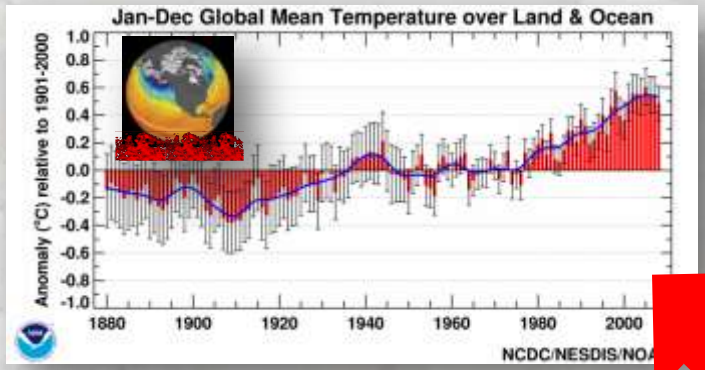
Climate Change & Aquatic Resources in the West: Where are We? What Does the Future Hold?

Dan Isaak, US Forest Service

Rocky Mountain Research Station



General outline:

1) What are global climate trends & how is western US being affected?

2) What do climate trends mean for stream environments and fish populations?

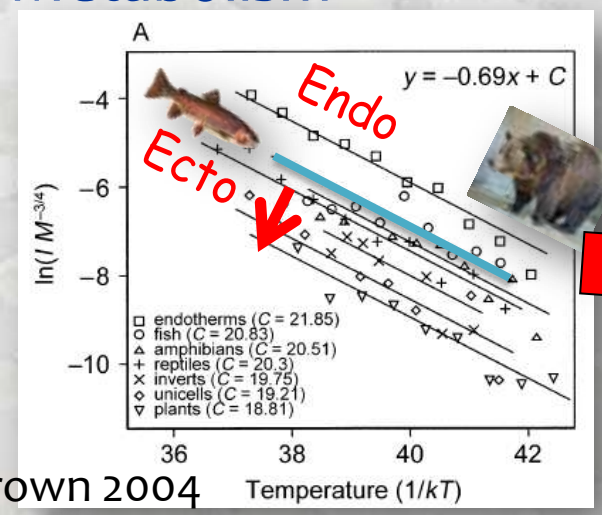
3) How climate change & technology are spurring innovations in collaborative resource management

4) Key future uncertainties (resolvable & not)

Charismatic MegaFishes of Concern

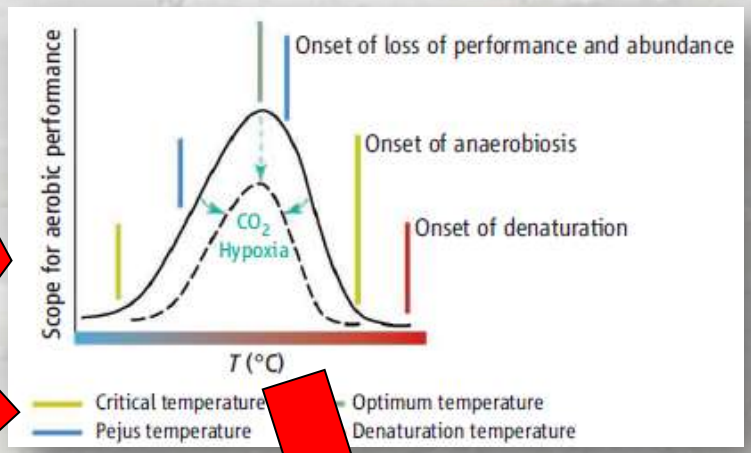
Temperature is Primary Control for Cold-Blooded Organisms Like Fish

Metabolism

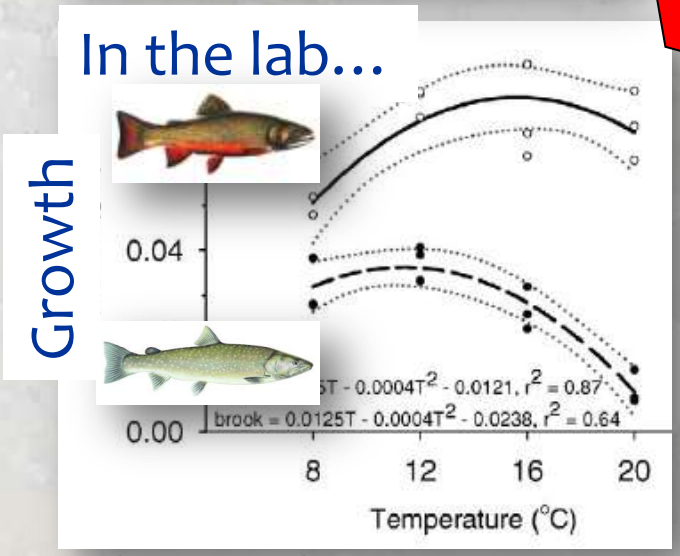


Brown 2004

Thermal Niche

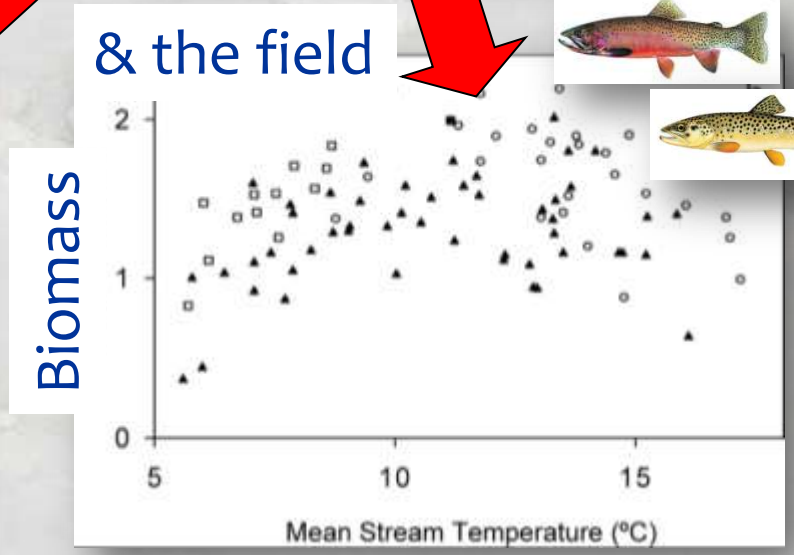


In the lab…



McMahon et al. 2007

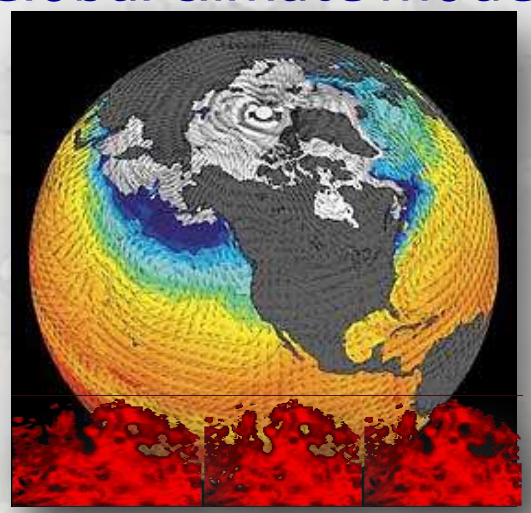
& the field



Isaak & Hubert 2004

How Will Global Climate Change Affect my Stream?

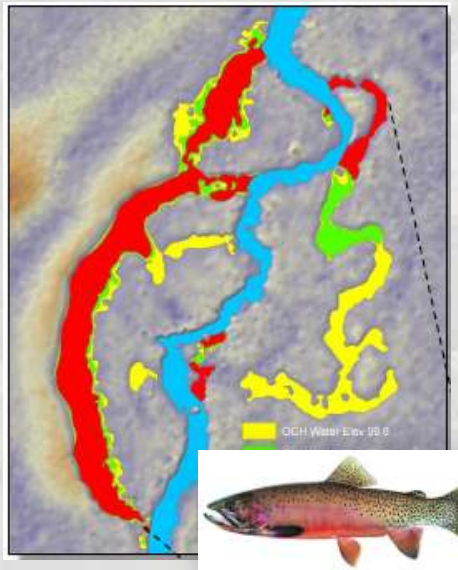
Global climate model



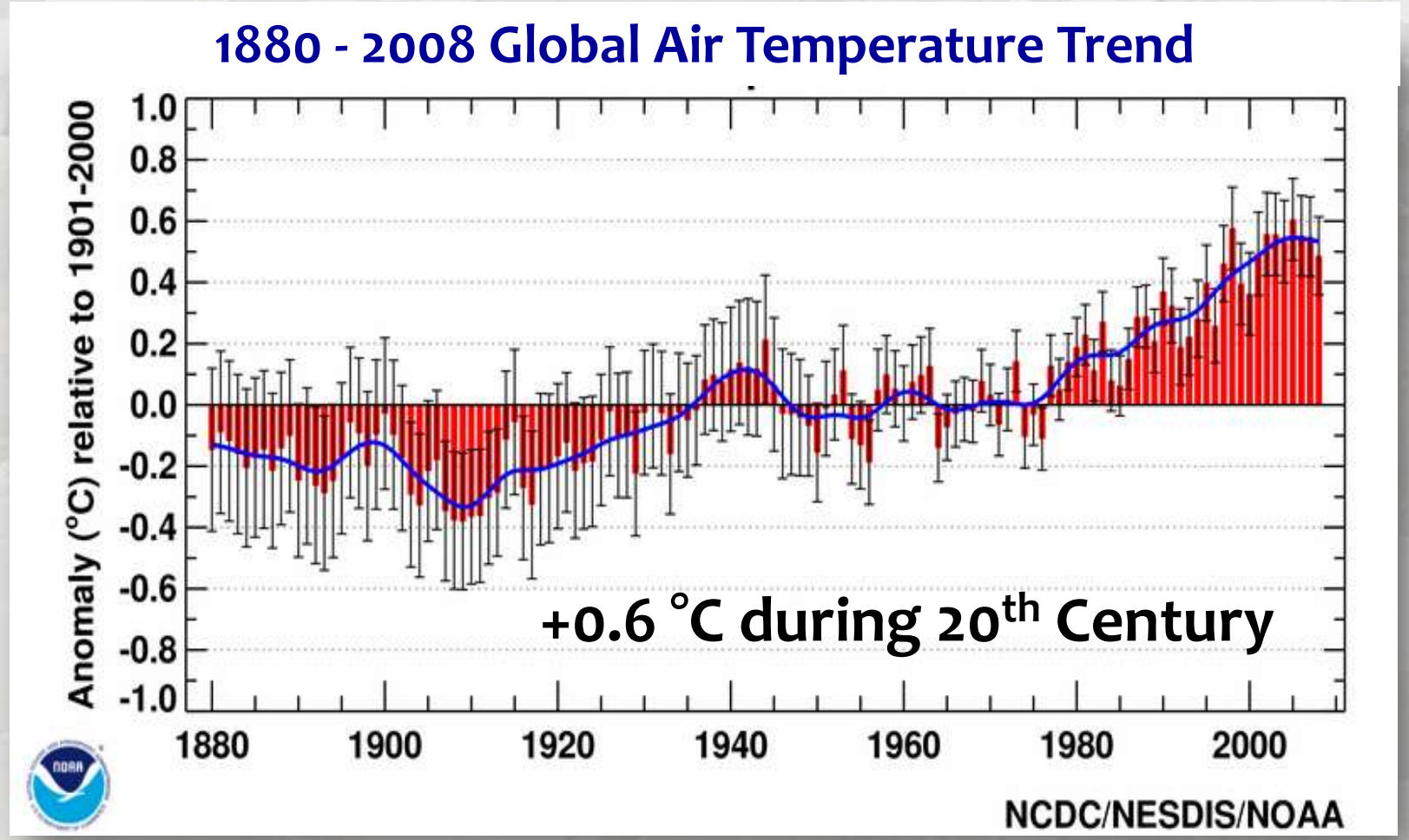
Regional climate model

River network temperatures

Stream reach

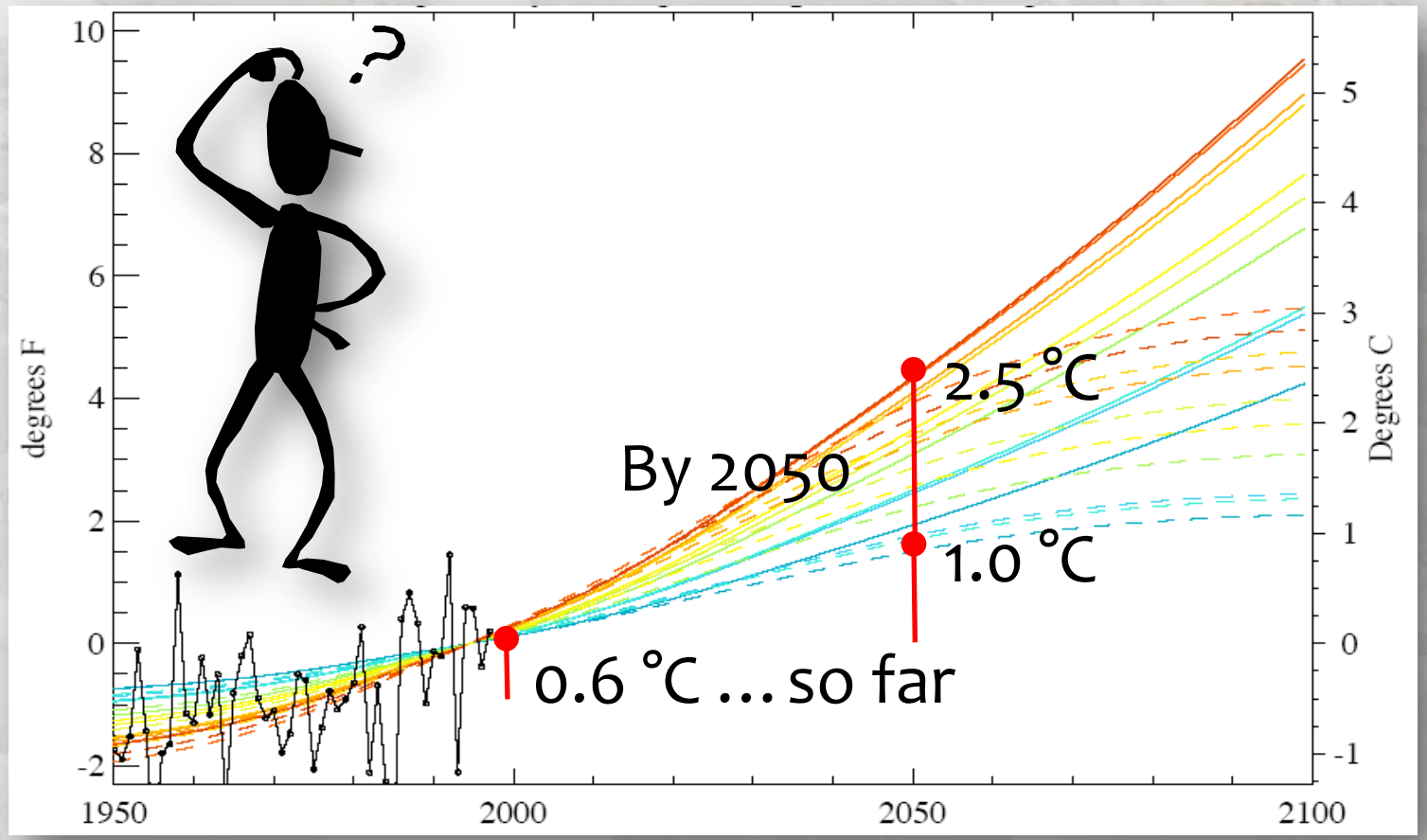


20th Century Observed Trend



21st Century Projected Trend

Larger changes coming



Mote et al. 2008

Short-term Variation in Warming

National Survey Finds Public Concern About Global Warming Drops Sharply

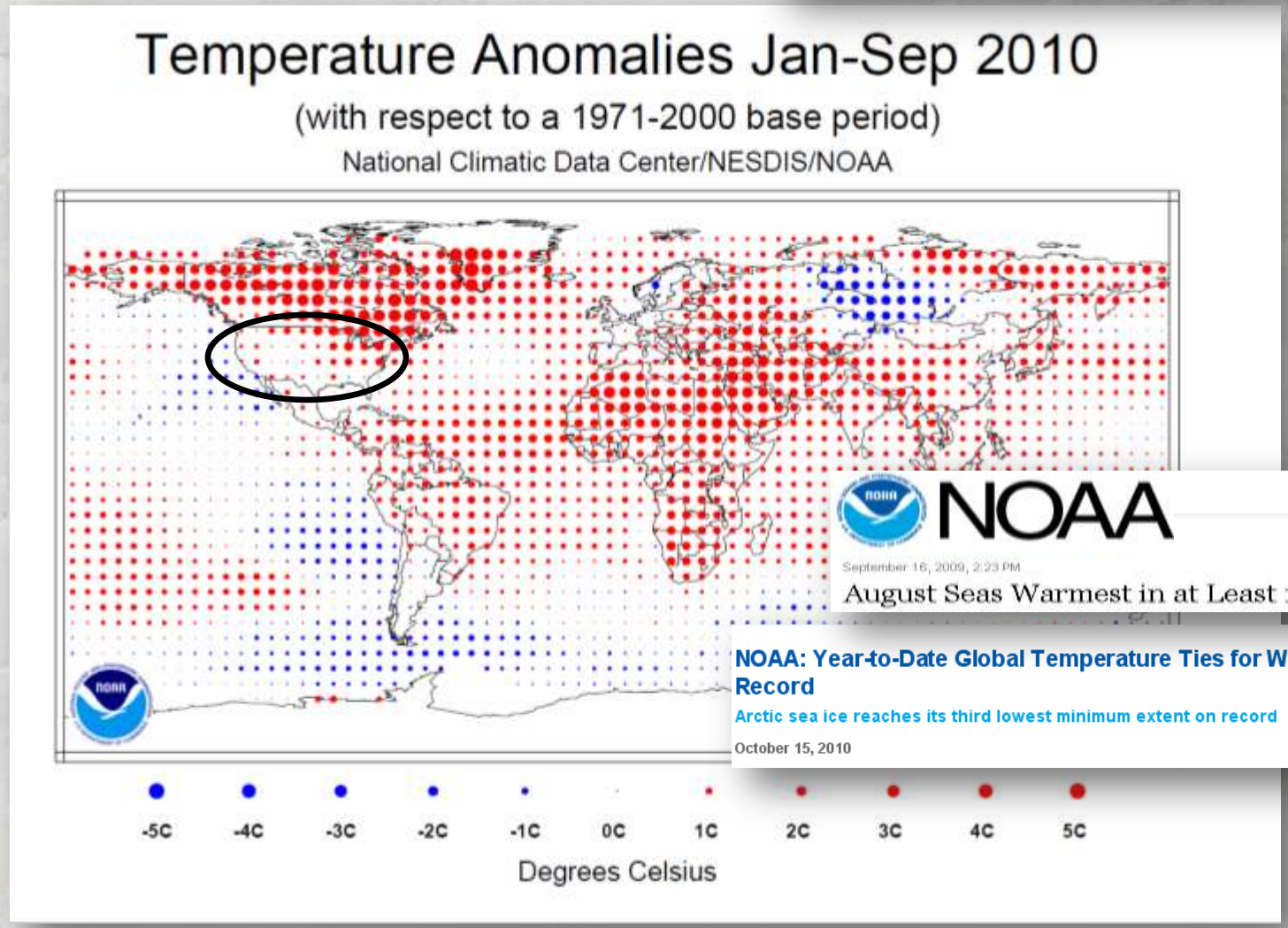
January 29, 2010 , CBB

NEWS ANALYSIS

Where Did Global Warming Go?

