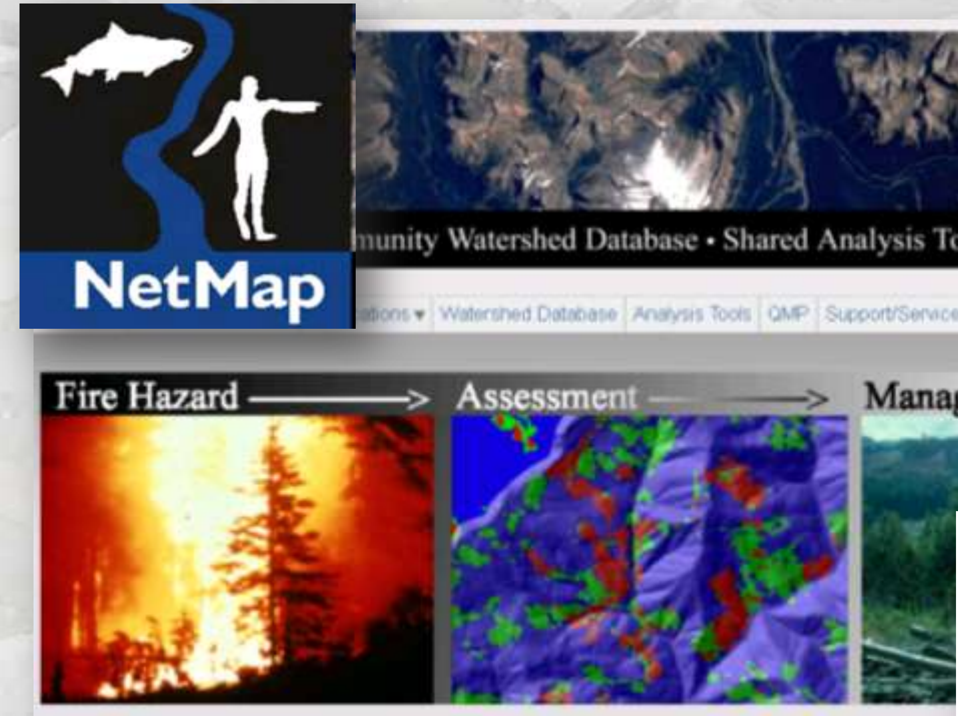
Where to invest?

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…



Additional Prioritization Tools…

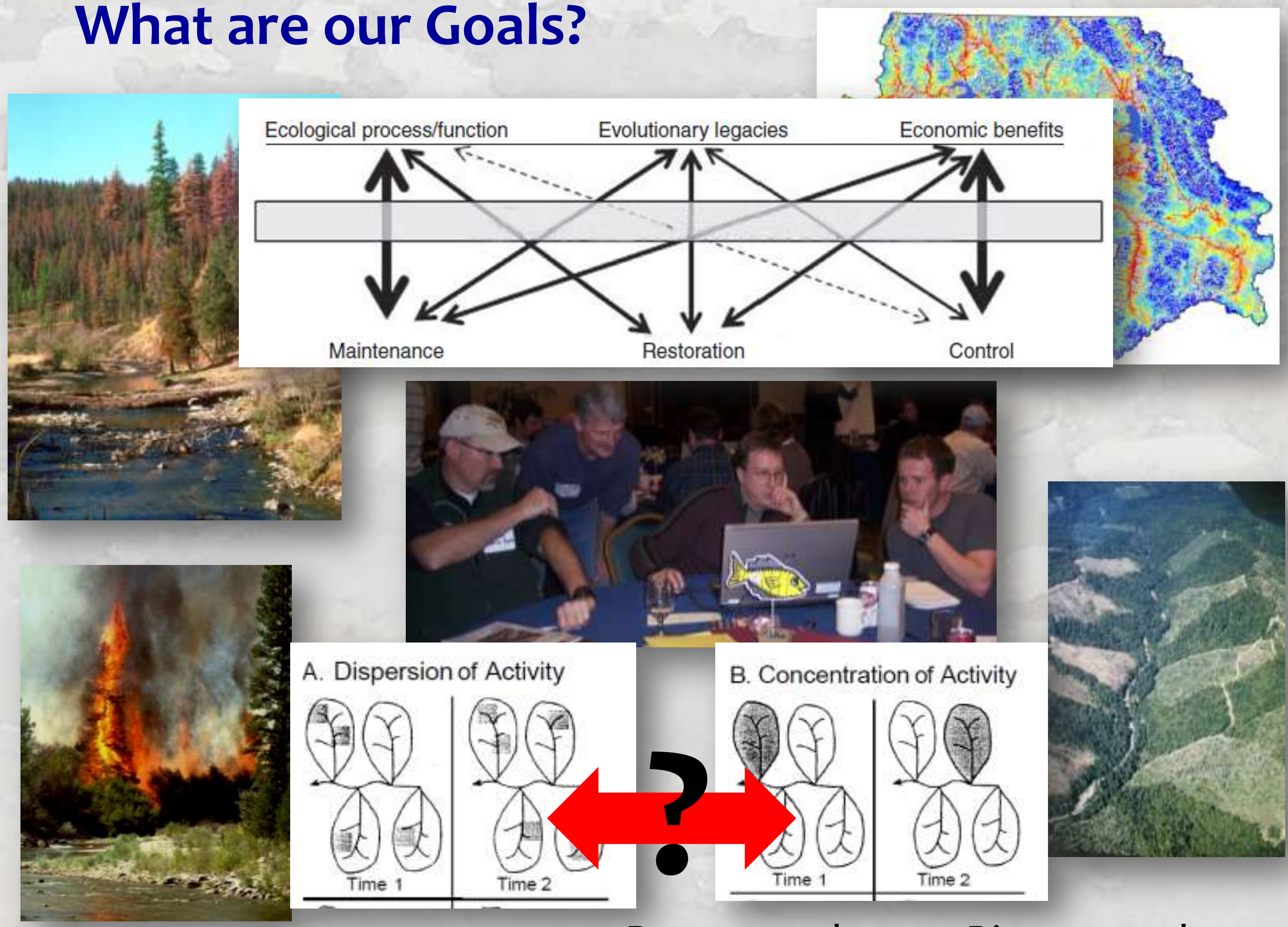


The Geomorphic Road Analysis and Inventory Package (GRAIP)

How do we Bring it All Together?