By ELISABETH ROSENTHAL

Published: October 15, 2011



NOAA

September 16, 2009, 2:23 PM

August Seas Warmest in at Least 120 Years

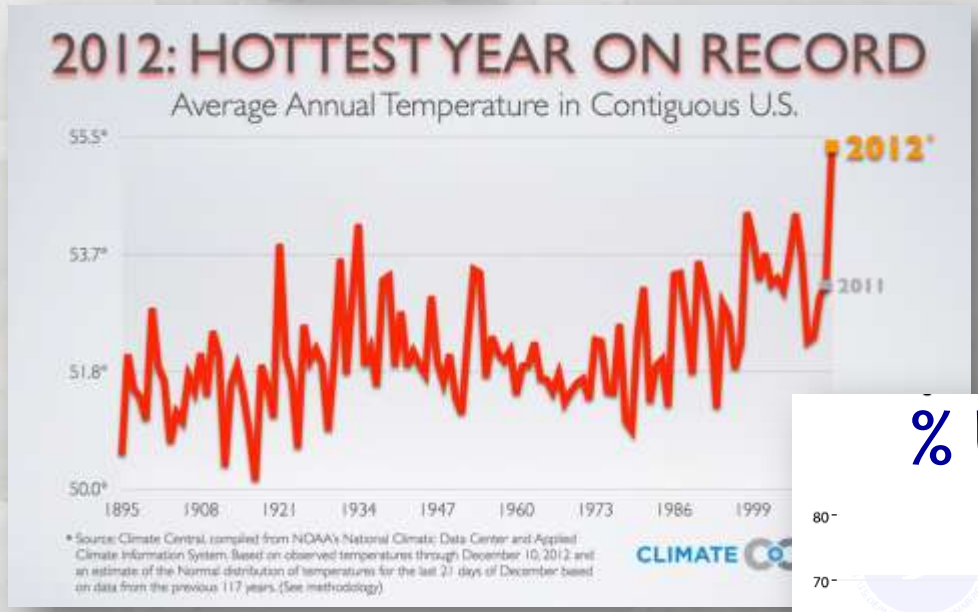
NOAA: Year-to-Date Global Temperature Ties for Warmest on Record

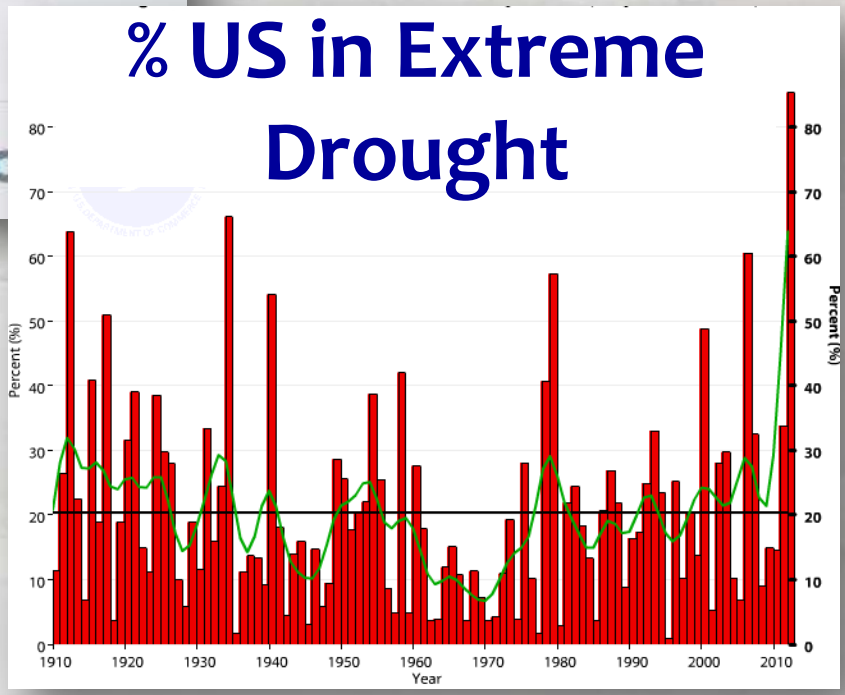
Arctic sea ice reaches its third lowest minimum extent on record

October 15, 2010

It's Back…

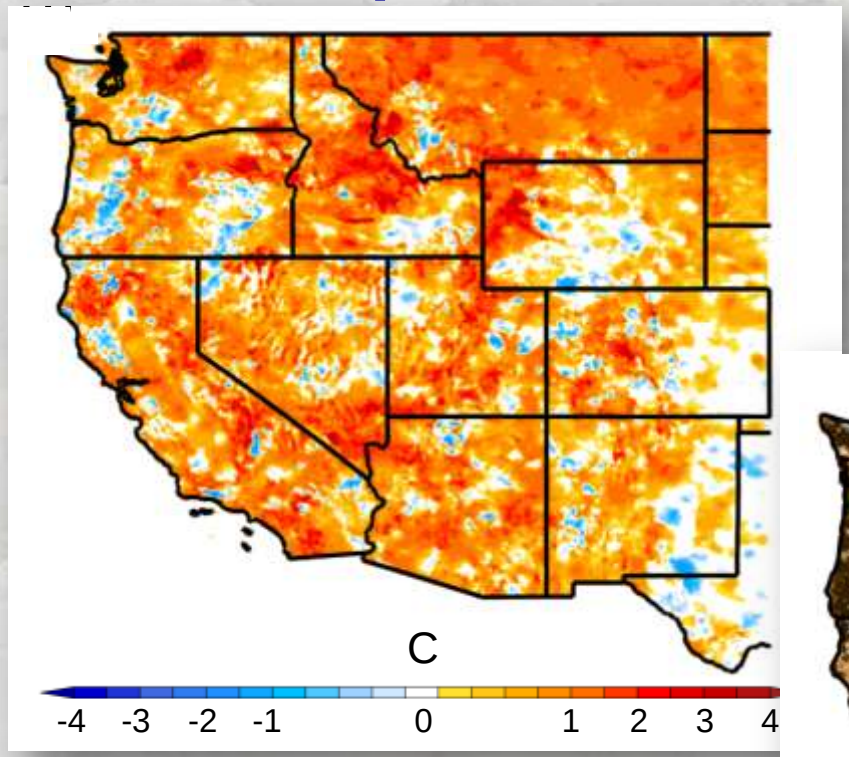
& it's not going away



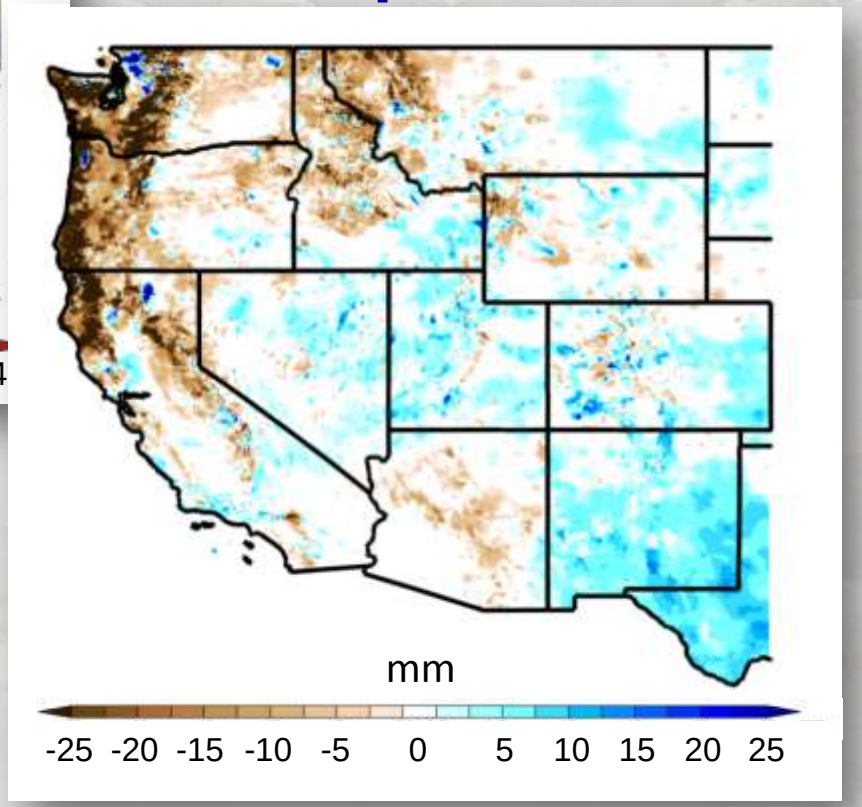


Western US Observed Climate Trends (1950 – 2009)

Air temperatures

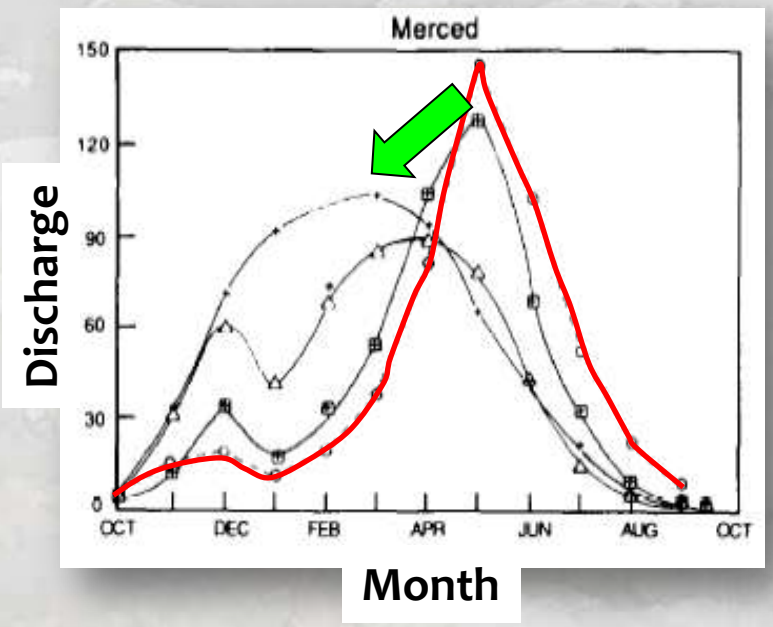


Total Annual Precipitation

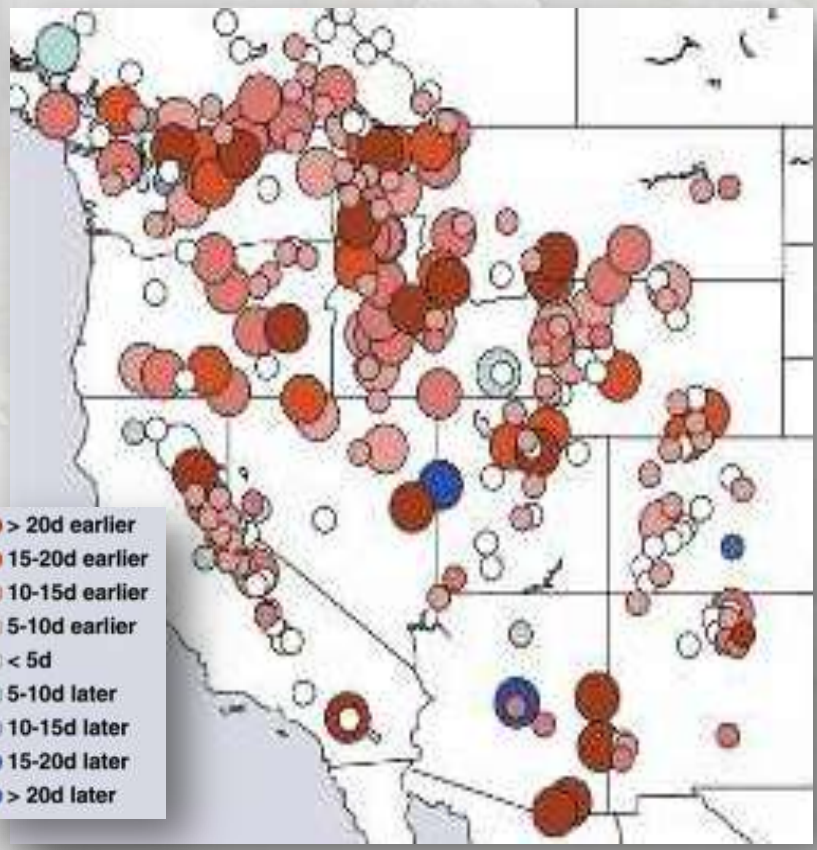


Trends in Stream Runoff Timing

(1948-2000)

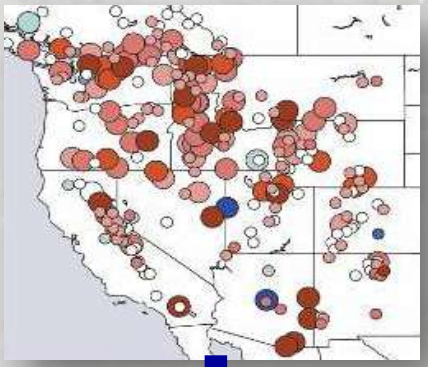


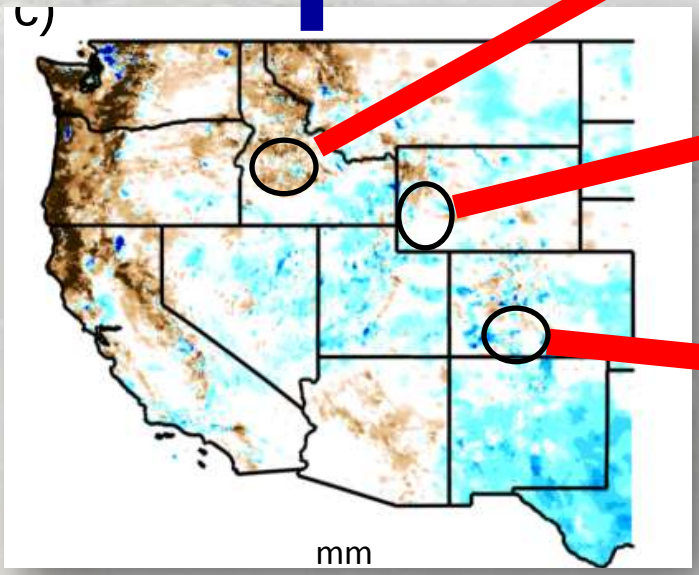
Smaller & earlier snowmelt & river runoff

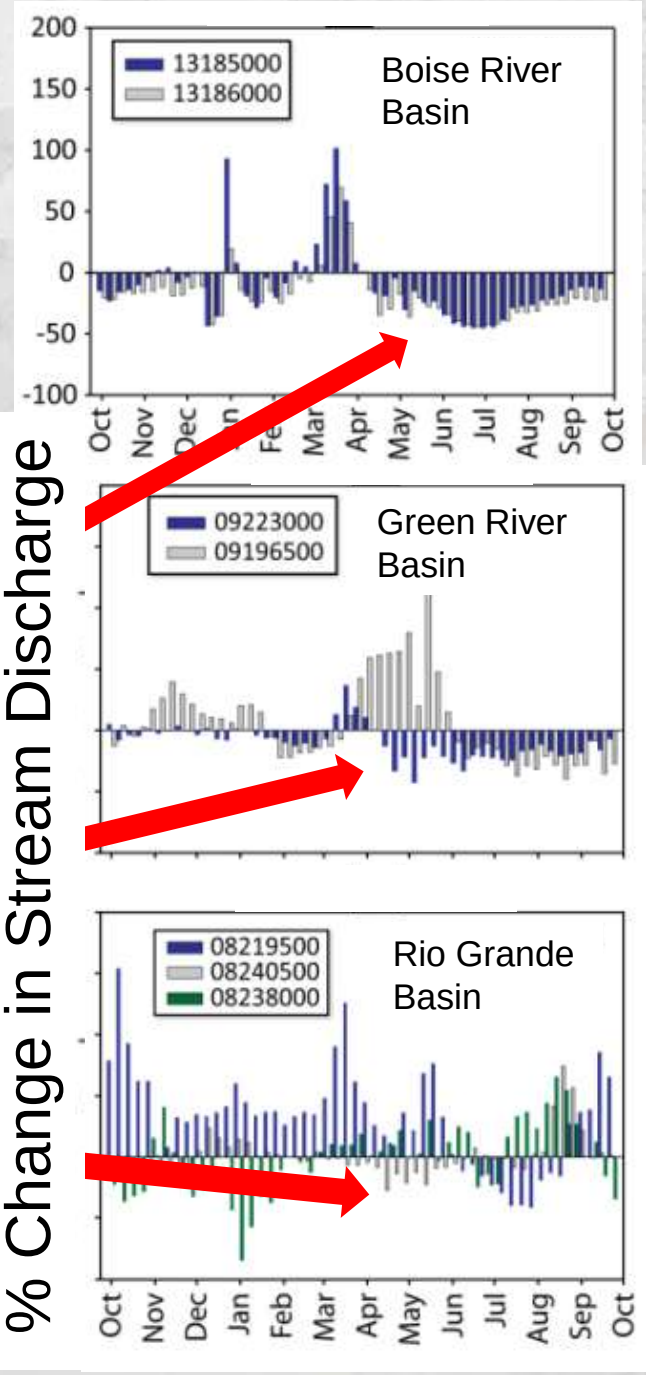


Stewart et al. 2005

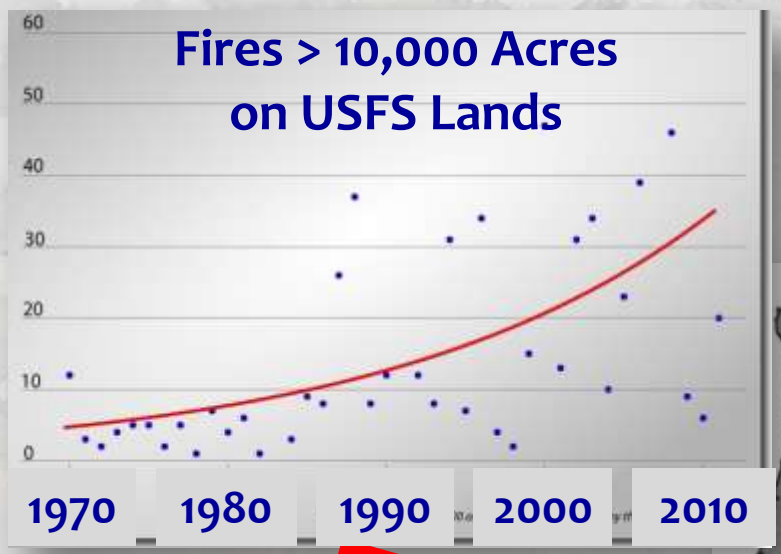
Runoff Timing Interacts with Precipitation



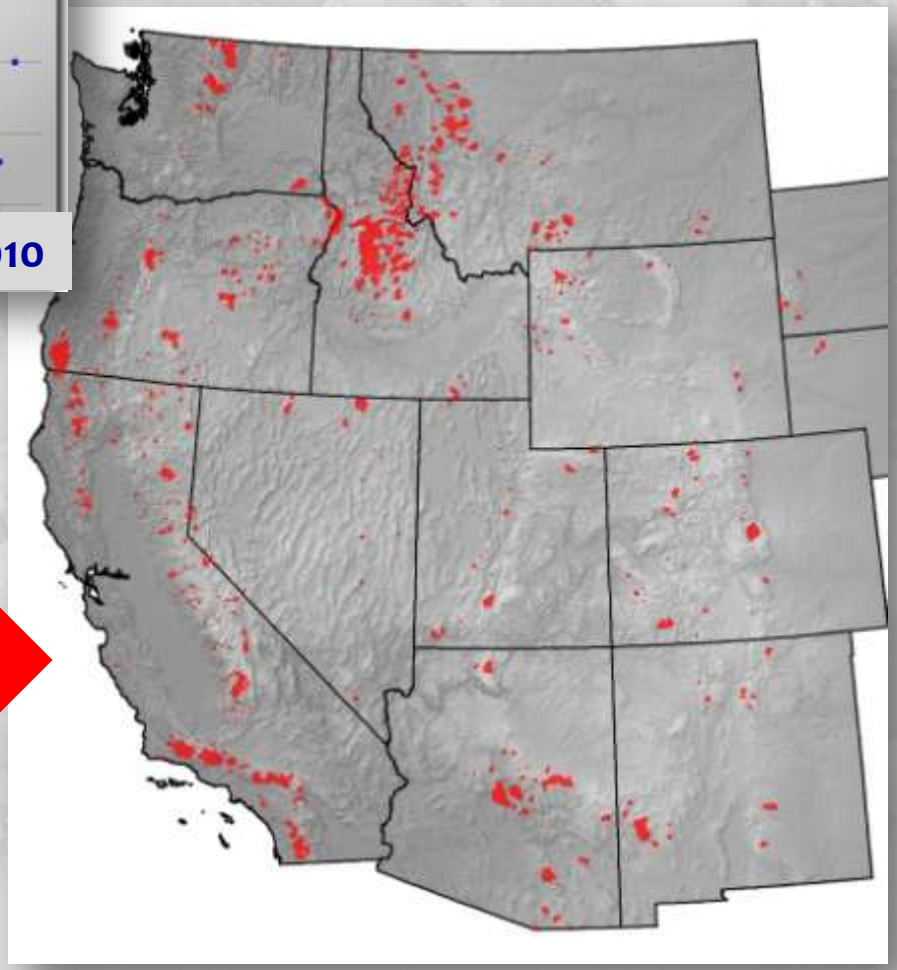




Wildfires Increasing Westwide



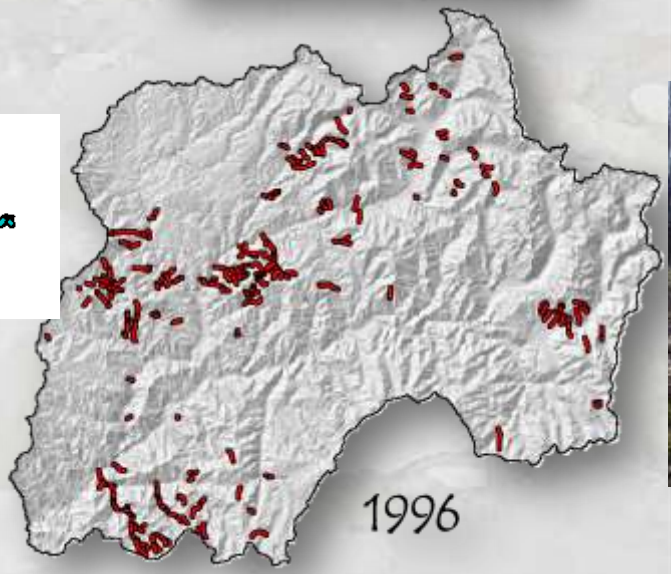
Fires from 2001 - 2007
on USFS Lands



National Research Council. 2011

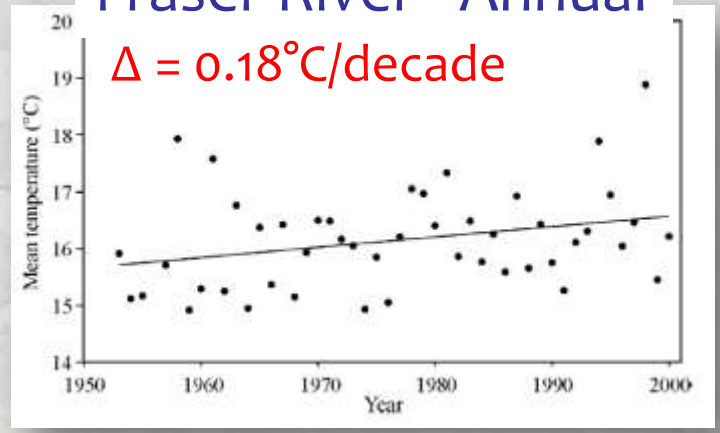
Sediment Regimes

Fire & Disturbance

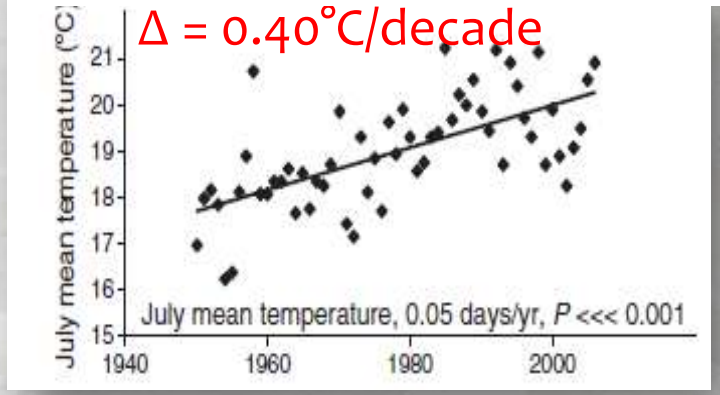


Temperature Trends In Northwest Rivers

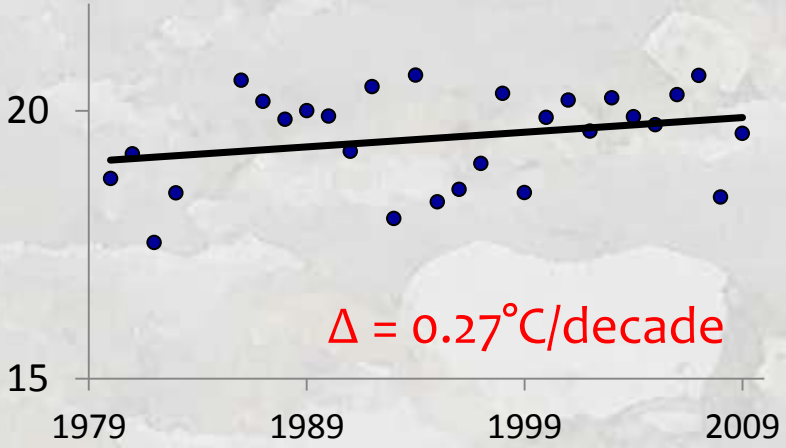
Fraser River - Annual



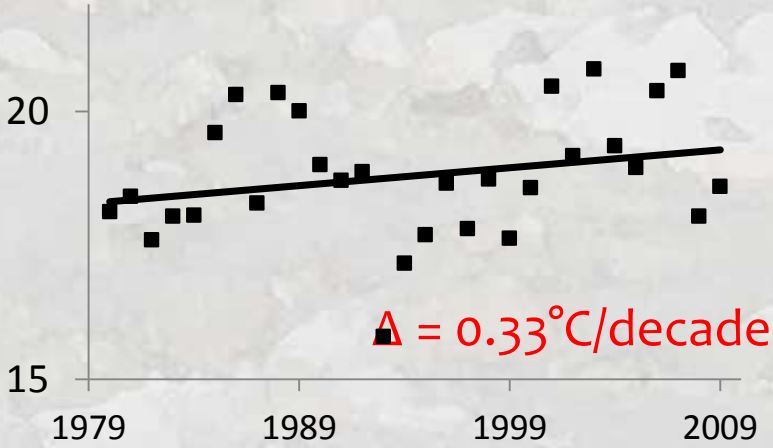
Columbia River - Summer



Snake River, ID - Summer

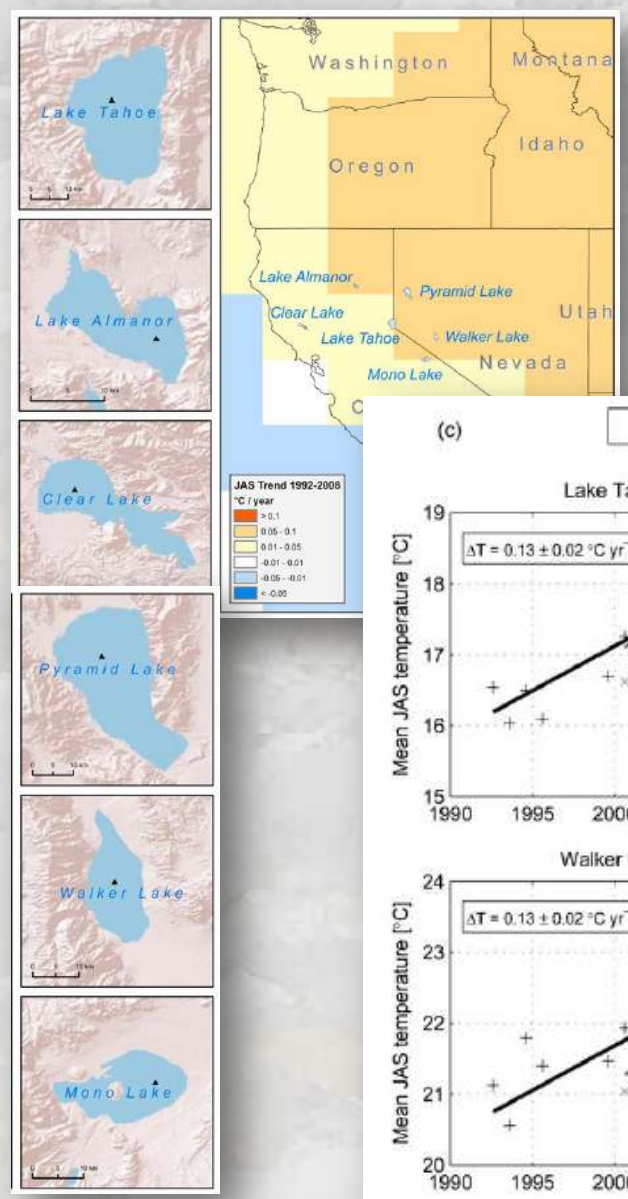


Missouri River, MT - Summer

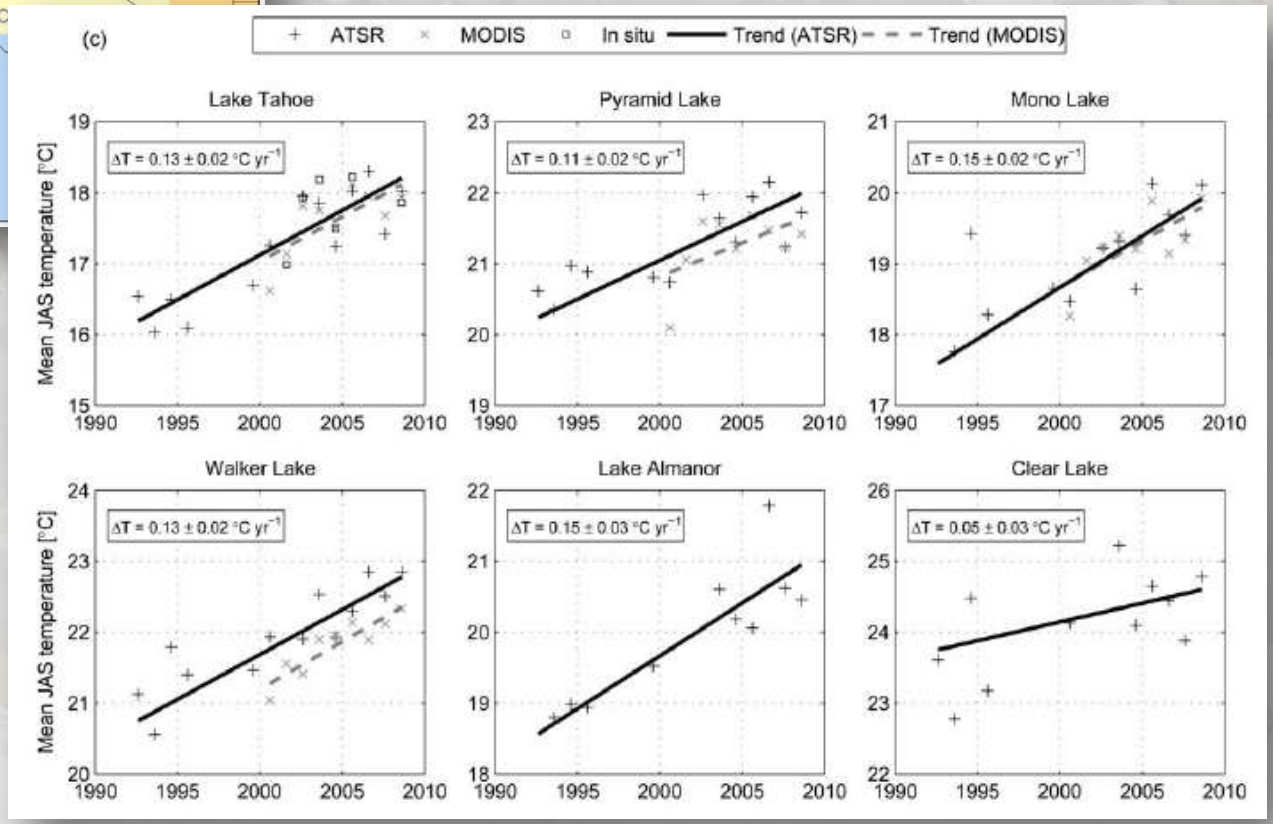


Isaak et al. 2012. *Climatic Change* **113**:499-524.

Temperature Trends In Western Lakes



+1.1°C/decade
from 1992-2008

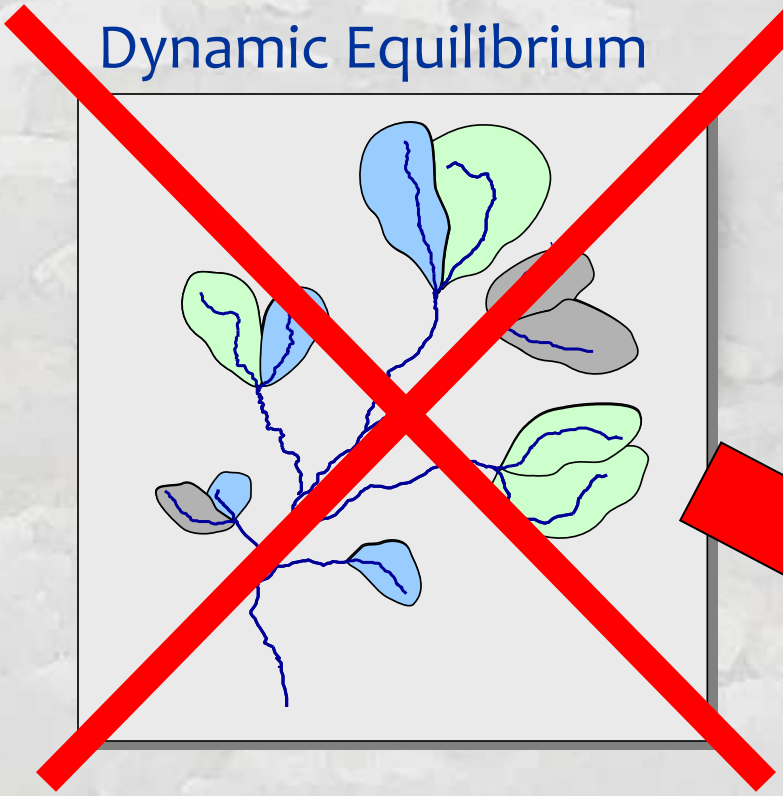


Schneider et al. 2009.

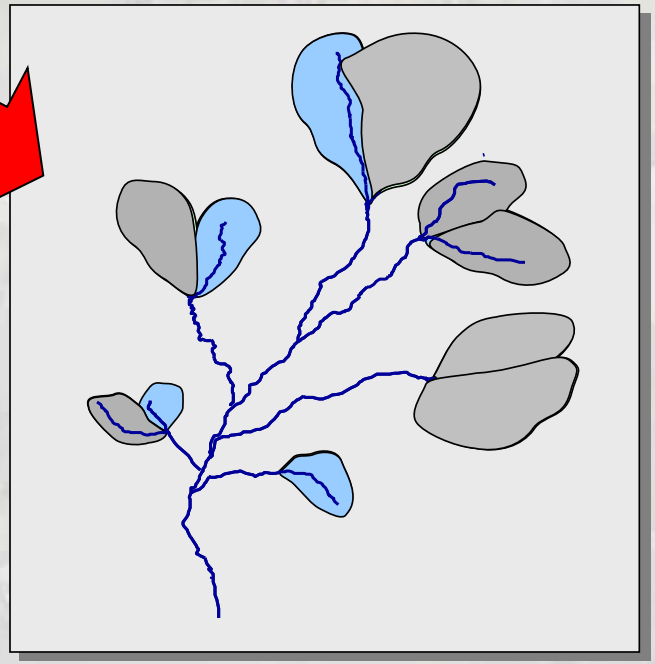

Western landscapes (and streams) are highly dynamic and aquatic organisms are adapted accordingly

“Balance of Nature” Paradigm no Longer Valid

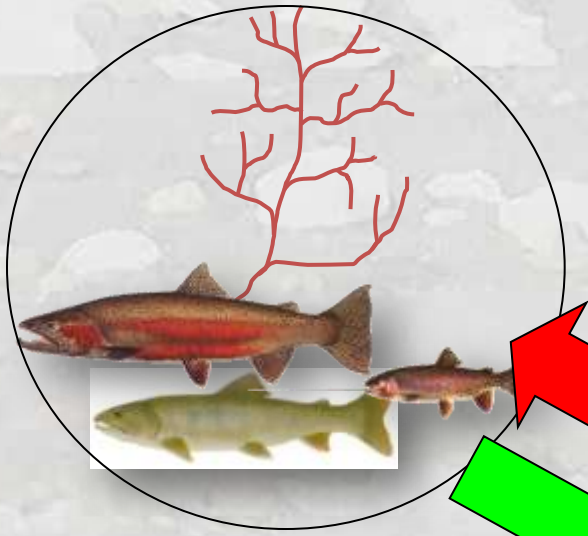
Dynamic Equilibrium

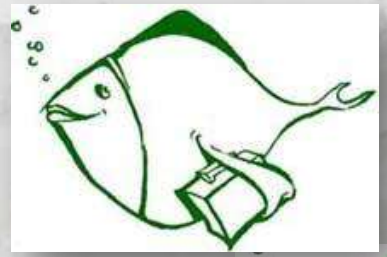


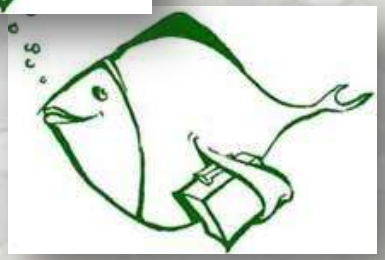
Dynamic Dis-Equilibrium

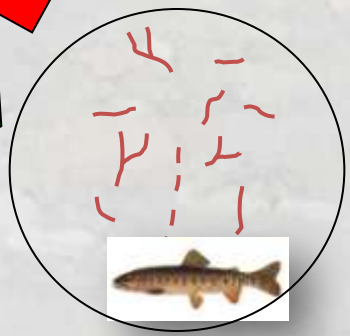


There Will be Winners & Losers

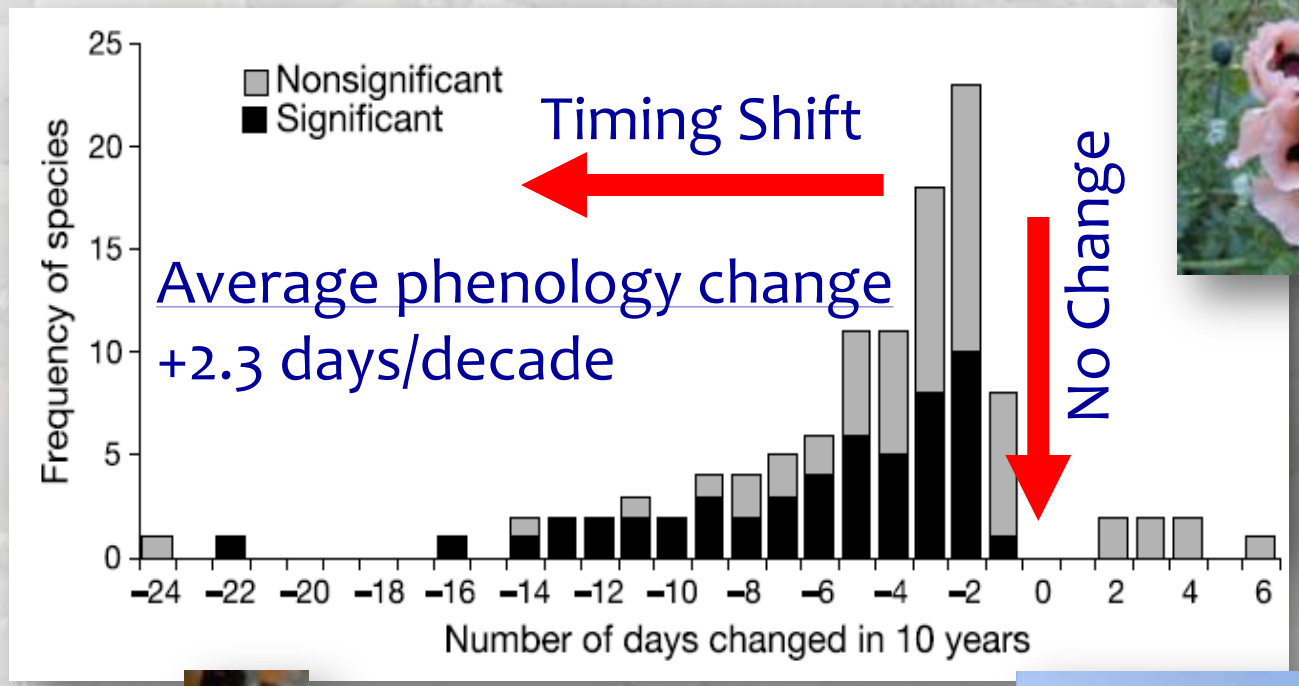


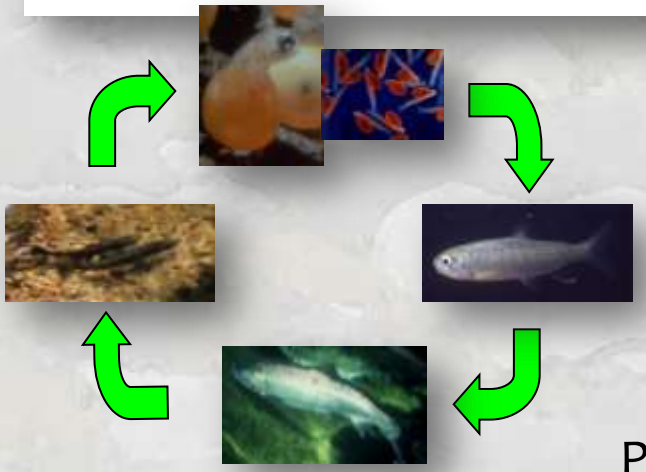






Species Phenologies are Accelerating

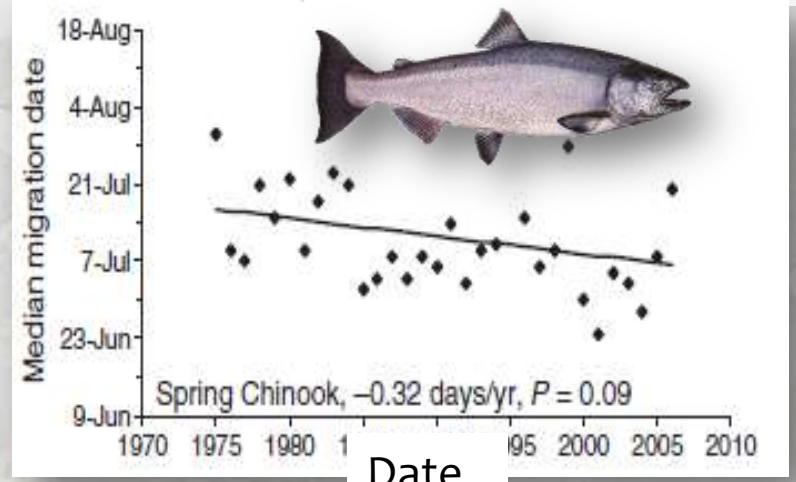




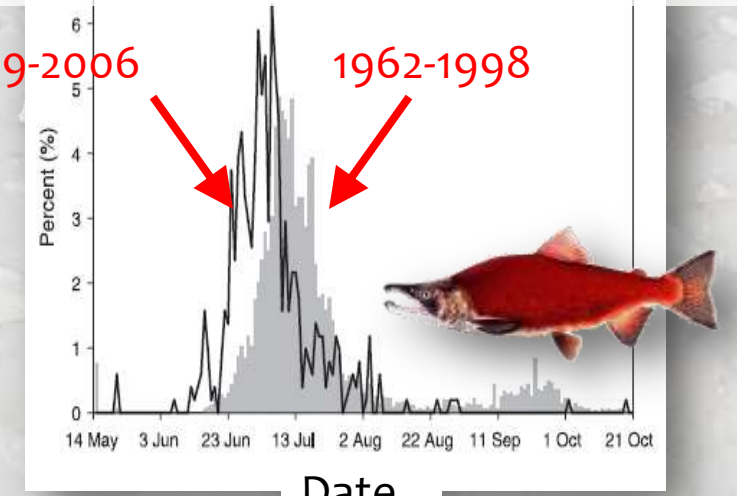
Parmesan and Yohe. 2003. *Nature* 421:37-42.