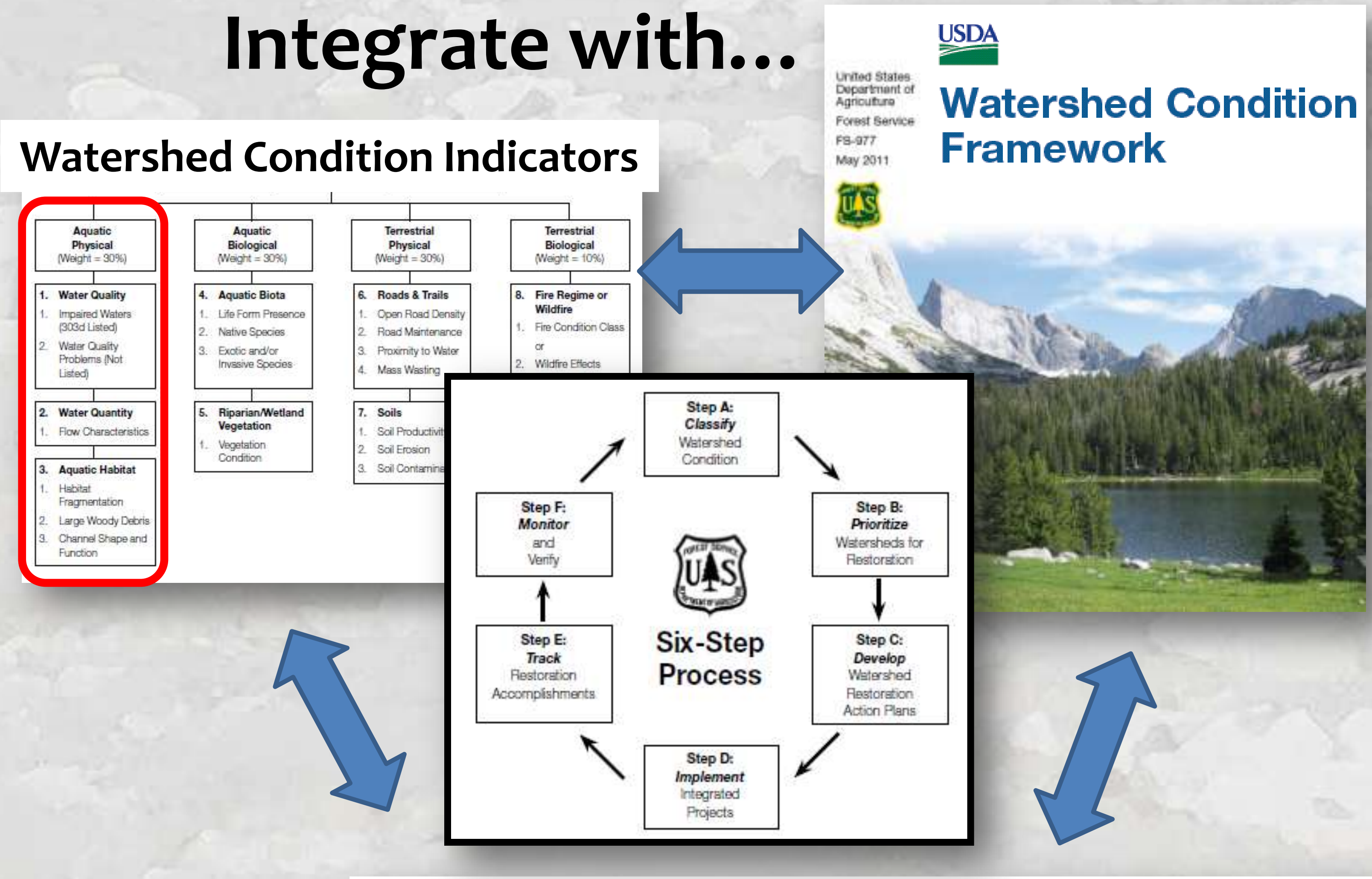
What is “Optimal” Management?

What are our Goals?



Reeves et al. 1995; Rieman et al. 2010.

Integrate with…



Watershed Condition Indicators

Aquatic Physical (Weight = 30%)	Aquatic Biological (Weight = 30%)	Terrestrial Physical (Weight = 30%)	Terrestrial Biological (Weight = 10%)
1. Water Quality 1. Impaired Waters (303d Listed) 2. Water Quality Problems (Not Listed)	**4. Aquatic Biota** 1. Life Form Presence 2. Native Species 3. Exotic and/or Invasive Species	**6. Roads & Trails** 1. Open Road Density 2. Road Maintenance 3. Proximity to Water 4. Mass Wasting	**8. Fire Regime or Wildfire** 1. Fire Condition Class or 2. Wildfire Effects
2. Water Quantity 1. Flow Characteristics	**5. Riparian/Wetland Vegetation** 1. Vegetation Condition	**7. Soils** 1. Soil Productivit 2. Soil Erosion 3. Soil Contamina	
3. Aquatic Habitat 1. Habitat Fragmentation 2. Large Woody Debris 3. Channel Shape and Function			

USDA

United States Department of Agriculture

Forest Service

FS-977

May 2011

Watershed Condition Framework

Step A: *Classify* Watershed Condition

Step B: *Prioritize* Watersheds for Restoration

Step C: *Develop* Watershed Restoration Action Plans

Step D: *Implement* Integrated Projects

Step E: *Track* Restoration Accomplishments

Step F: *Monitor* and Verify

Six-Step Process

Forest Plan Revisions

USDA

United States Department of Agriculture

Forest Service

Northern Region

March 2007

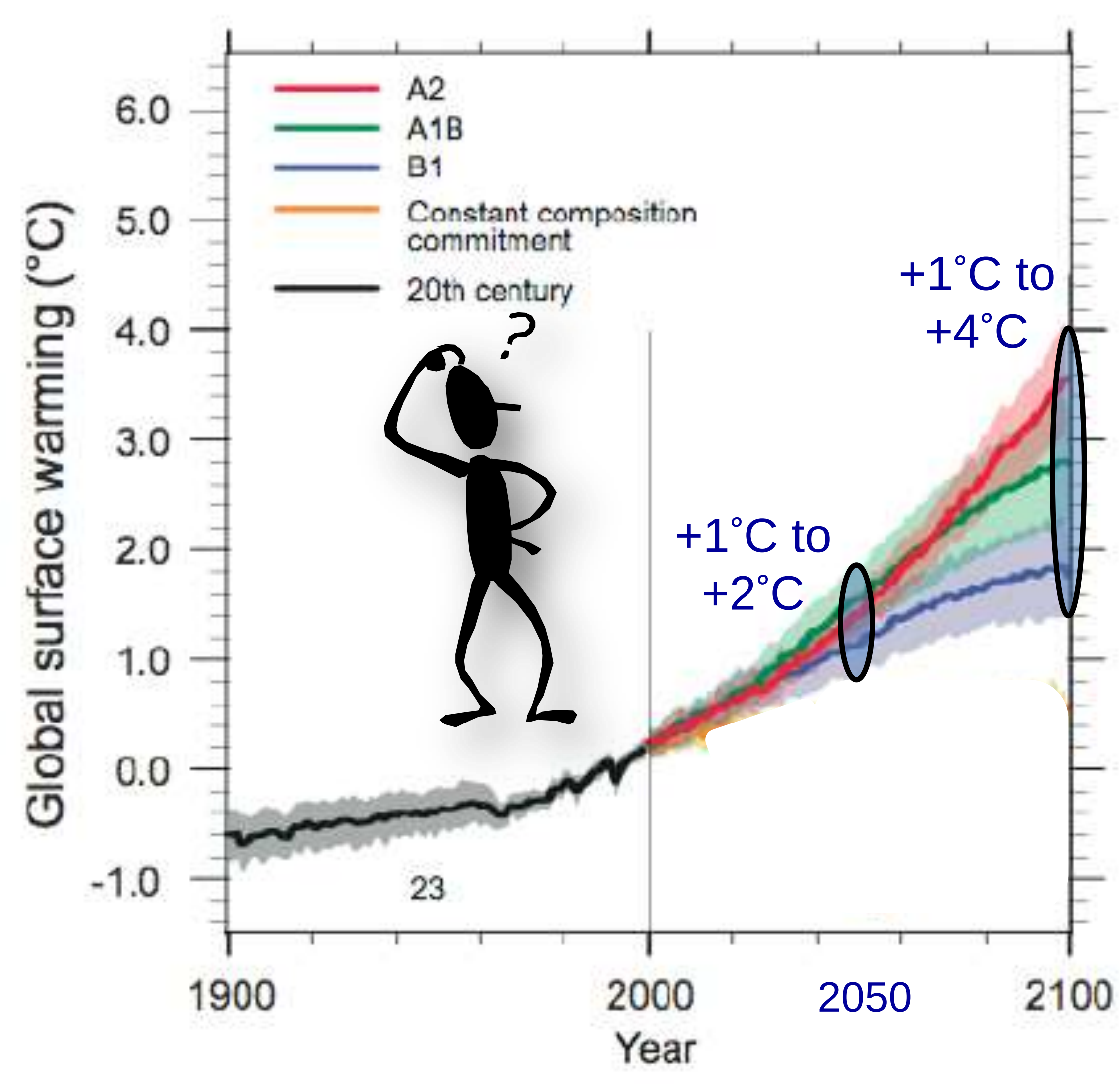
Proposed

Land Management Plan

Clearwater National Forest

Significant Unknown:

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

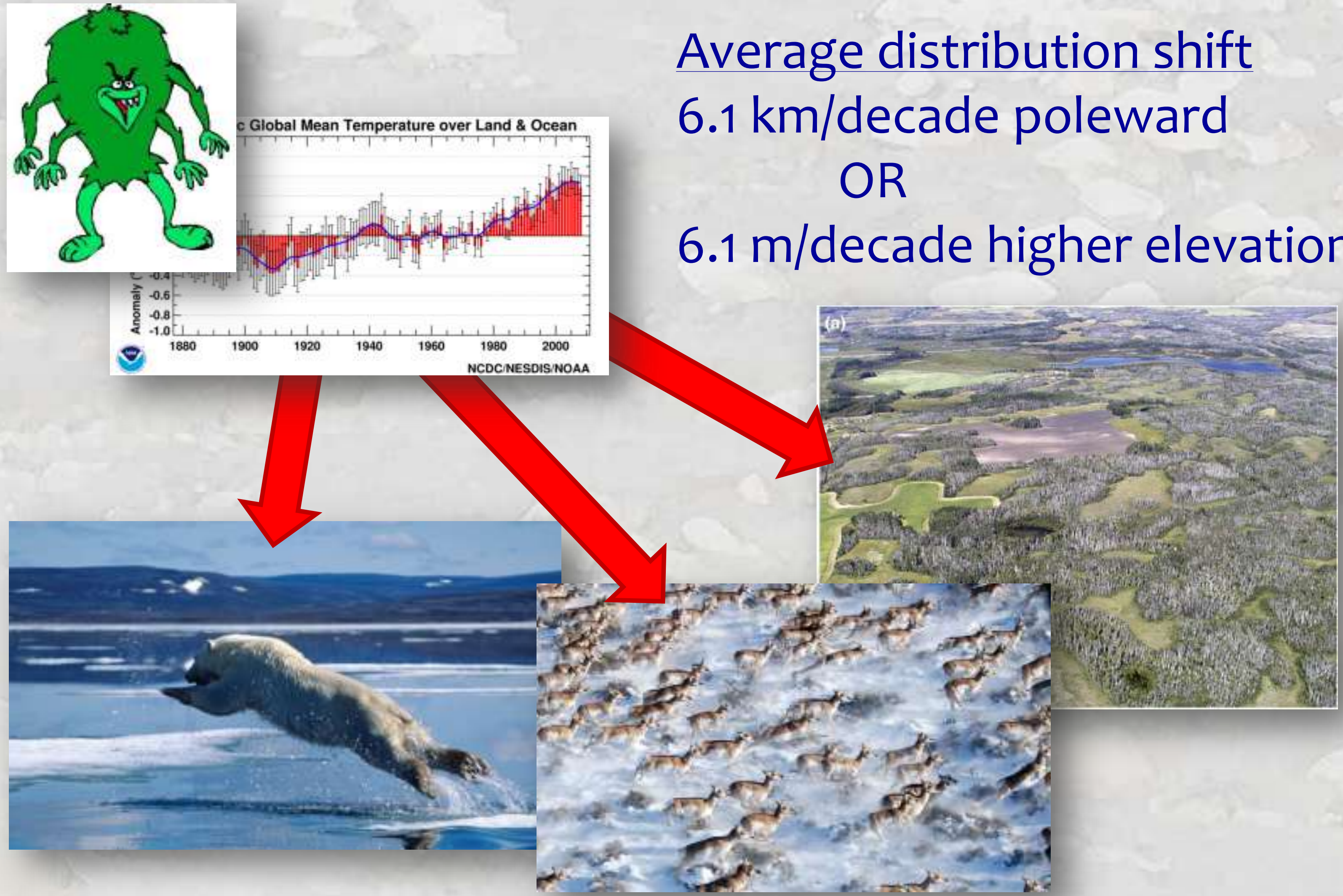


A2?
A1B?
B1?

IPCC 2007

The Clock is Ticking…

Distribution Shifts Already in Many Species



Average distribution shift

6.1 km/decade poleward

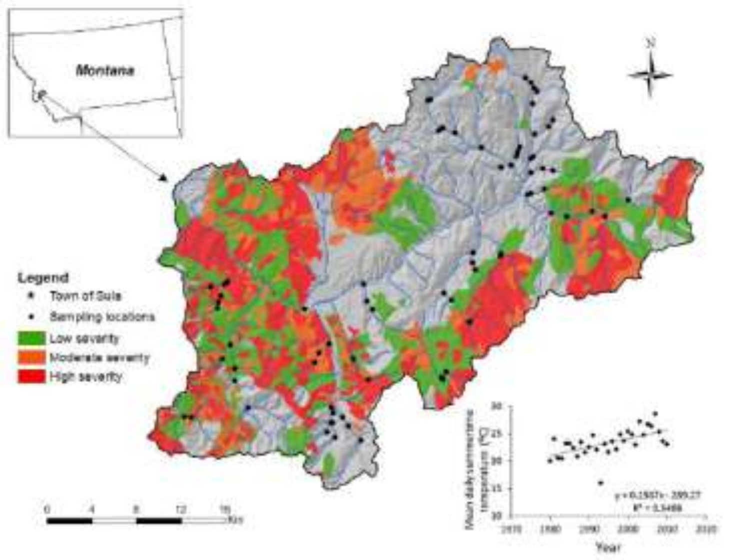
OR

6.1 m/decade higher elevation

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

Distribution Shifts in Montana Bull Trout Populations

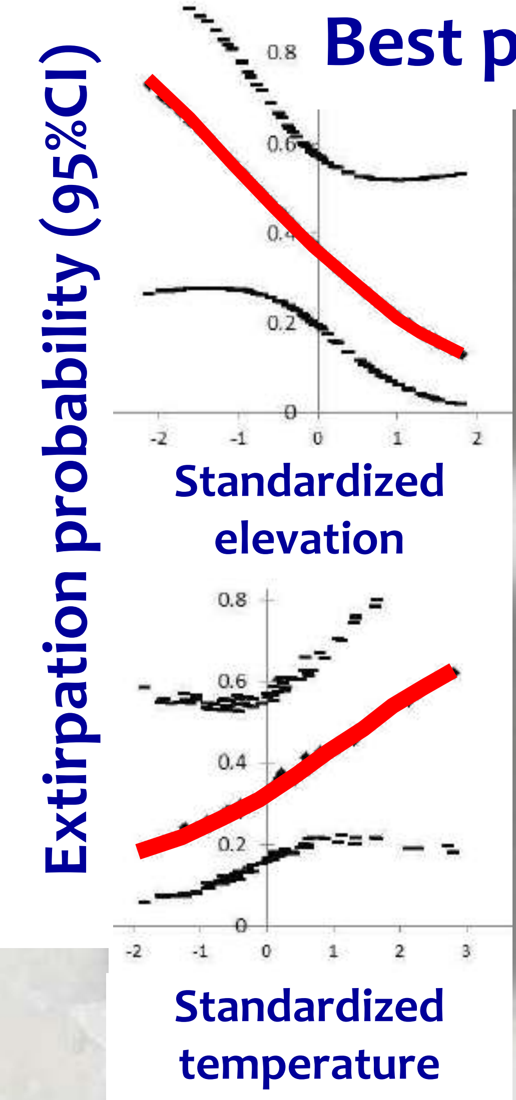
- Resurveyed Rich et al. 2003 sites 20 years later
- 77 sites, 500 m in length
- Modeled extirpations/colonizations accounting for detection efficiency