Shifts in Salmon Migration Timing

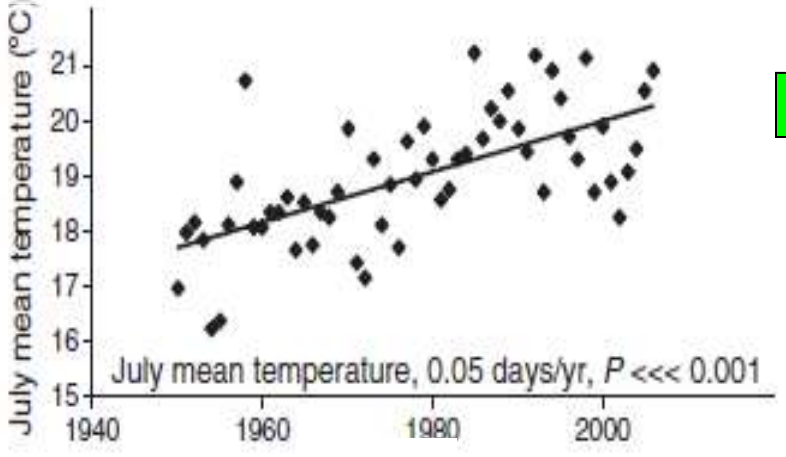
Median Spring Chinook Migration Dates at Bonneville



Distribution of Sockeye Migrations at Lower Granite



July Stream Temps at Bonneville

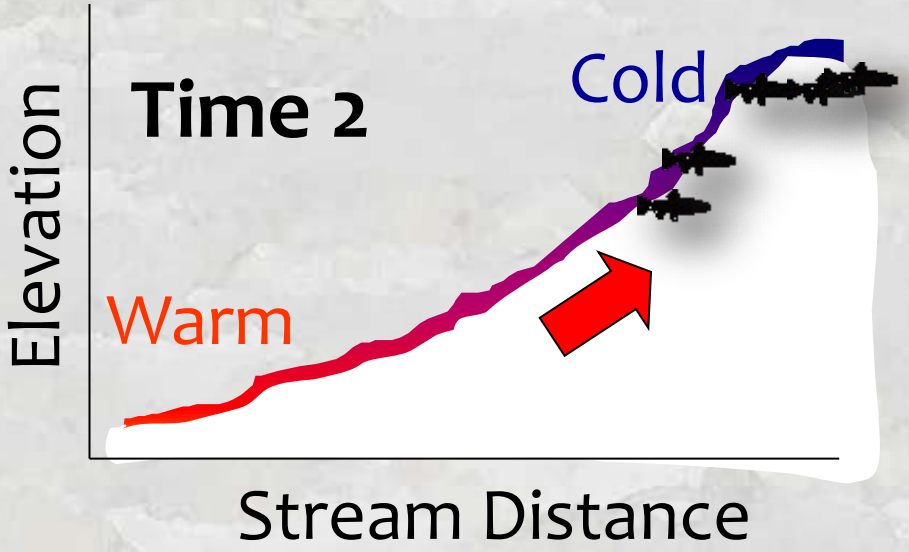


Studies…

- Juanes et al. 2003
- Crozier et al. 2008
- Keefer et al. 2009
- Wedekind & Kung 2010
- Crozier et al. 2011
- Etc.

Species Distributions are Shifting

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

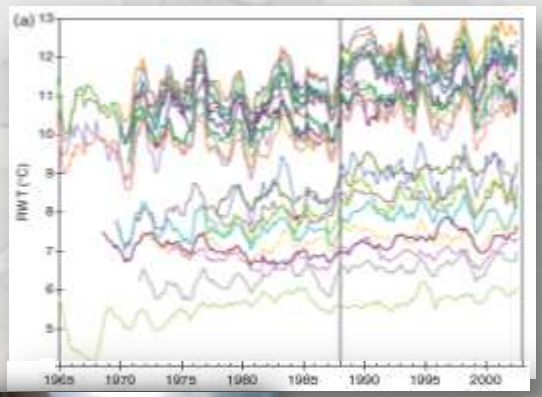


Parmesan and Yohe. 2003. *Nature* **421**:37-42.

Brown Trout Distribution Shifts

Switzerland (1978-2002)

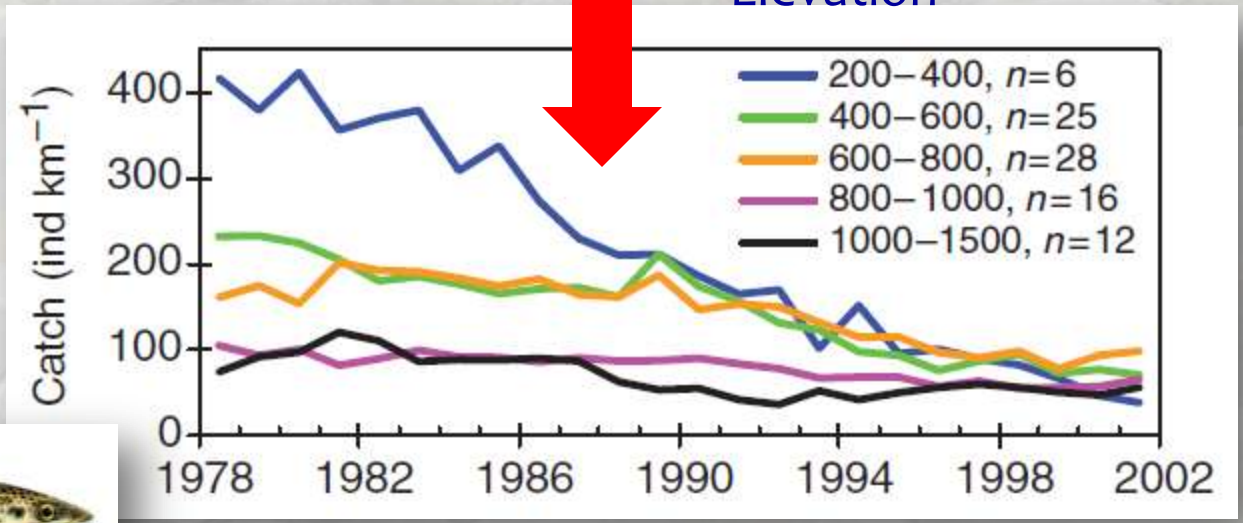
Stream Temp Increases



+

Disease Outbreaks

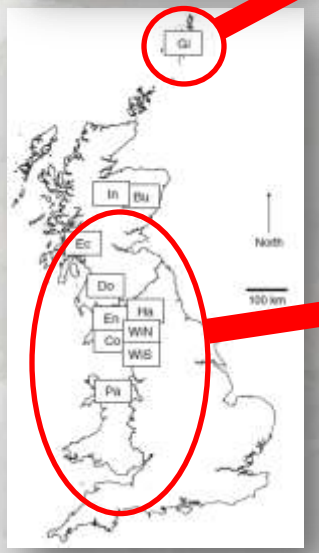
Elevation



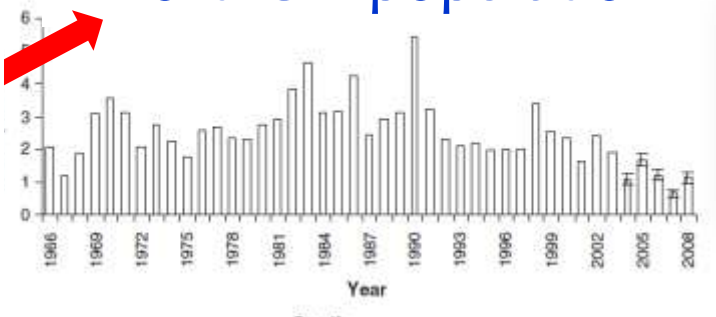
Hari et al. 2006

Arctic Char Declines in the U.K.

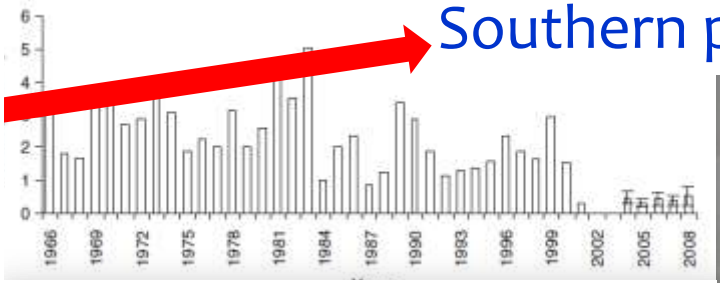
Declining Fastest at Southern Range Extent

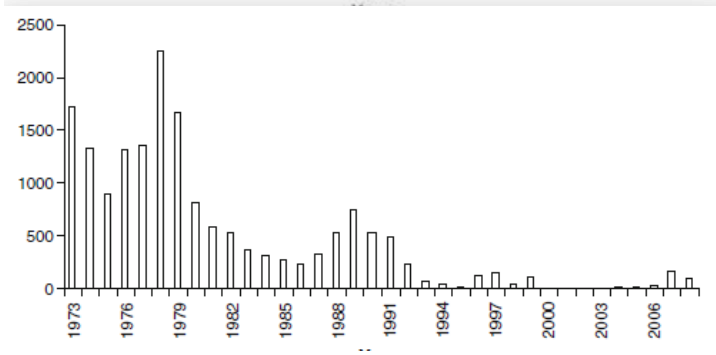


Northern population



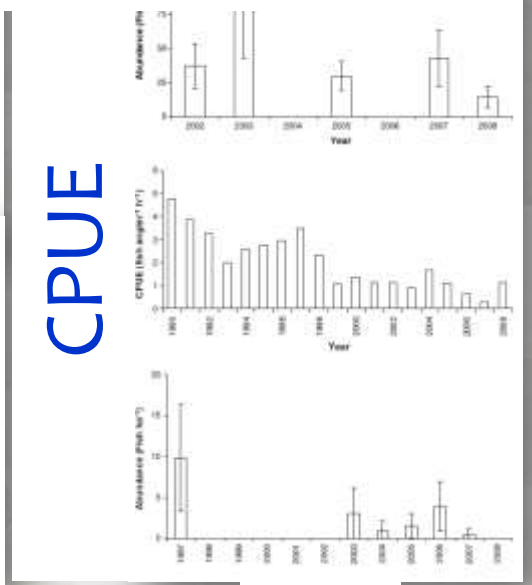
Southern populations





Catch Per Unit Effort

CPUE

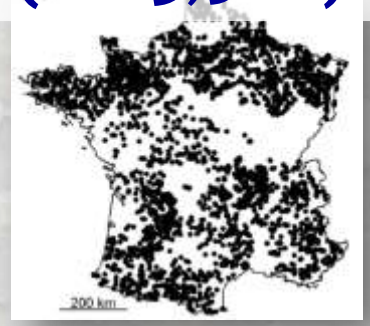


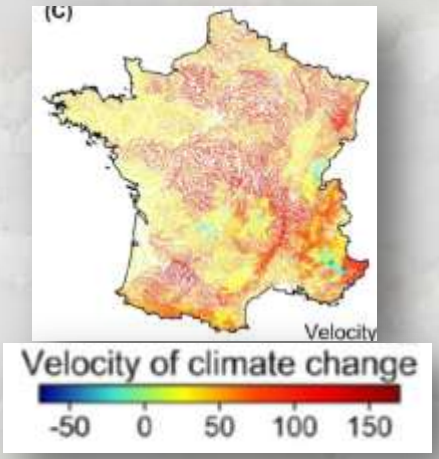
Year

Winfield et al. 2010. *Hydrobiologia* **650**:55-65.

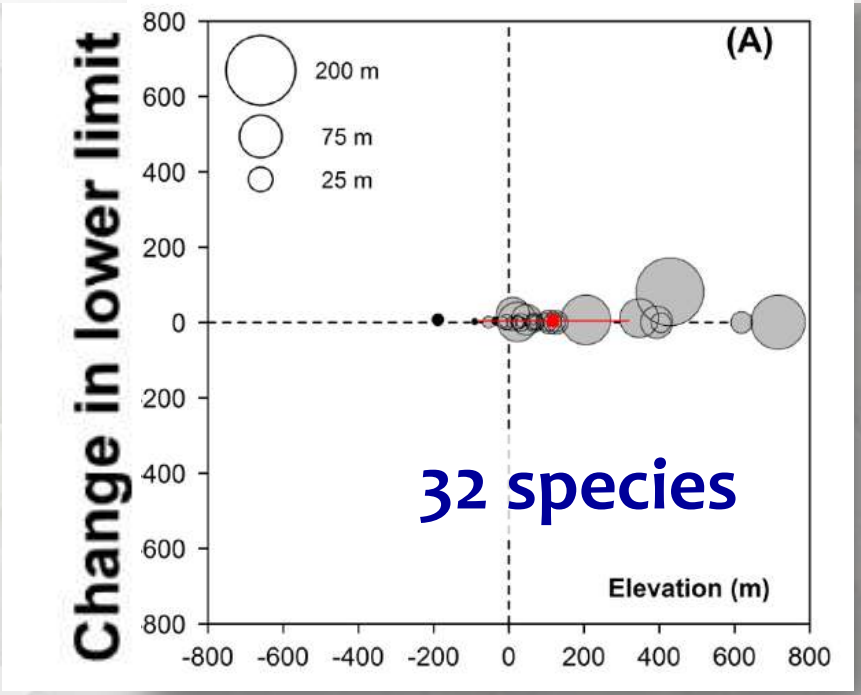
Climate is Causing Stream Fish Distributions to Shift…

Fish surveys (n = 3,500)





French stream fish distributions (1980's vs 2000's)

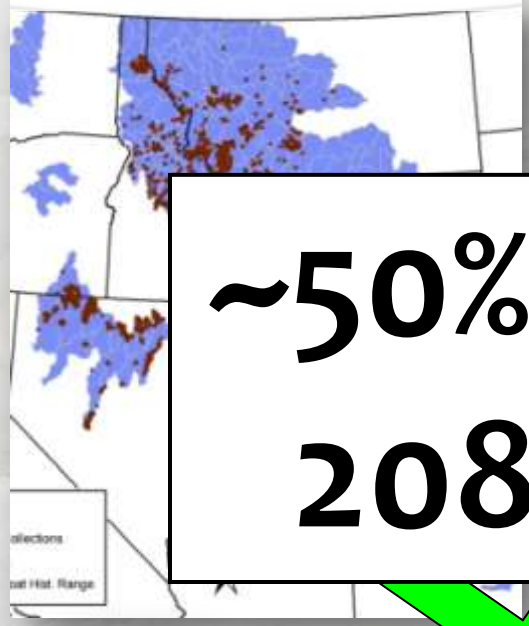


…but shifts are slower than Climate Velocity

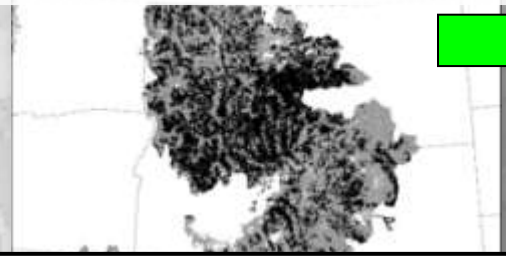
Comte & Grenouillet. 2013. Do stream fish track climate change? Assessing distibution shifts in recent decades. *Ecography*.