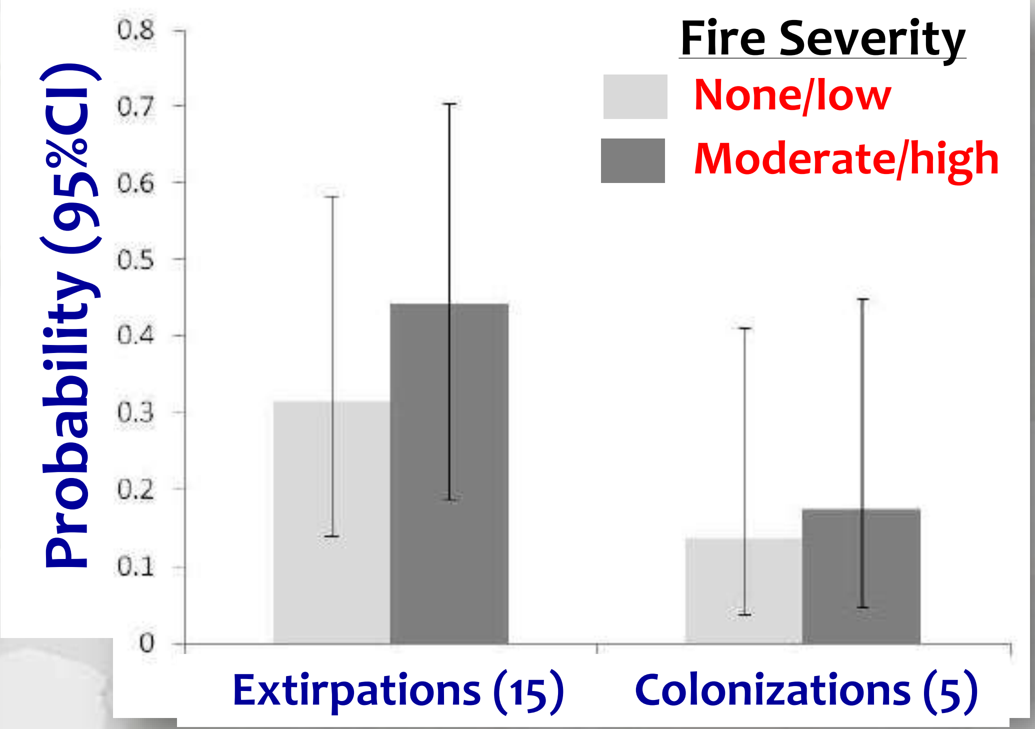


Eby et al. In Review. Evidence of climate-induced range contractions for bull trout to cooler, higher elevation sites in a Rocky Mountain watershed, U.S.A. *Global Change Biology*

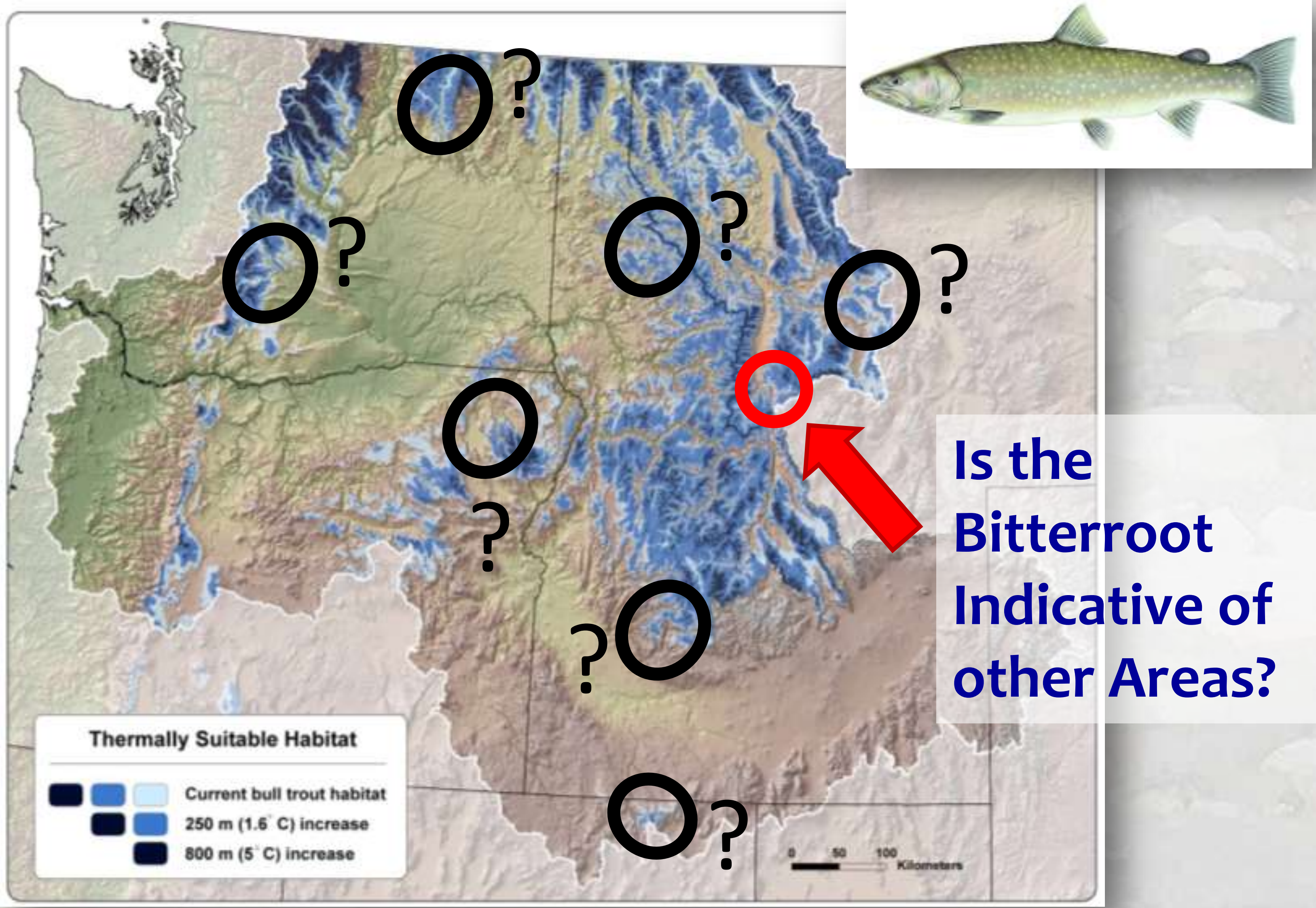
Distribution Shifts in Montana Bull Trout Populations

Best predictors





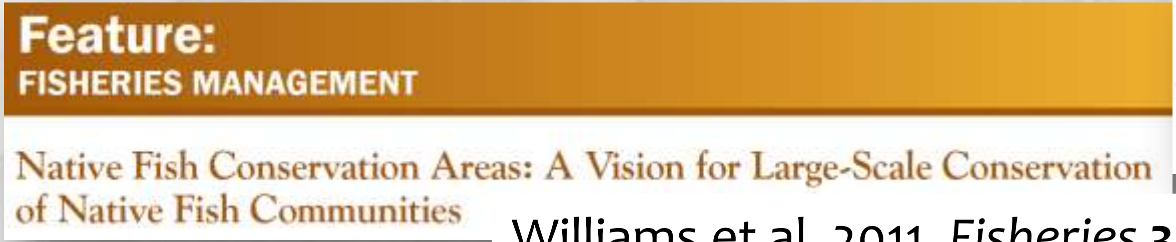
More Resurveys Needed to Understand Potential Breadth of Declines



Is the Bitterroot Indicative of other Areas?

Do "Climate-Proof" Habitats Exist for Key Species in Some Areas?