Western US Trout Climate Assessment

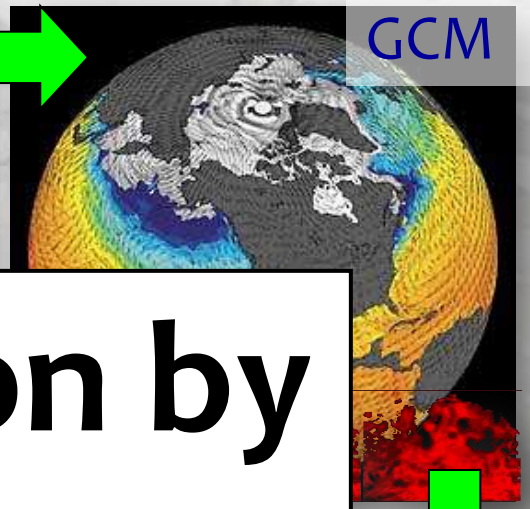
Fish survey database
~10,000 sites



Historic Distributions

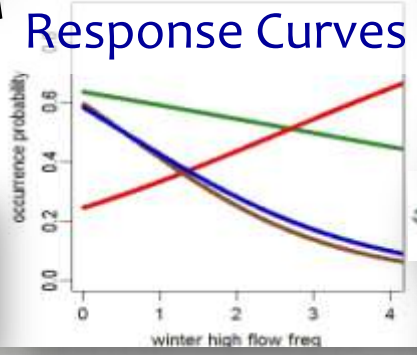


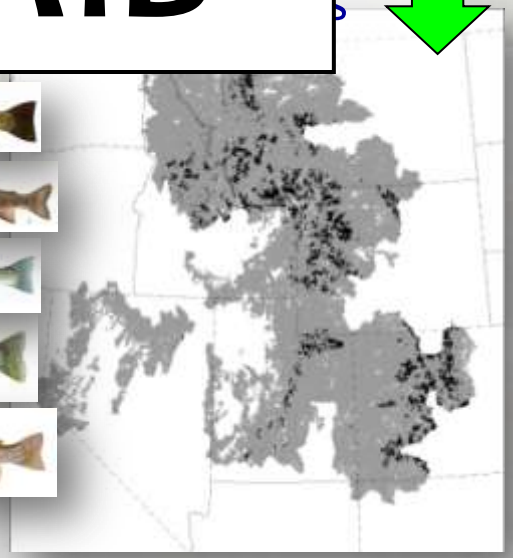
GCM



~50% reduction by 2080 under A1B

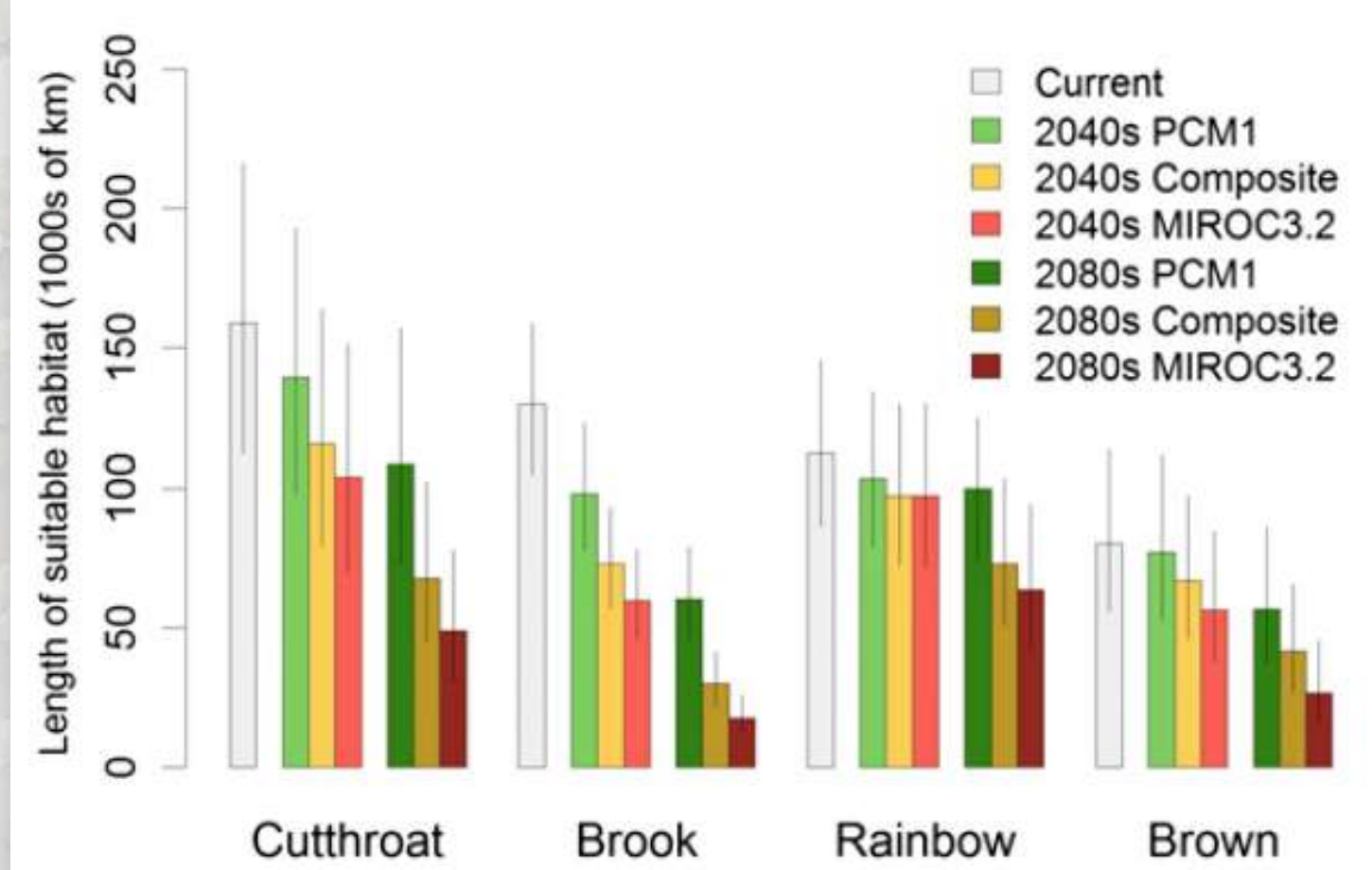
Habitat
Response Curves





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

Species Vary in Climate Response



Predicted reduction (2080) =

57%

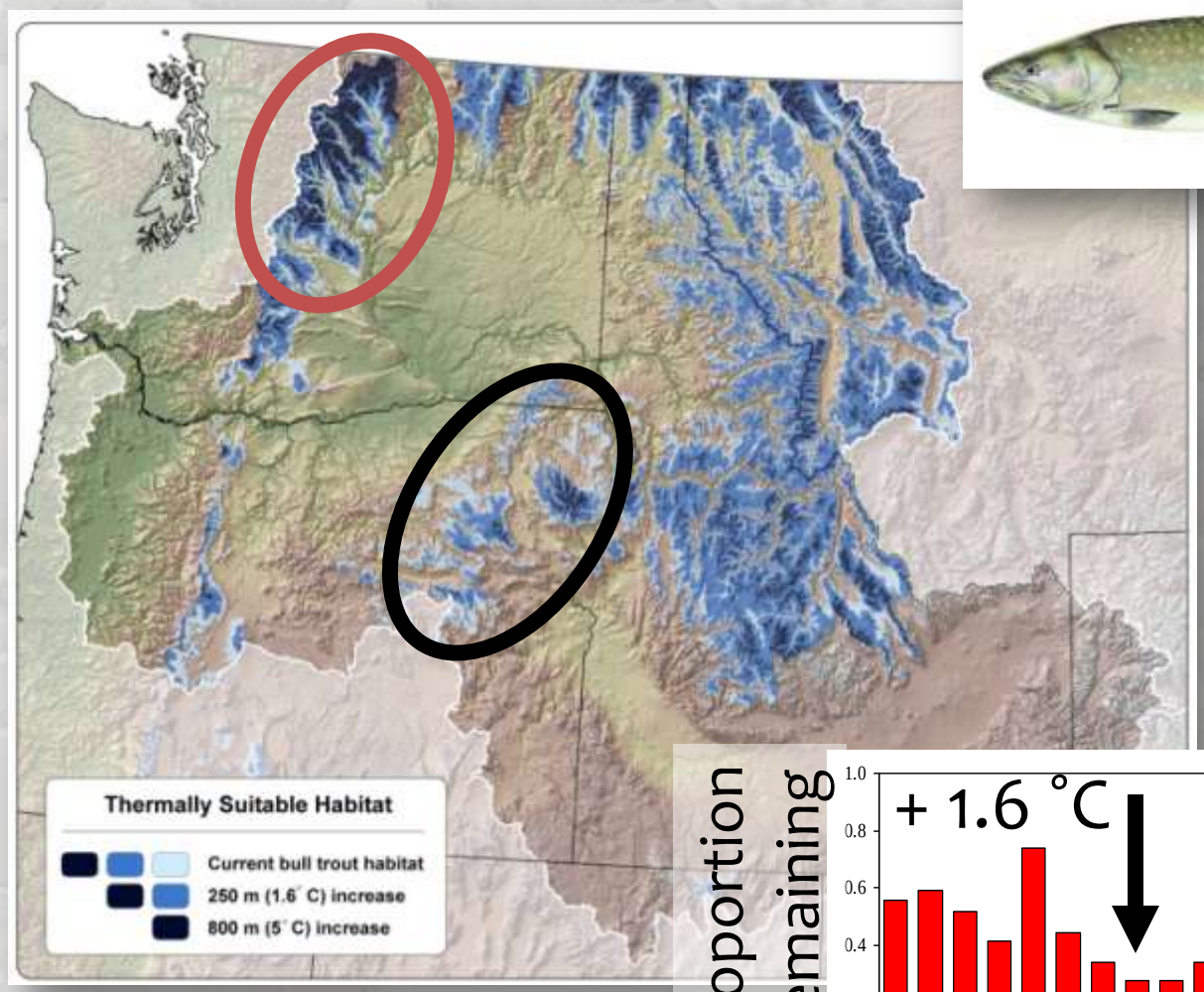
77%

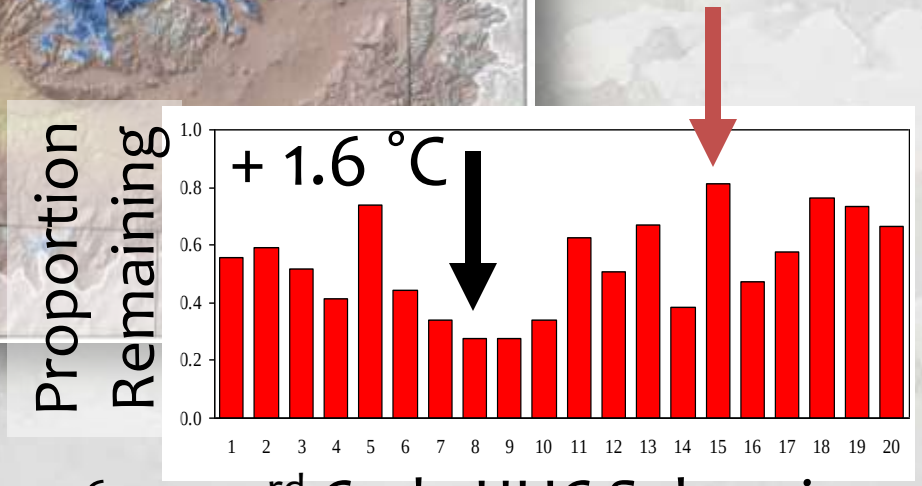
35%

48%

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

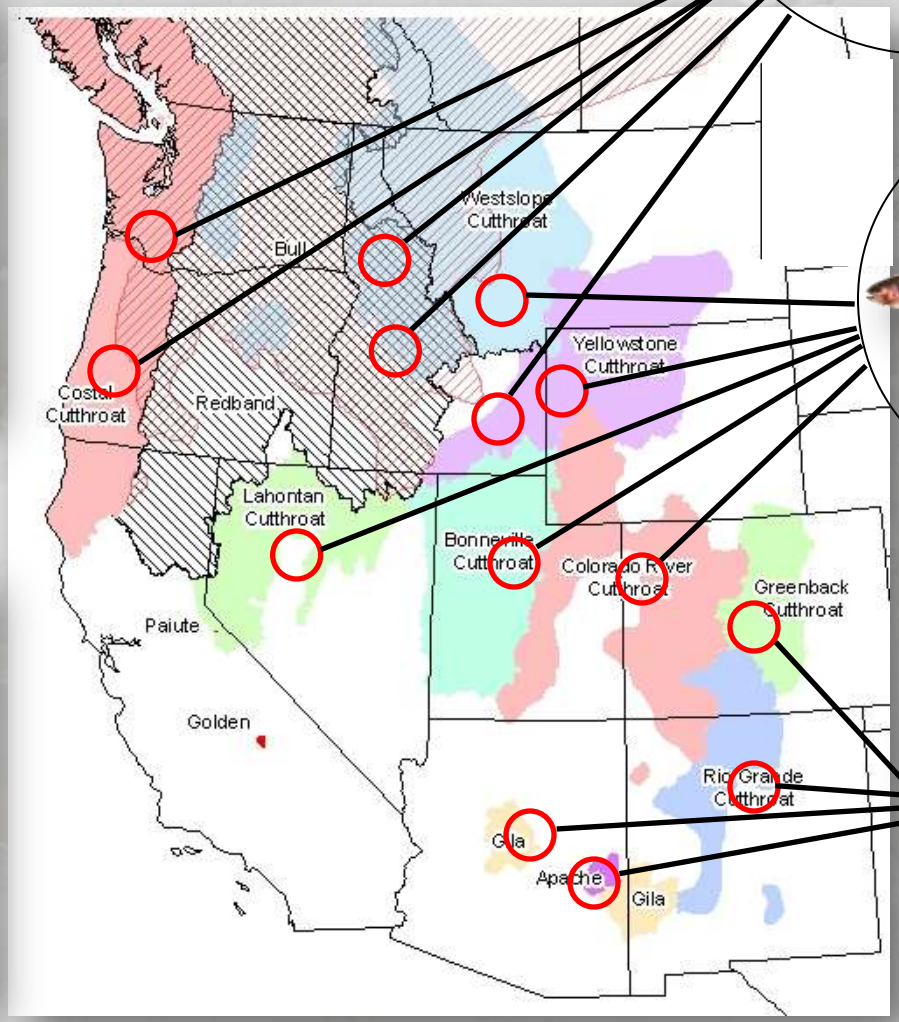
Context Matters: Spatial Variation in Habitat Loss

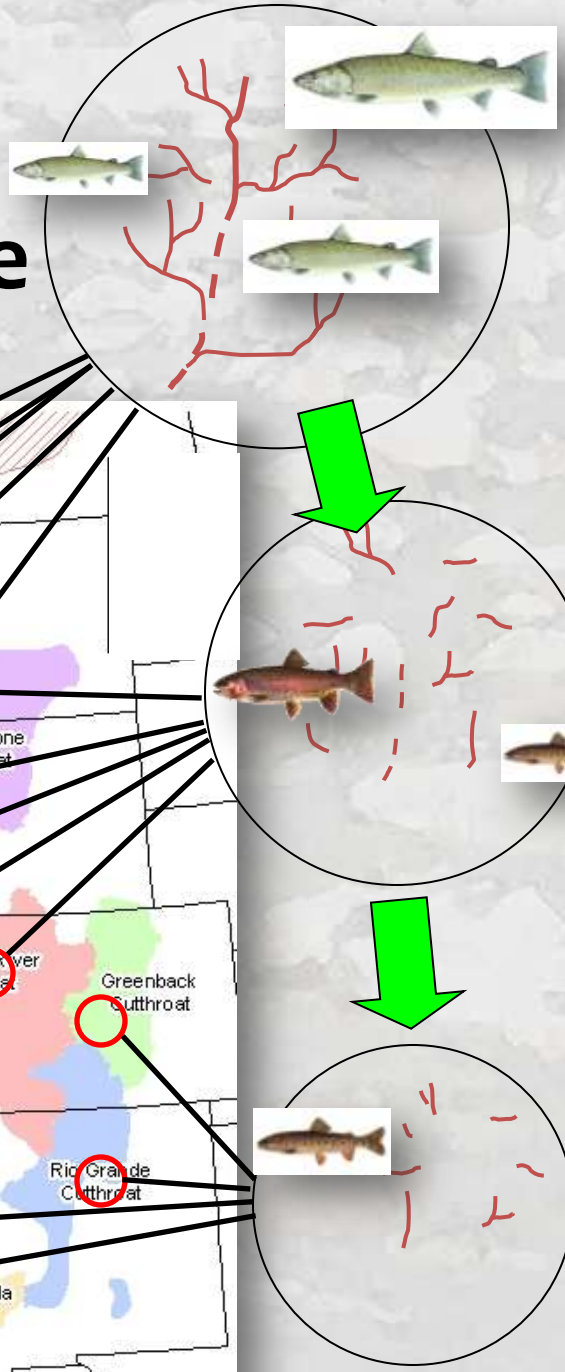




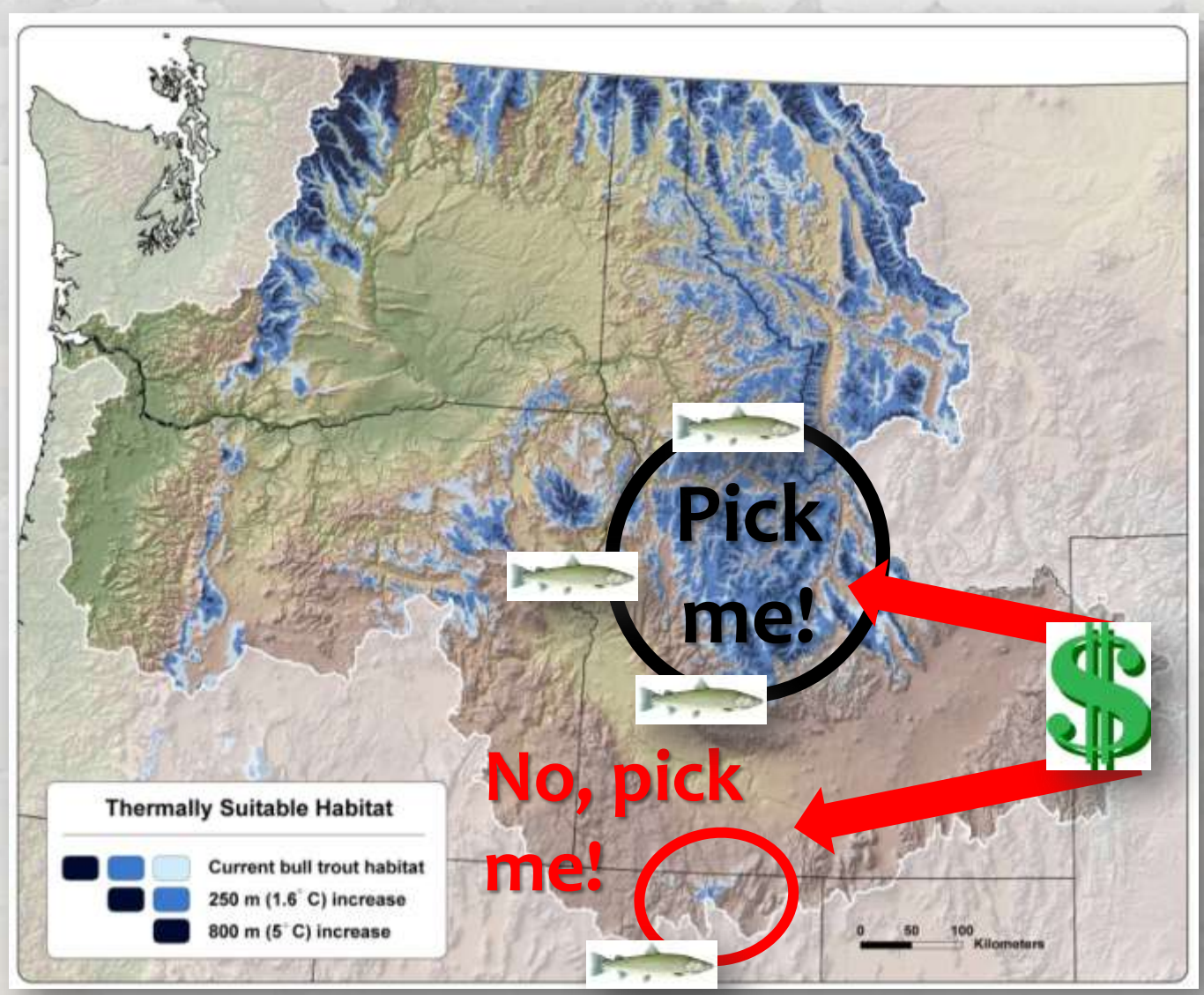
Rieman et al. 2007. *TAFS* **136**:1552-1565

Westwide Gradient in Habitat Size & Resilience

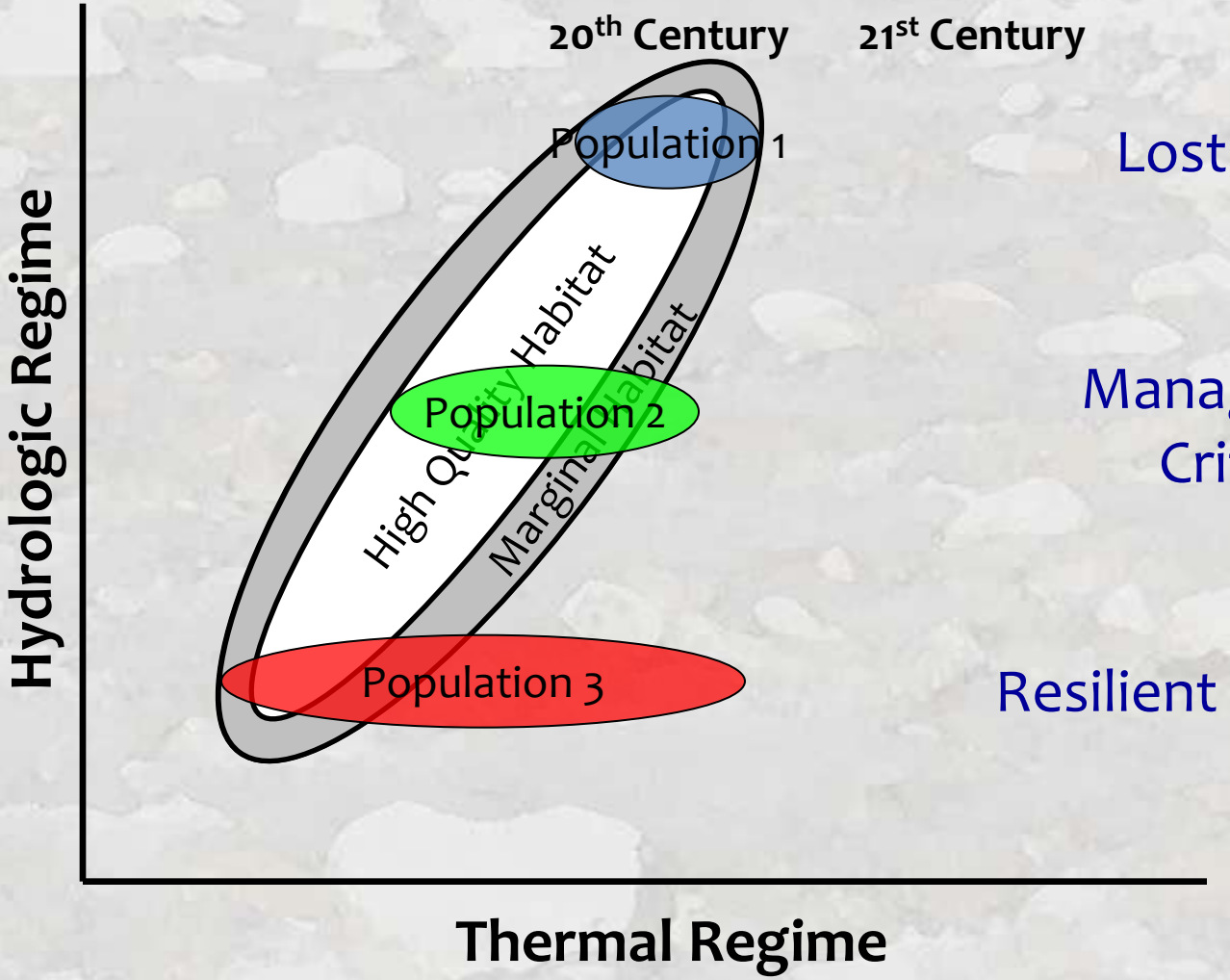




Where should conservation resources be spent?



Where Can We Make a Difference?



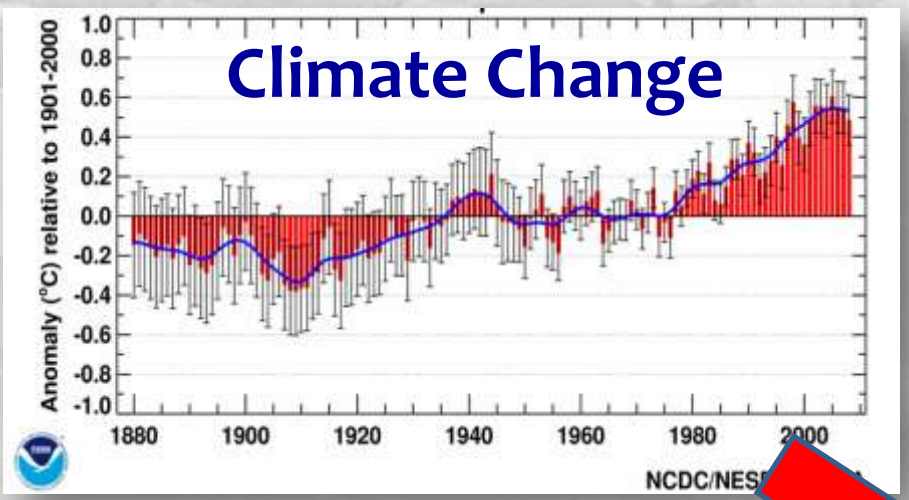
Lost Cause

Management Critical!

Resilient Population

Modified from Williams et al. 2007

More Pressure, Fewer Resources



Urbanization & Population Growth

Shrinking Budgets

Need to do more with less

There's A Lot on the Line

Climate Boogeyman

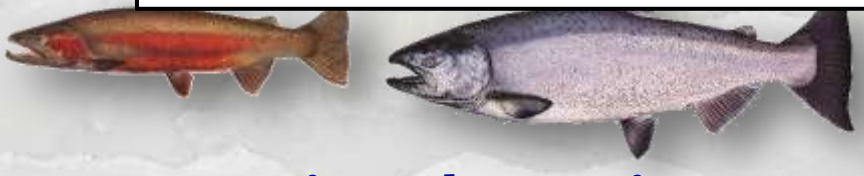
Recreational Fisheries

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

Wednesday, September 29, 2004
Fishing

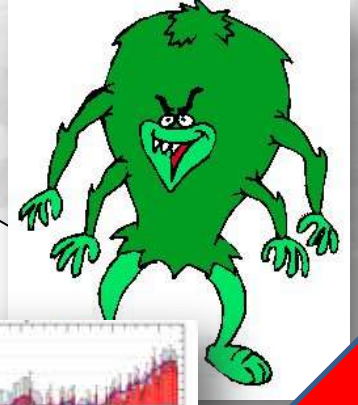
High Water Temperature In Grande

$4 - $30 Billion on Fish & Wildlife Recovery Efforts in PNW Since 1980

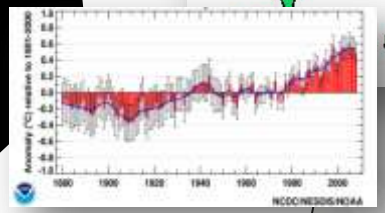


ESA Listed Species

Climate Boogeyman



Onus?



Opportunity?