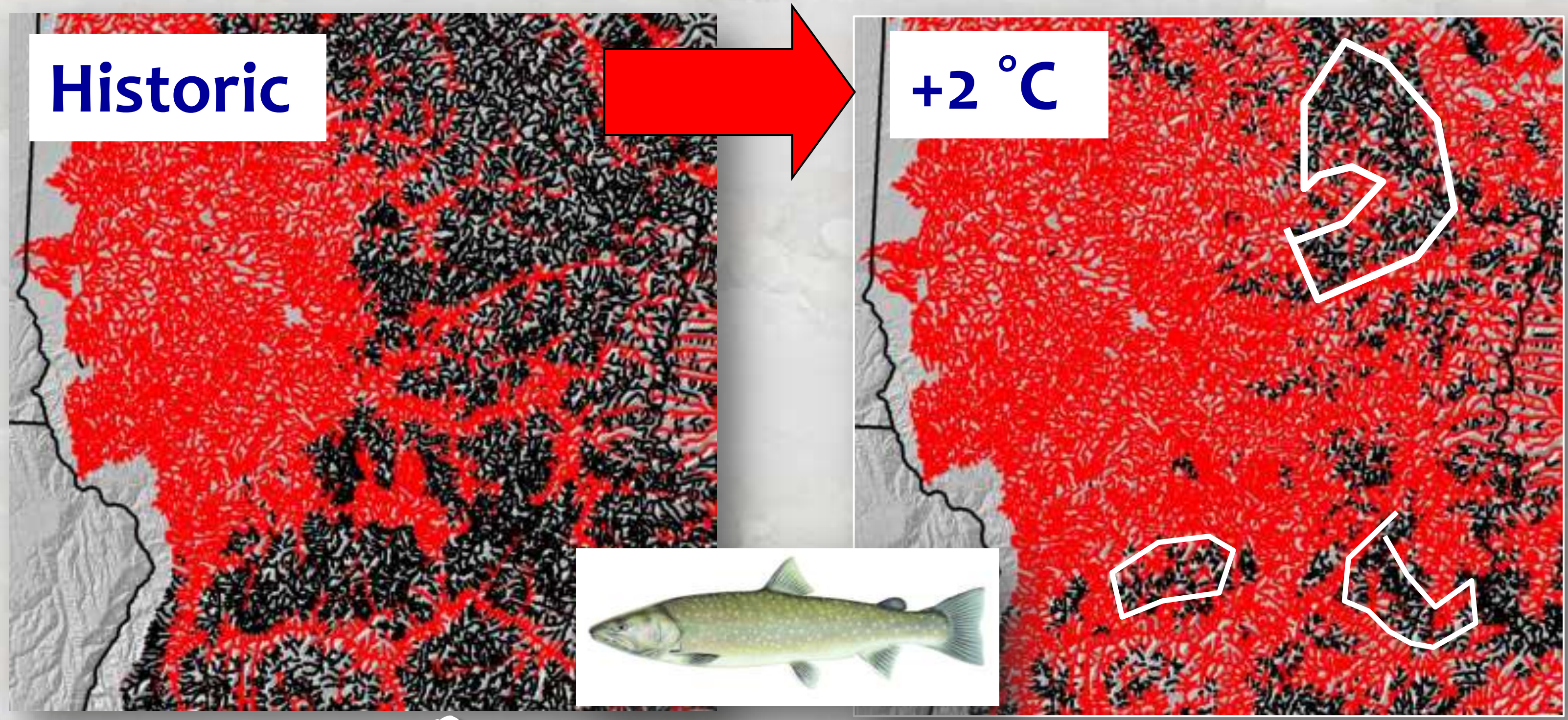
If Not, Can Targeted Restoration Create Them?



Feature:
FISHERIES MANAGEMENT

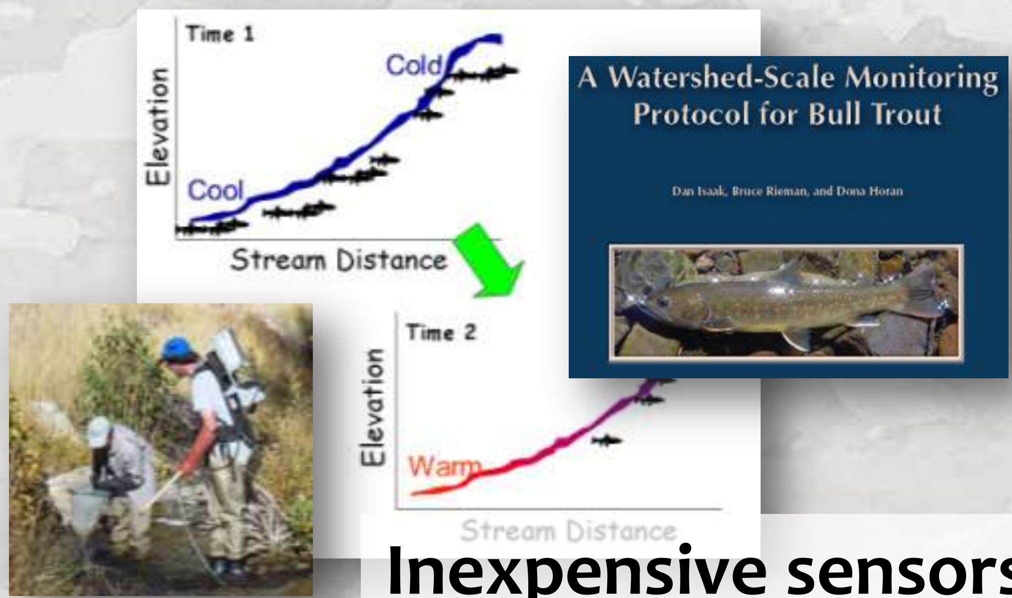
Native Fish Conservation Areas: A Vision for Large-Scale Conservation of Native Fish Communities