Analytical Capacity

- Remote sensing/GIS
- Georeferenced, corporate databases
- Computational capacity
- Spatial models

NOAA Fisheries

IDAHO FISH & GAME

USGS science for a changing world

Washington Department of FISH and WILDLIFE

BONNEVILLE POWER ADMINISTRATION

FOREST SERVICE U.S. DEPARTMENT OF AGRICULTURE

More Collaboration

CLIMATE IMPACTS GROUP

CENTER FOR ECOHYDRAULICS RESEARCH University of Idaho

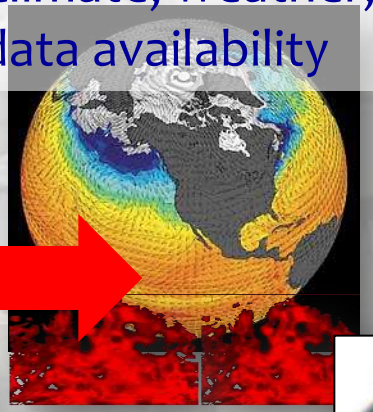
TROUT UNLIMITED

Geospatial Tools for Accurate Regional Scale Stream Models

Remote Sensing

GIS / Computing Capacity

Climate, weather, GCM data availability

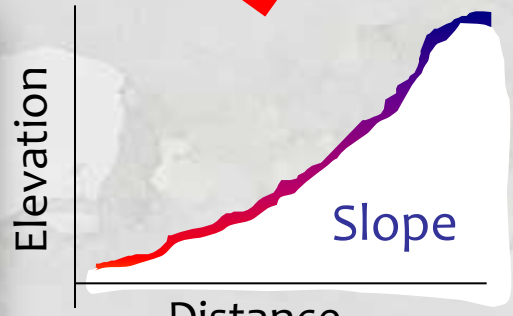


Digital sensors

Visualization Tools

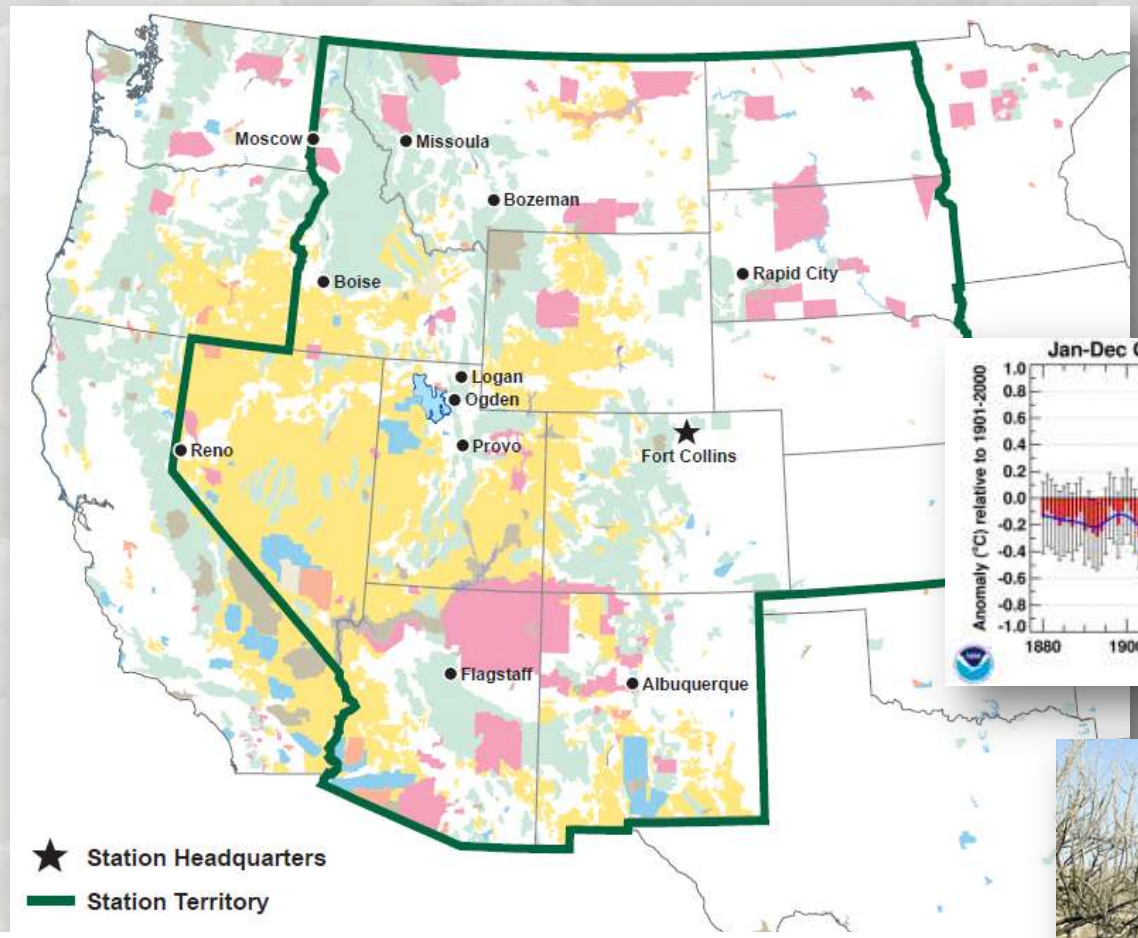
Nationally Consistent Hydrocoverages like USGS NHD+

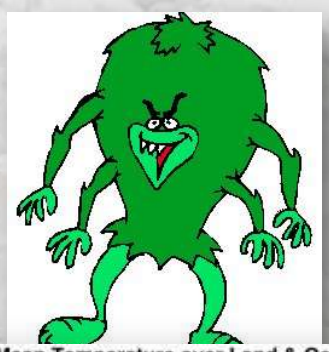
Elevation

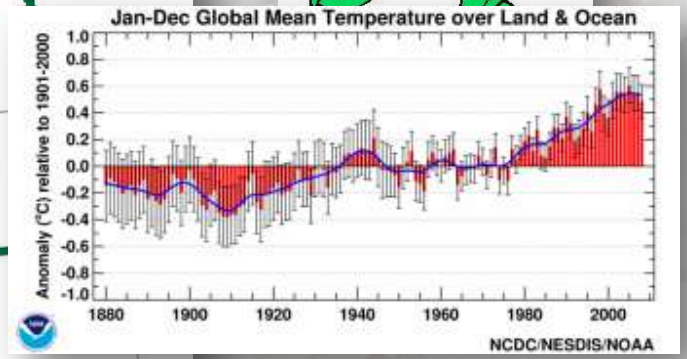


Drainage Area

Accurate, Spatially Consistent Information Needed Across Agencies

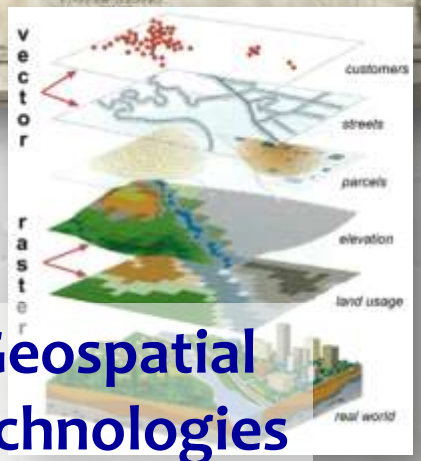






There's an army of people doing stuff if it can be coordinated…

Maps Significantly Reduce Uncertainty



Geospatial technologies

"Smart" Maps Can Be Developed from the Army's Data

NorWeST: A Regional Stream Temperature Database & Model for High-Resolution Climate Vulnerability Assessments

Dan Isaak, Seth Wenger[1], Erin Peterson[2], Jay Ver Hoef[3] Charlie Luce, Steve Hostetler[4], Jason Dunham[4], Jeff Kershner[4], Brett Roper, Dave Nagel, Dona Horan, Gwynne Chandler, Sharon Parkes, Sherry Wollrab

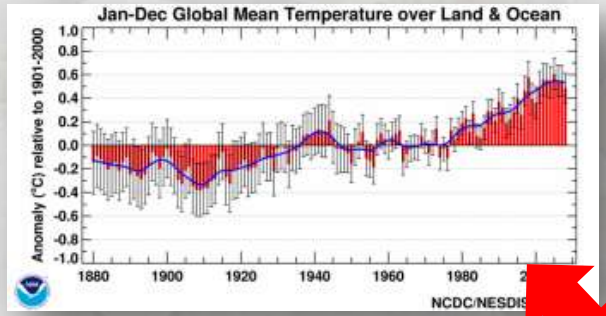
U.S. Forest Service

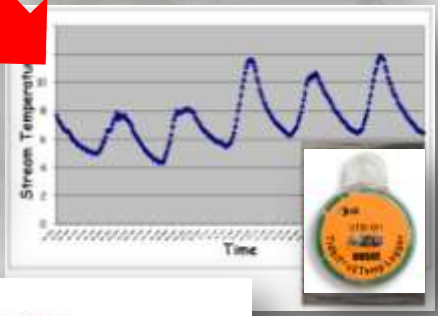
[1]Trout Unlimited

[2]CSIRO

[3]NOAA

[4]USGS





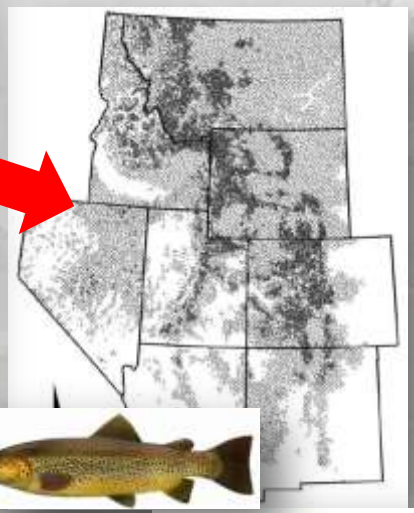
USGS science for a changing world

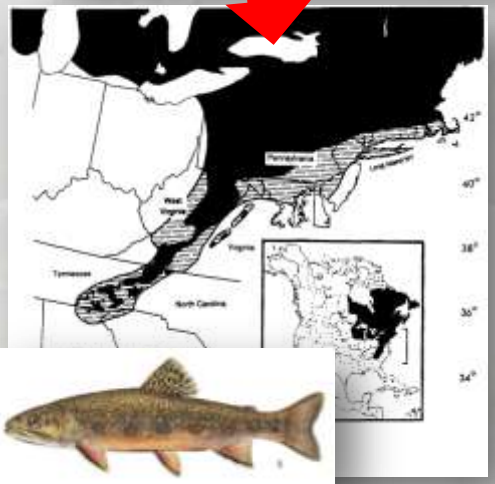
Great Northern LANDSCAPE CONSERVATION COOPERATIVE

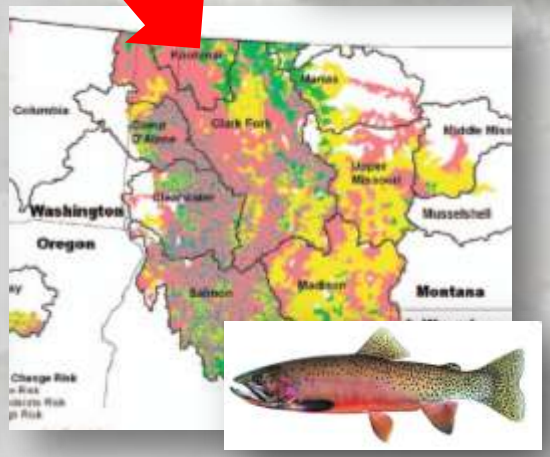
Previous Trout Climatic Assessments

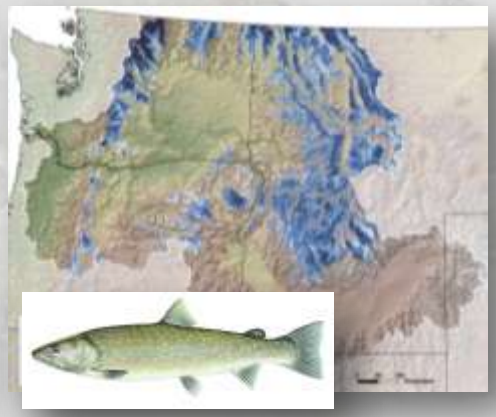
No stream temperature component

PRISM Air Map





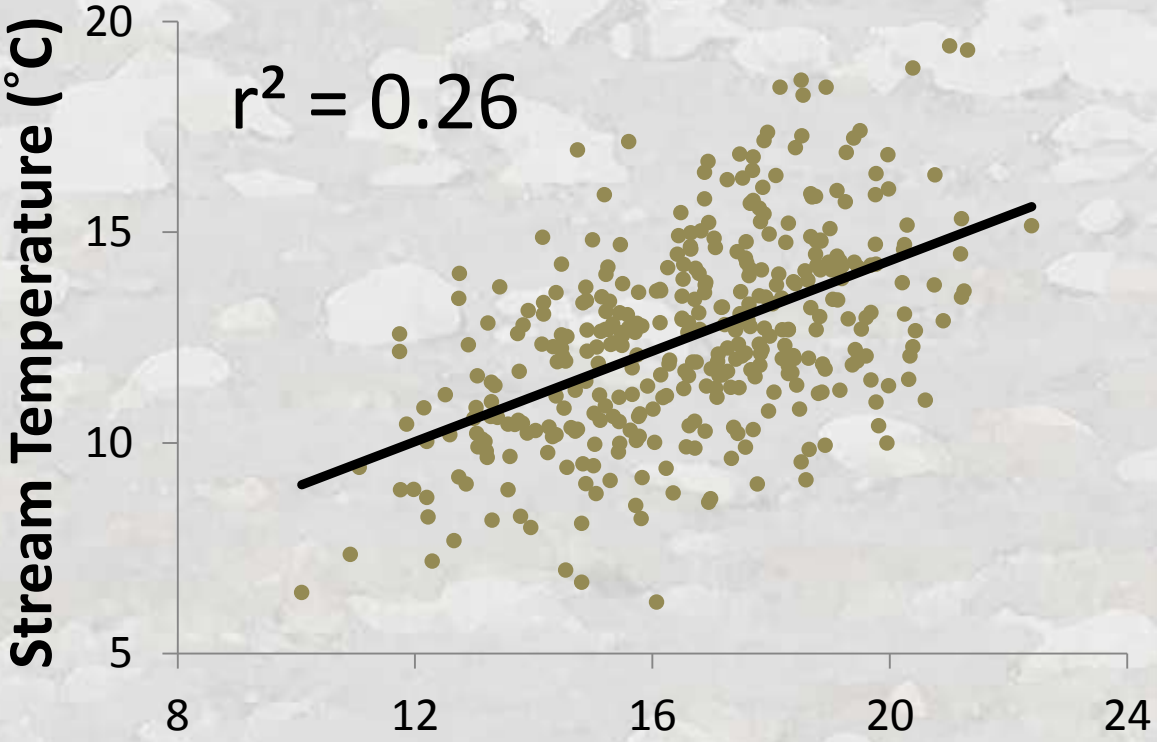


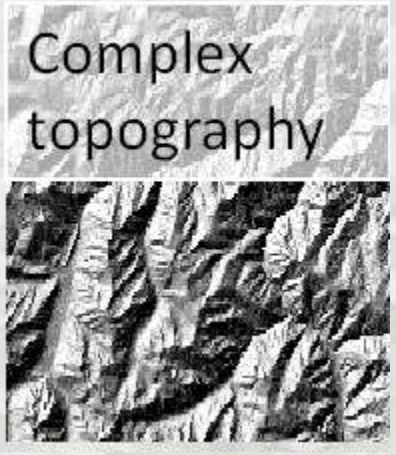


Air Temperatures…

- Meisner 1988, 1990
- Eaton & Schaller 1996
- Keleher & Rahel 1996
- Rahel et al. 1996
- Mohseni et al. 2003
- Flebbe et al. 2006
- Rieman et al. 2007
- Kennedy et al. 2008
- Williams et al. 2009
- Wenger et al. 2011
- Almodovar et al. 2011
- Etc.

Air Temp ≠ Stream Temp



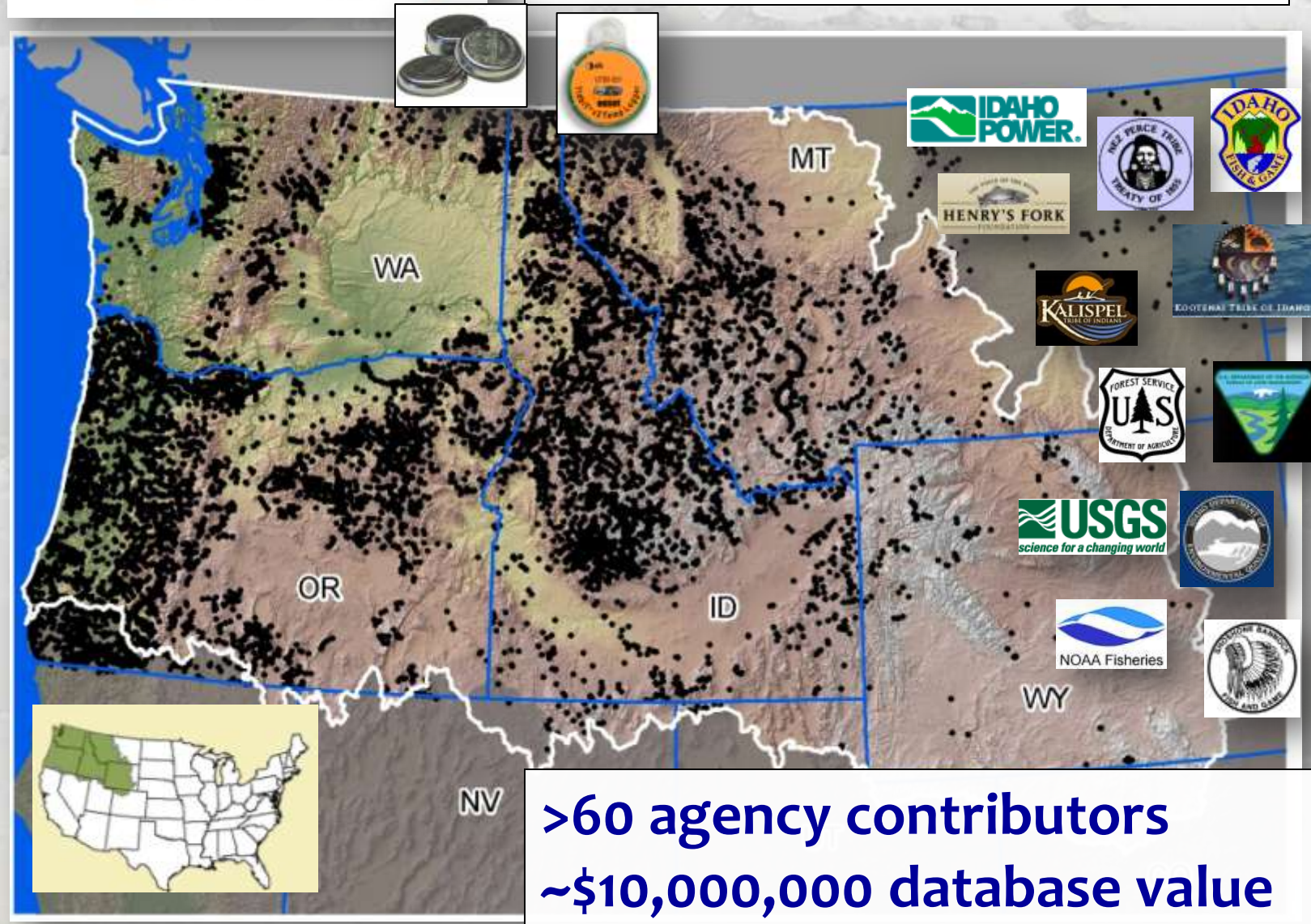


Lots of Temperature Data Out There…

Stealth Sensor Network

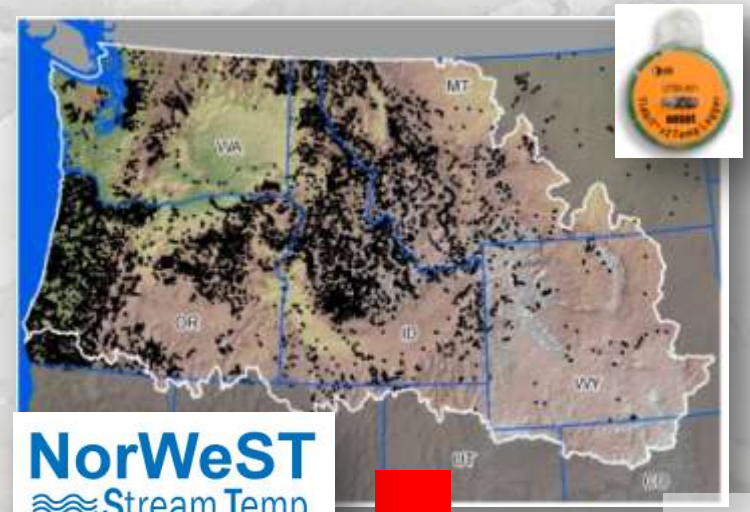
NorWeST Stream Temp

>45,000,000 hourly records
>15,000 unique stream sites

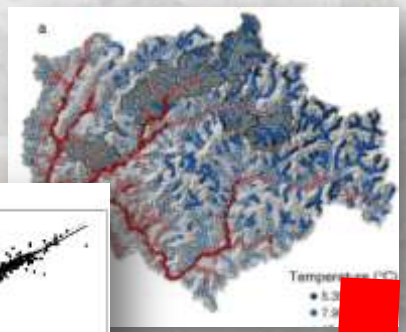


>60 agency contributors
~$10,000,000 database value

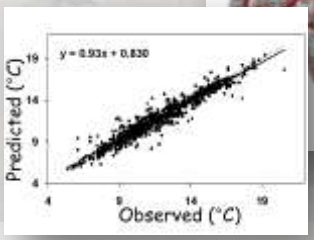
Regional Temperature Model



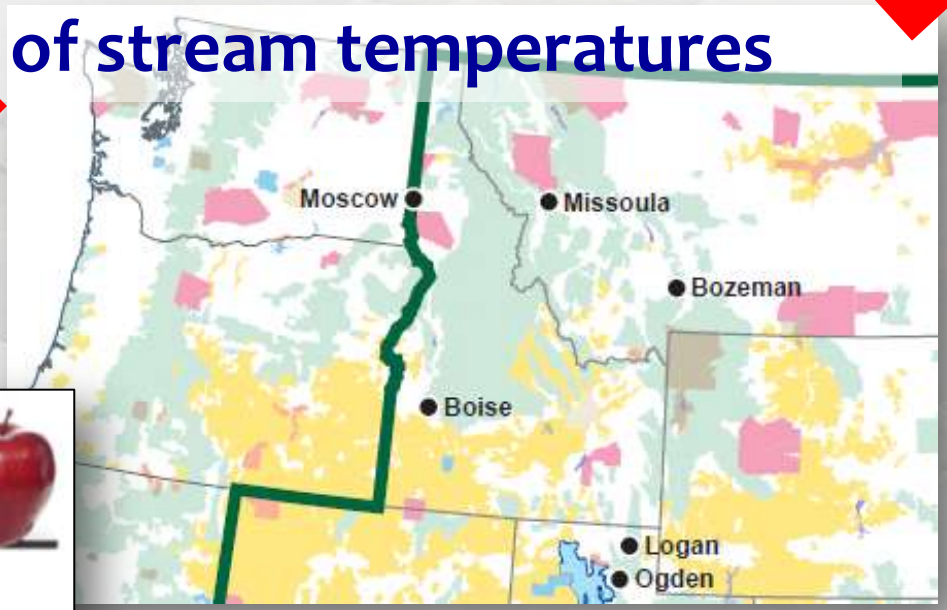
Accurate temperature models



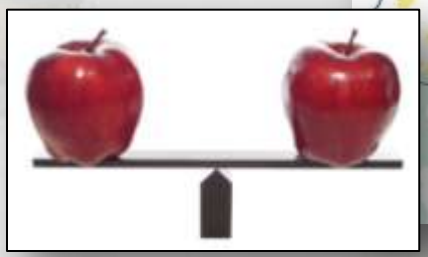
+



Cross-jurisdictional "maps" of stream temperatures

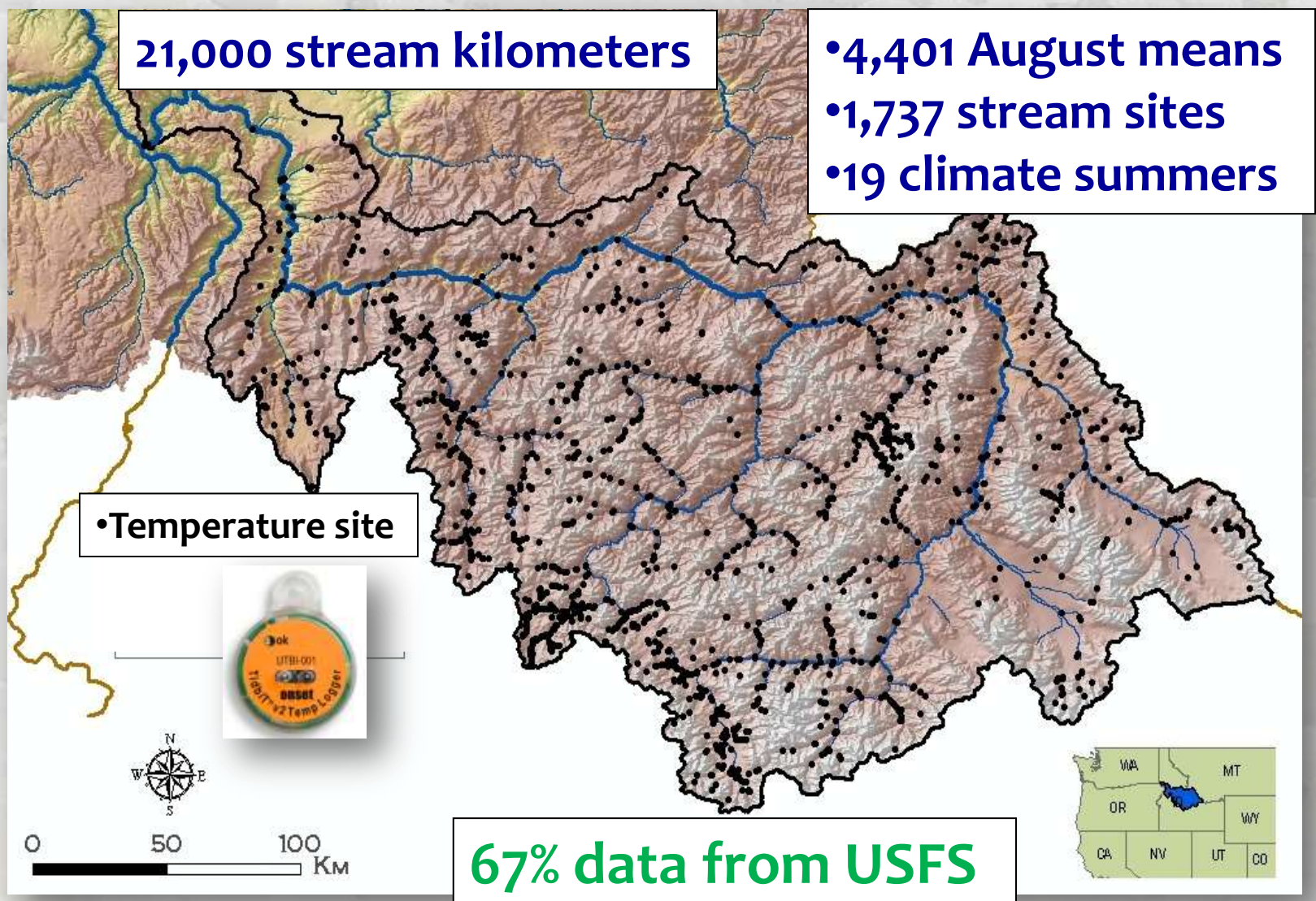


Consistent datum for strategic assessments across 350,000 stream kilometers



Example: Salmon River Basin

Data extracted from NorWeST



Salmon River Temperature Model

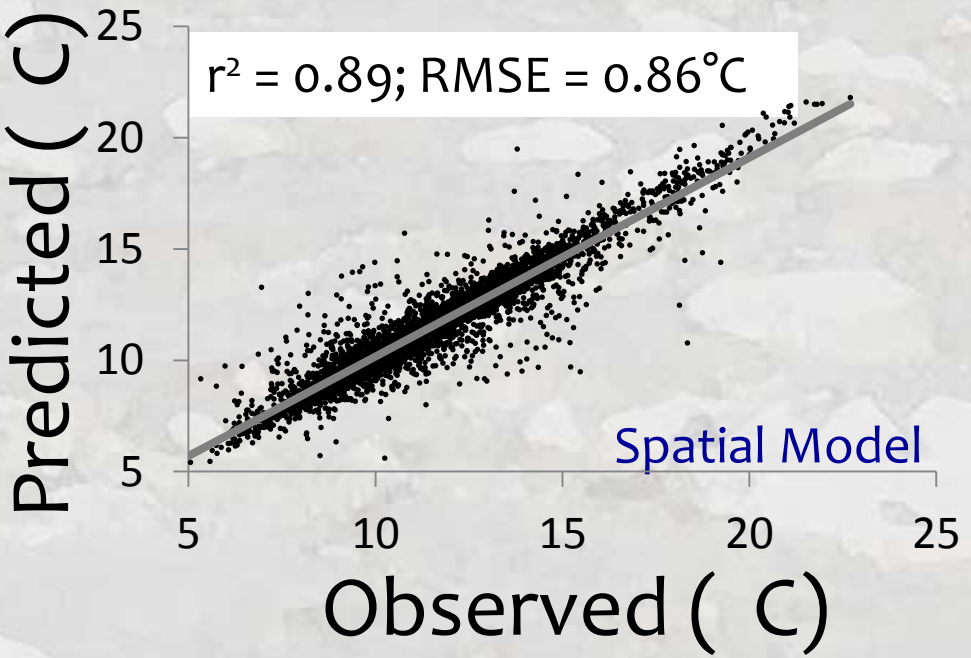
n = 4,401

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 (km^2)

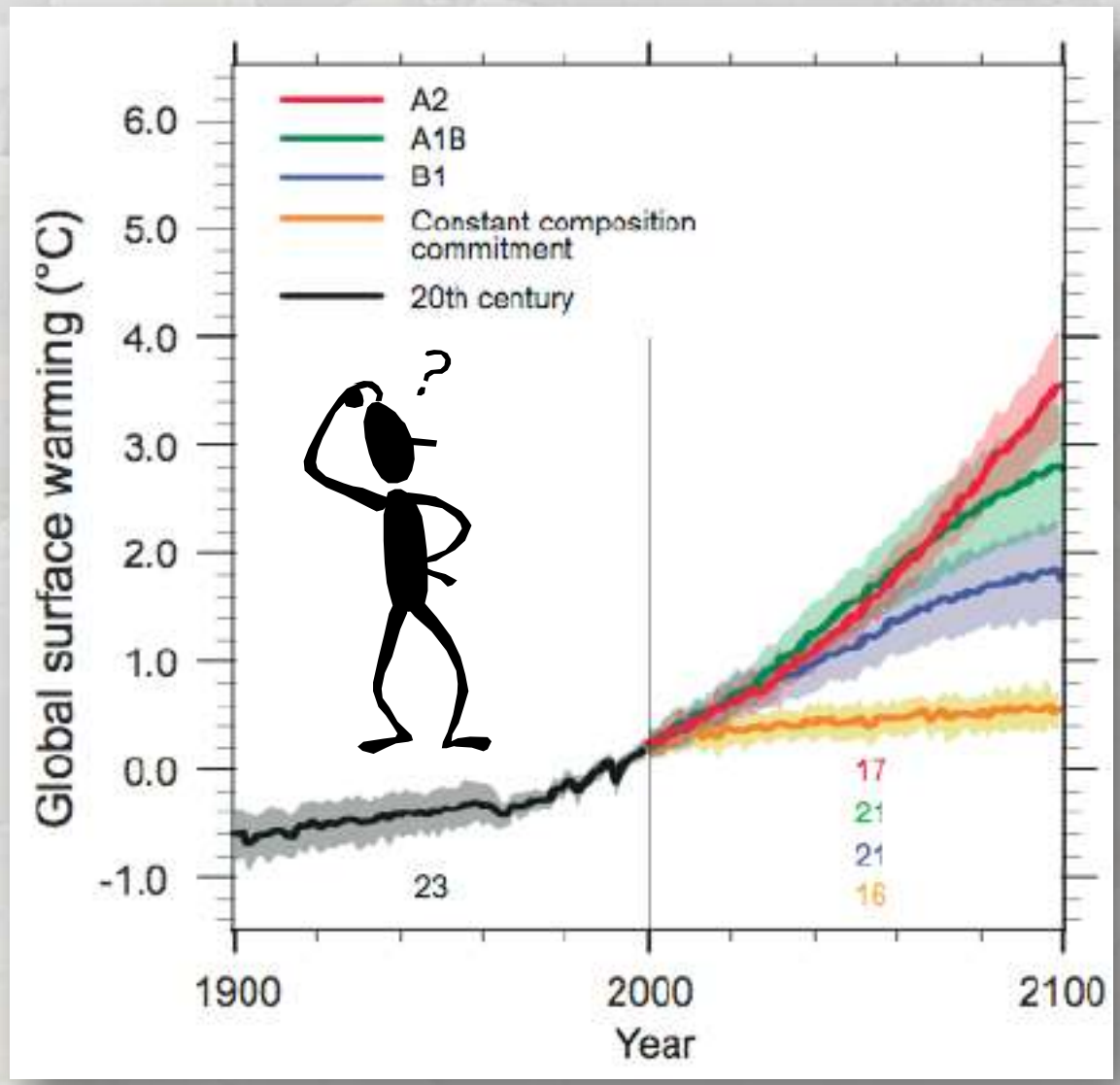
9. Discharge (m^3/s)
   USGS gage data
10. Air Temperature (˚C)
    RegCM3 NCEP reanalysis
    Hostetler et al. 2011

Mean August Temperature



Models Enable Climate Scenario Maps

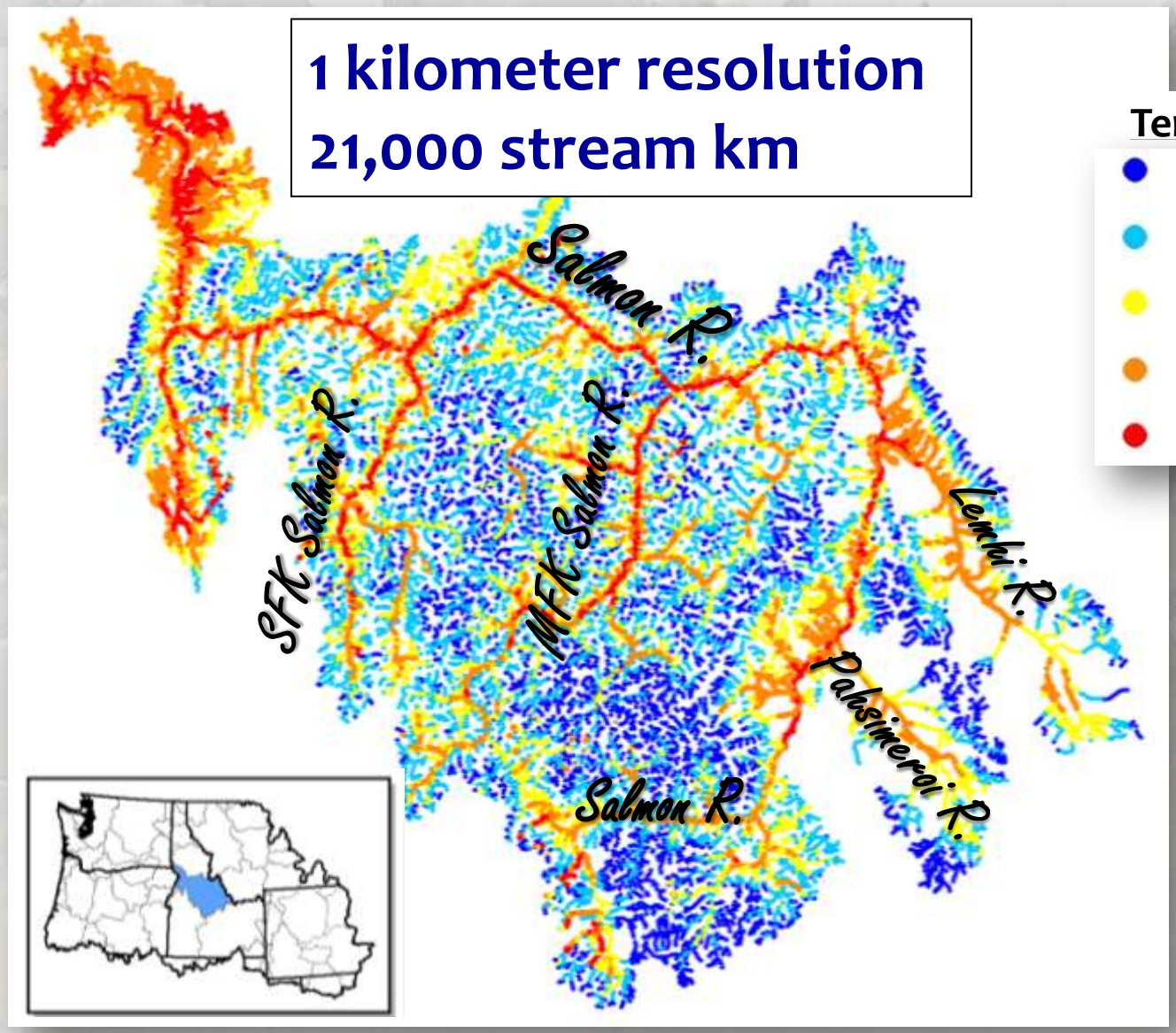
Many possibilities exist…



Adjust air & discharge values to represent scenarios

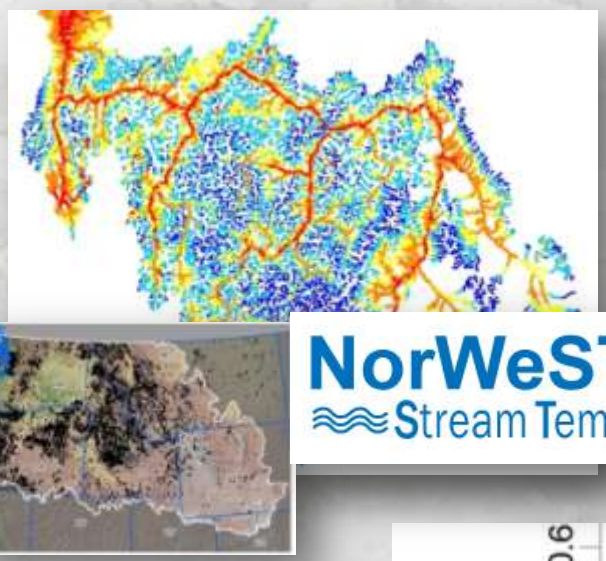
Historic Scenario: Salmon River (S2_02-11)

2002-2011 mean August stream temperatures

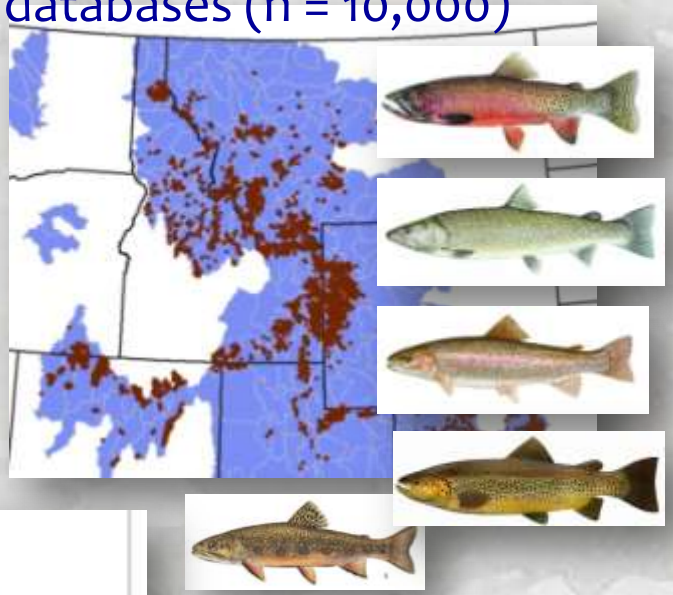


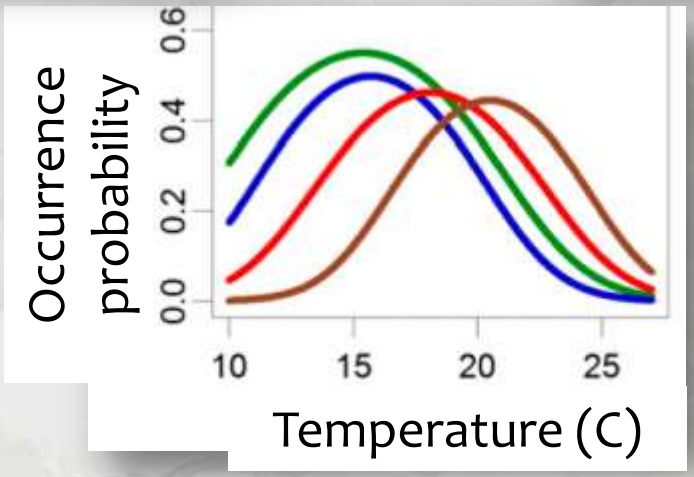
Translate Stream Temperature Maps to Thermally Suitable Habitats

Stream temperature maps



Regional fish survey databases (n = 10,000)