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



Monitoring Data are Key to Reducing Uncertainty

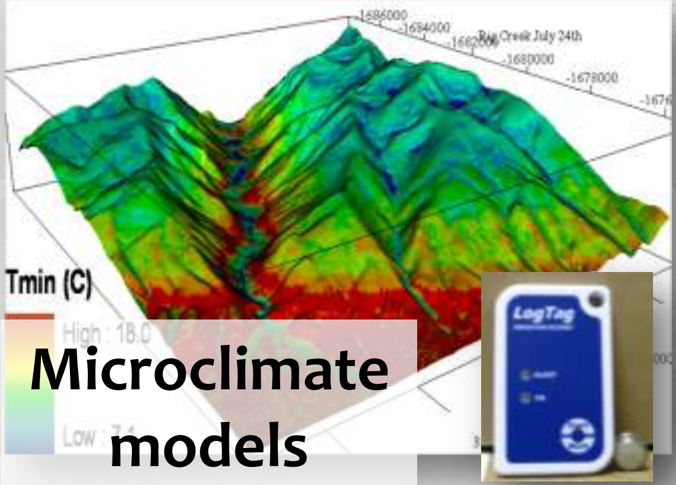
Temperature, streamflow, species distributions



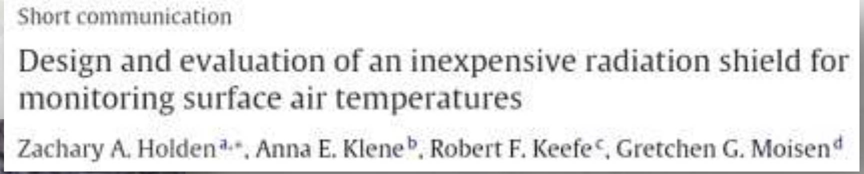
A Watershed-Scale Monitoring Protocol for Bull Trout

Dan Isaak, Bruce Rieman, and Dona Horan

Inexpensive sensors, bioassays & standardized protocols



Microclimate models



Short communication

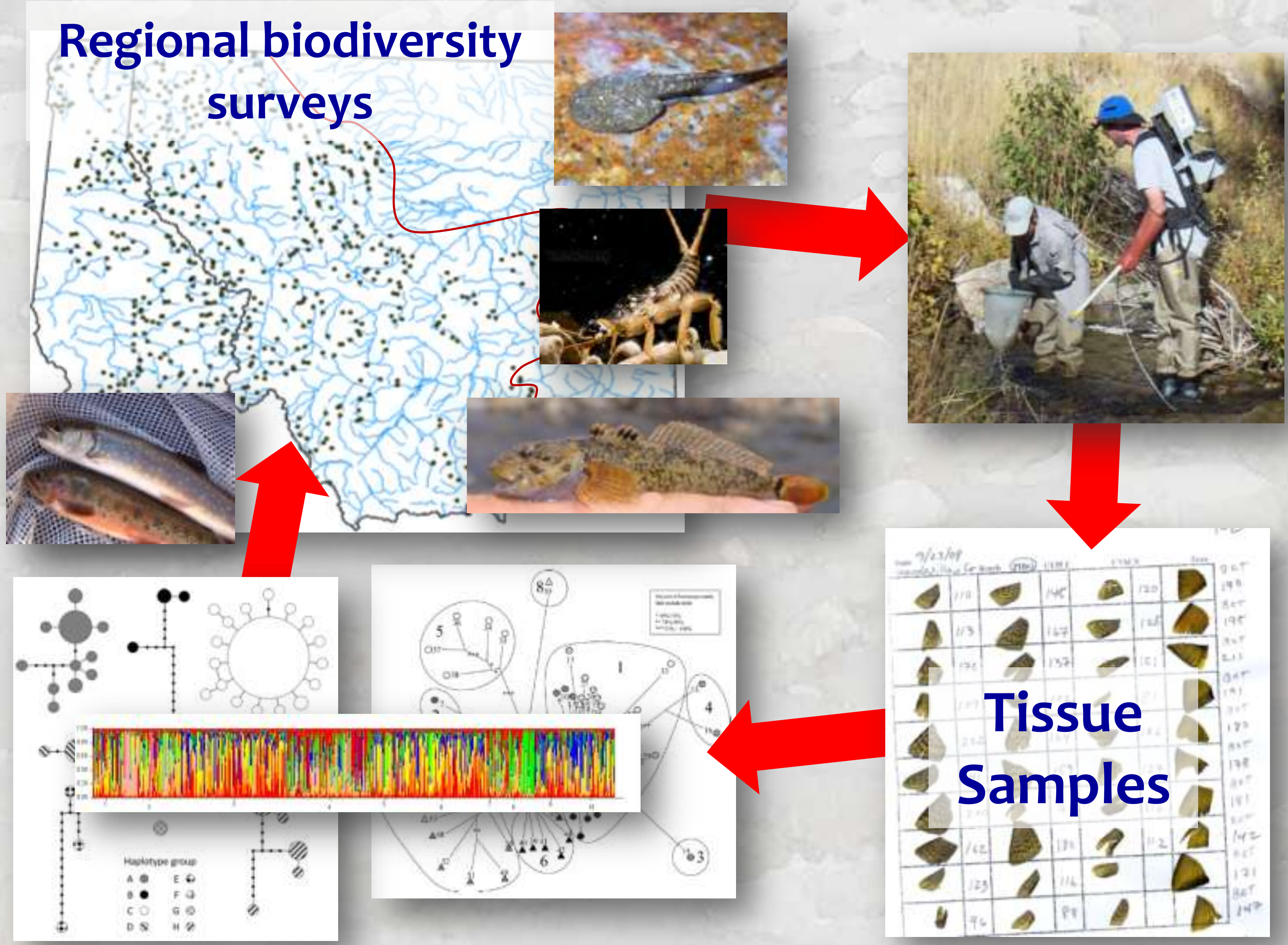
Design and evaluation of an inexpensive radiation shield for monitoring surface air temperatures

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



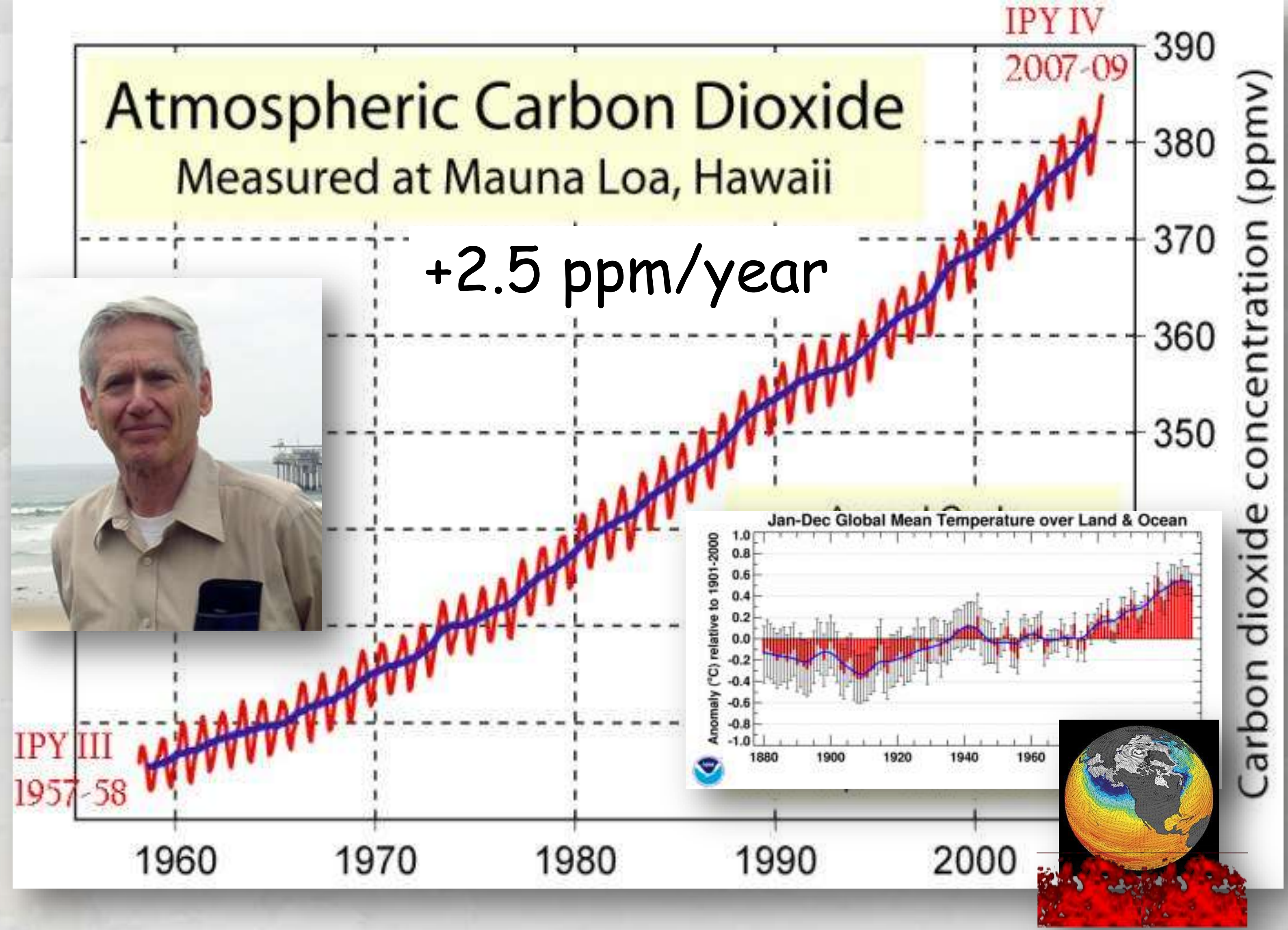
Regional biodiversity surveys

Tissue Samples

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

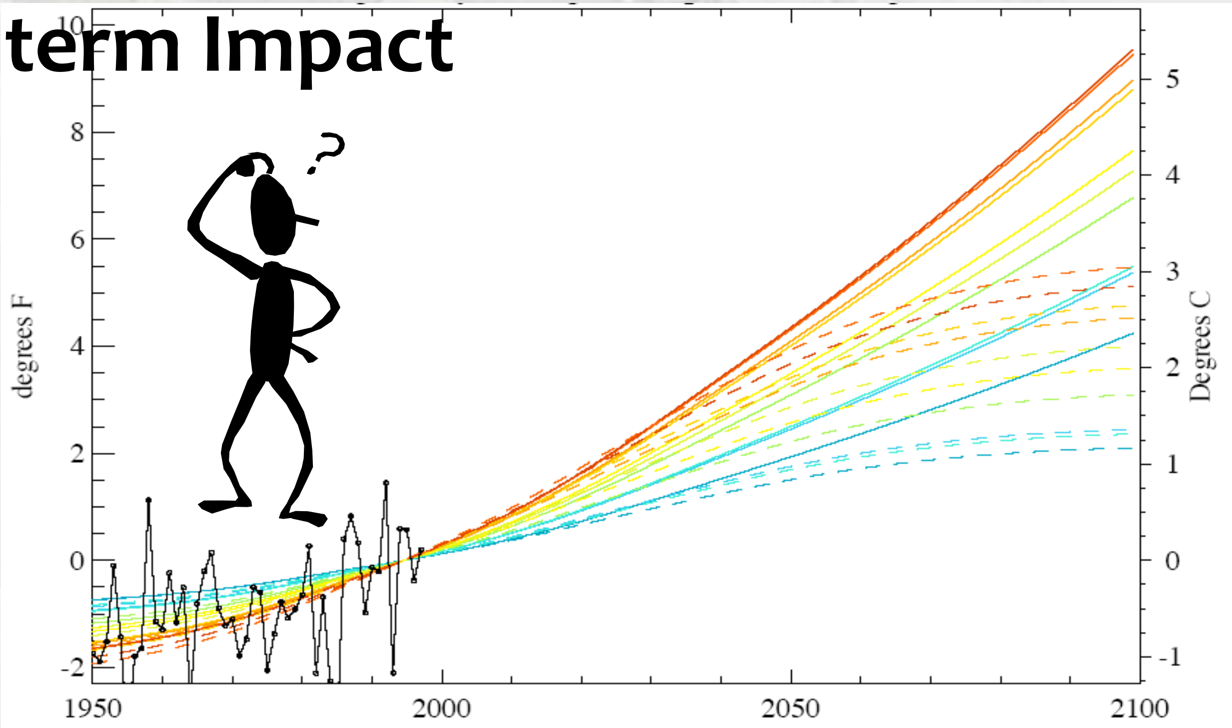
Without Good Monitoring, We Wouldn't Know Much

The Keeling Curve



+2.5 ppm/year

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”

Global Warming Is …

NOT COOL!

The End