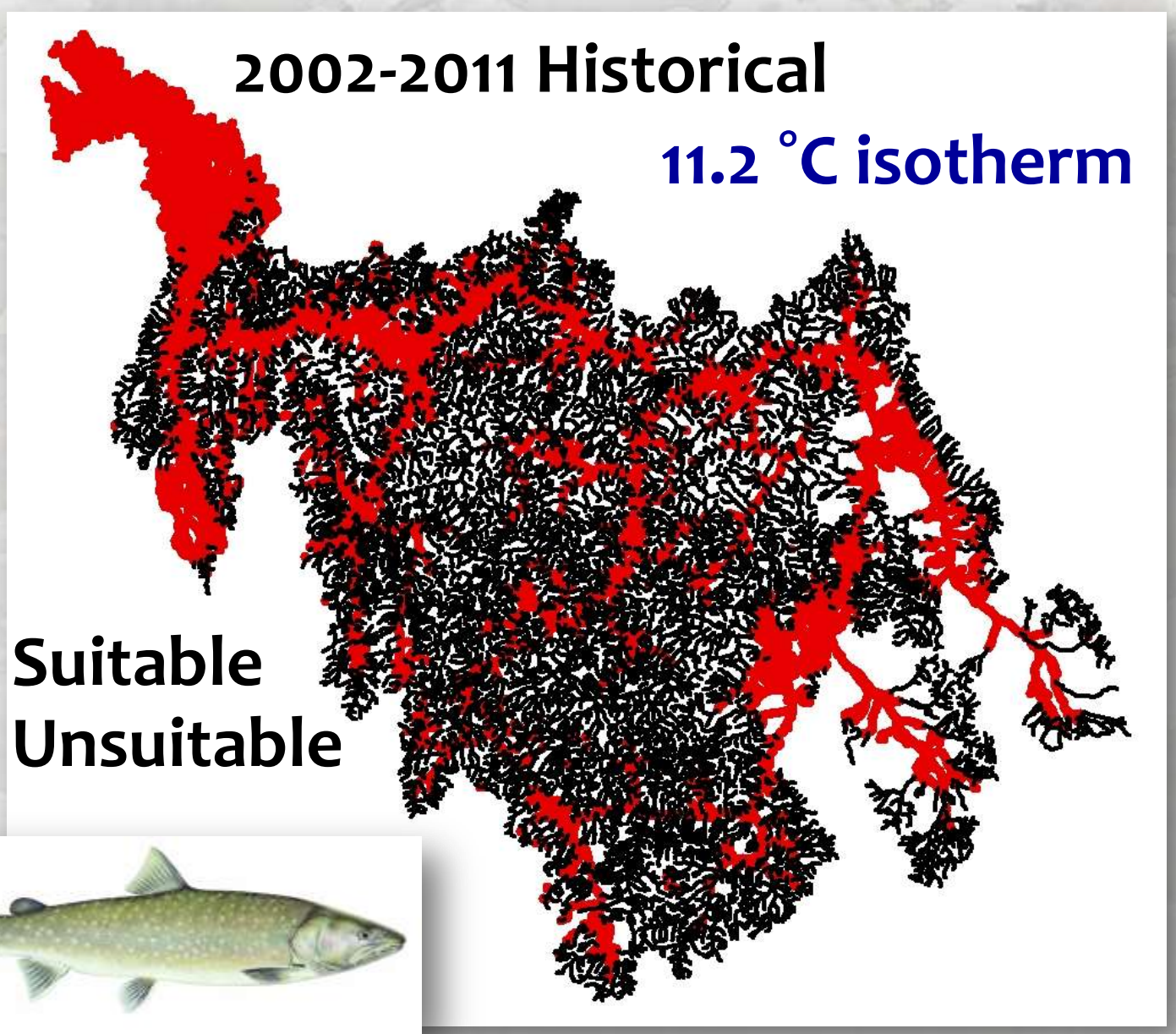
Wenger et al. 2011a. *PNAS* **108**:14175-14180
Wenger et al. 2011b. *CJFAS* **68**:988-1008; Wenger et al., *In Preparation*

Generalizable to All Stream Biotas

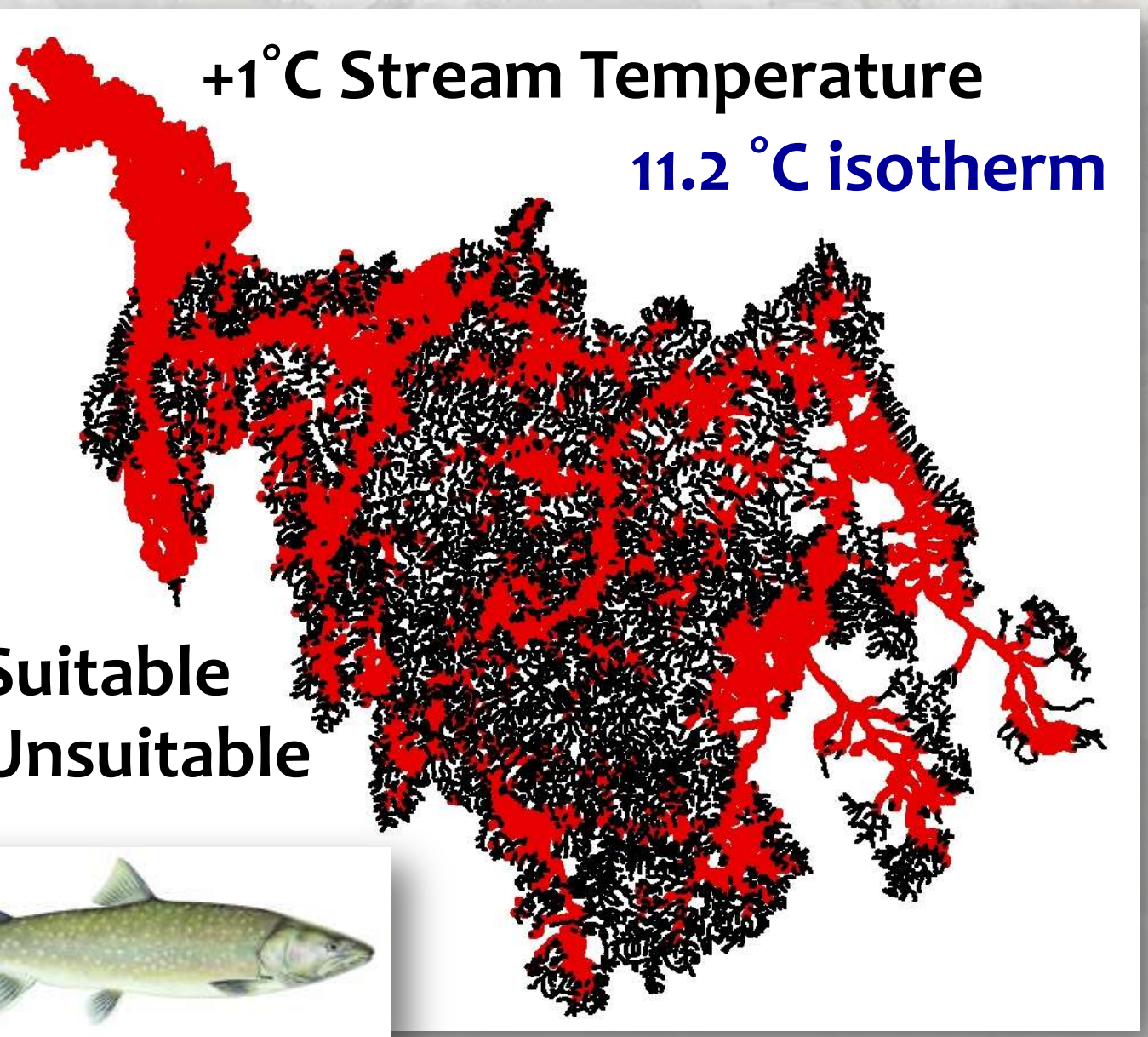
There will be other vulnerable species besides trout

Too warm…Too cold… Just right

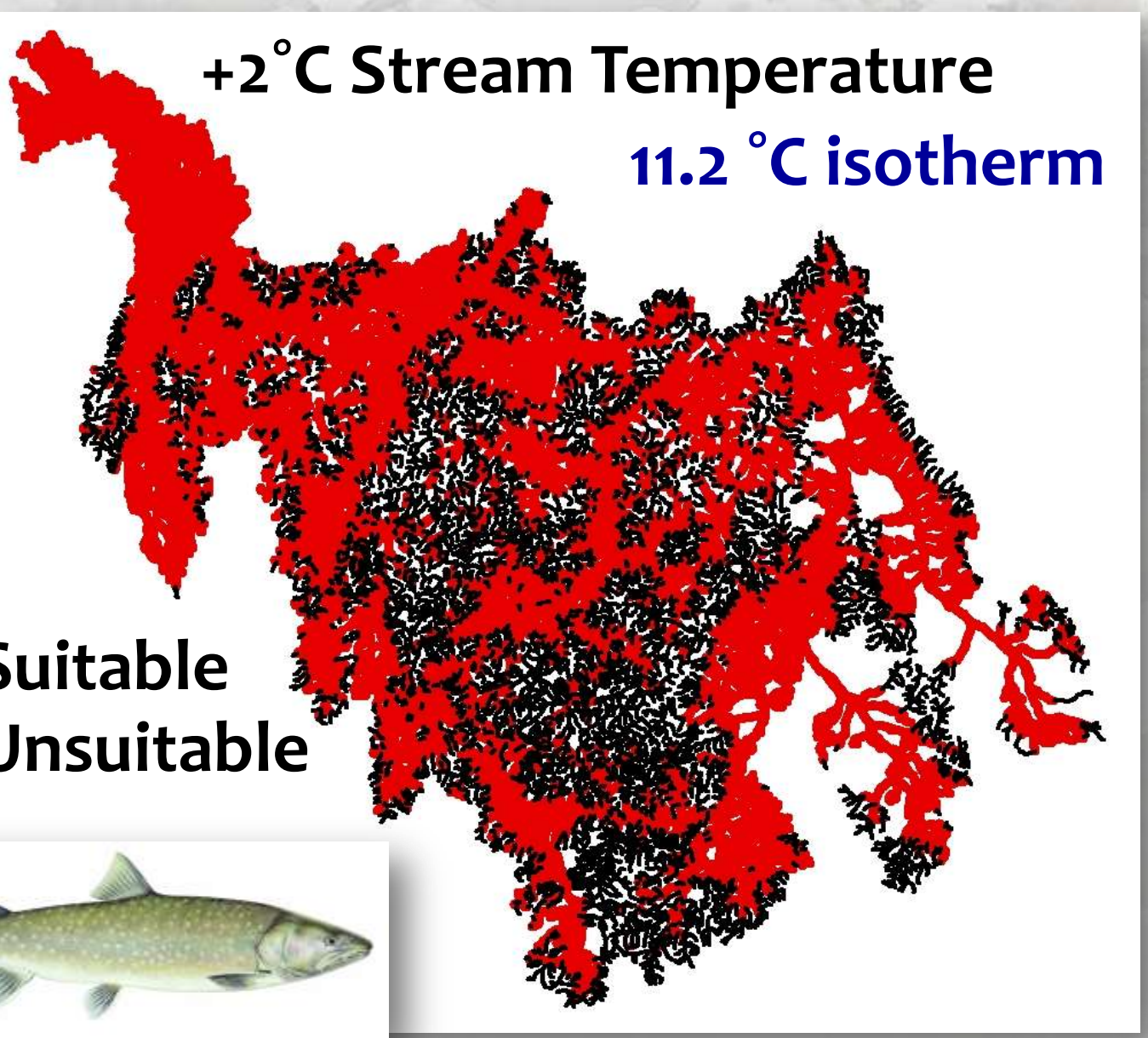
Salmon River Bull Trout Habitats



Salmon River Bull Trout Habitats

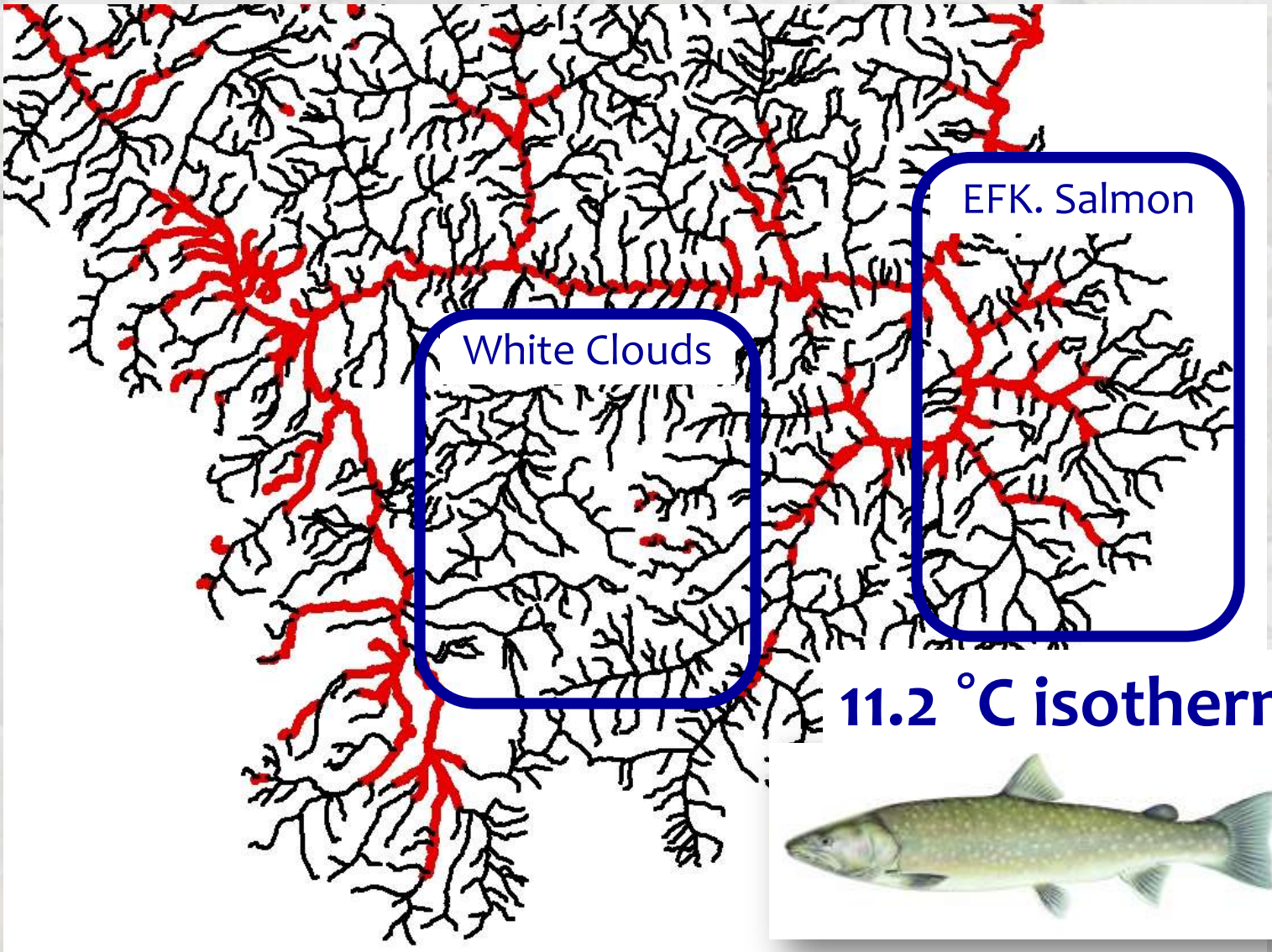


Salmon River Bull Trout Habitats



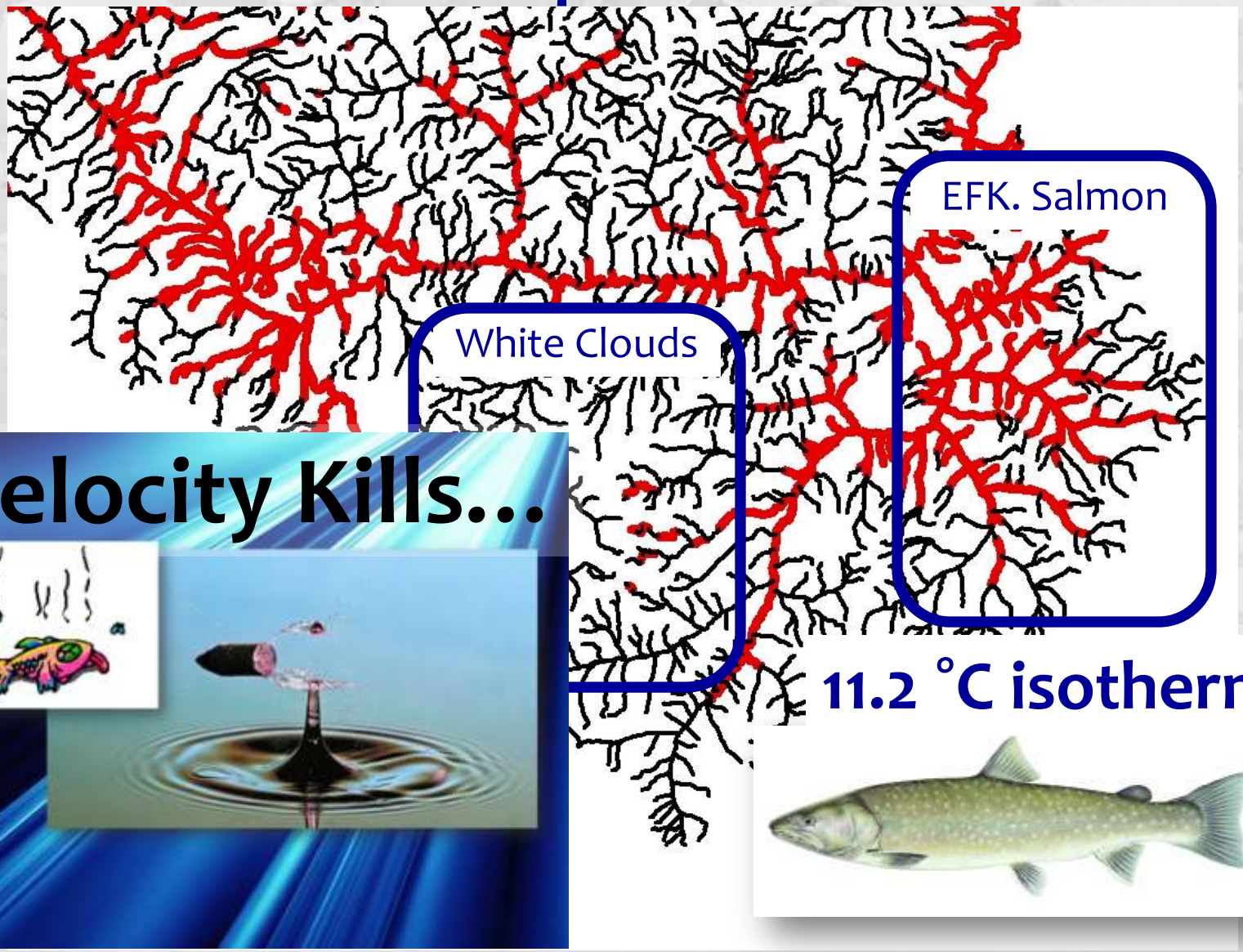
Spatial Variation in Habitat Loss

2002-2011 historical scenario



Spatial Variation in Habitat Loss

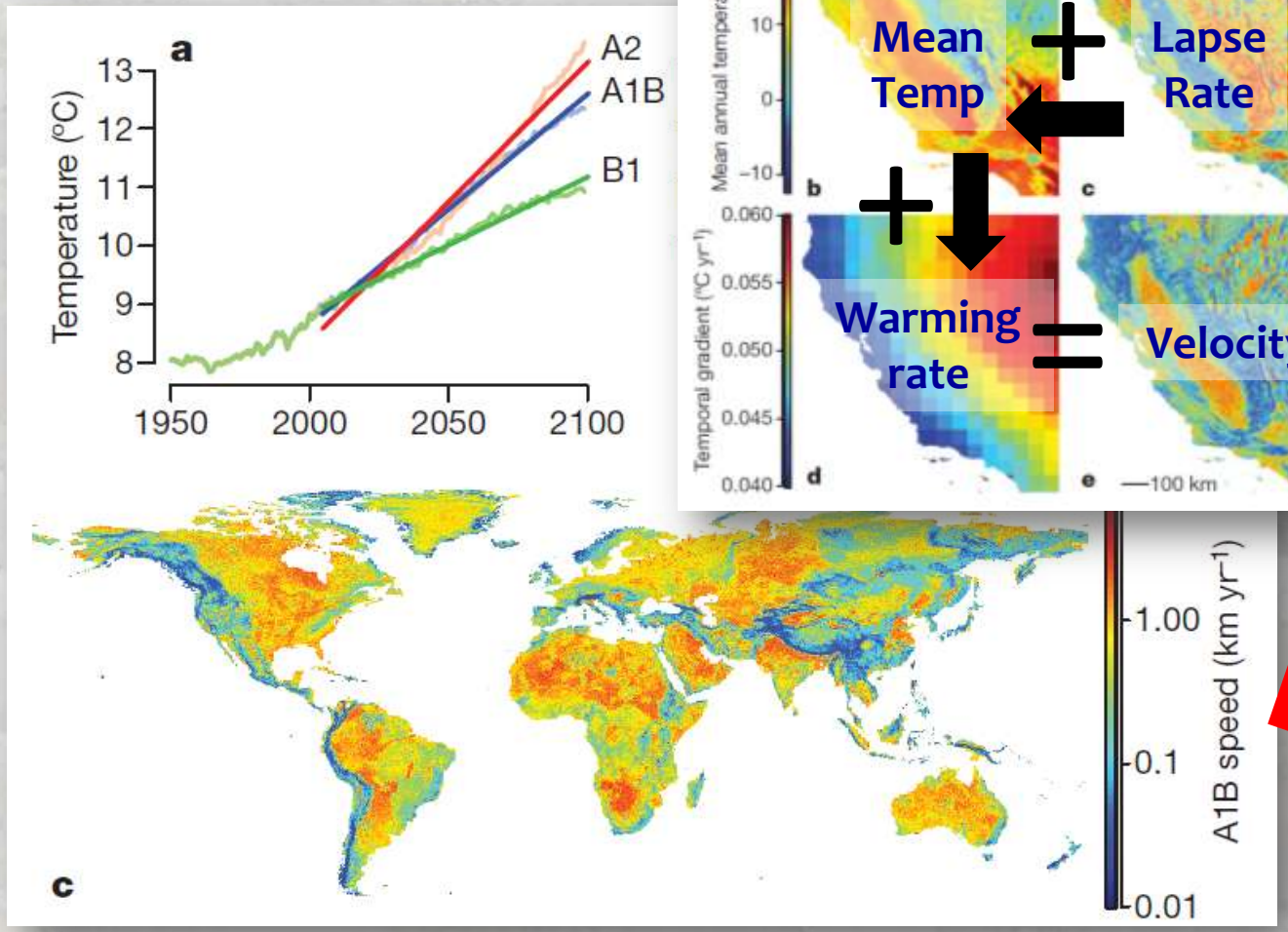
+1°C stream temperature scenario



Velocity Kills…

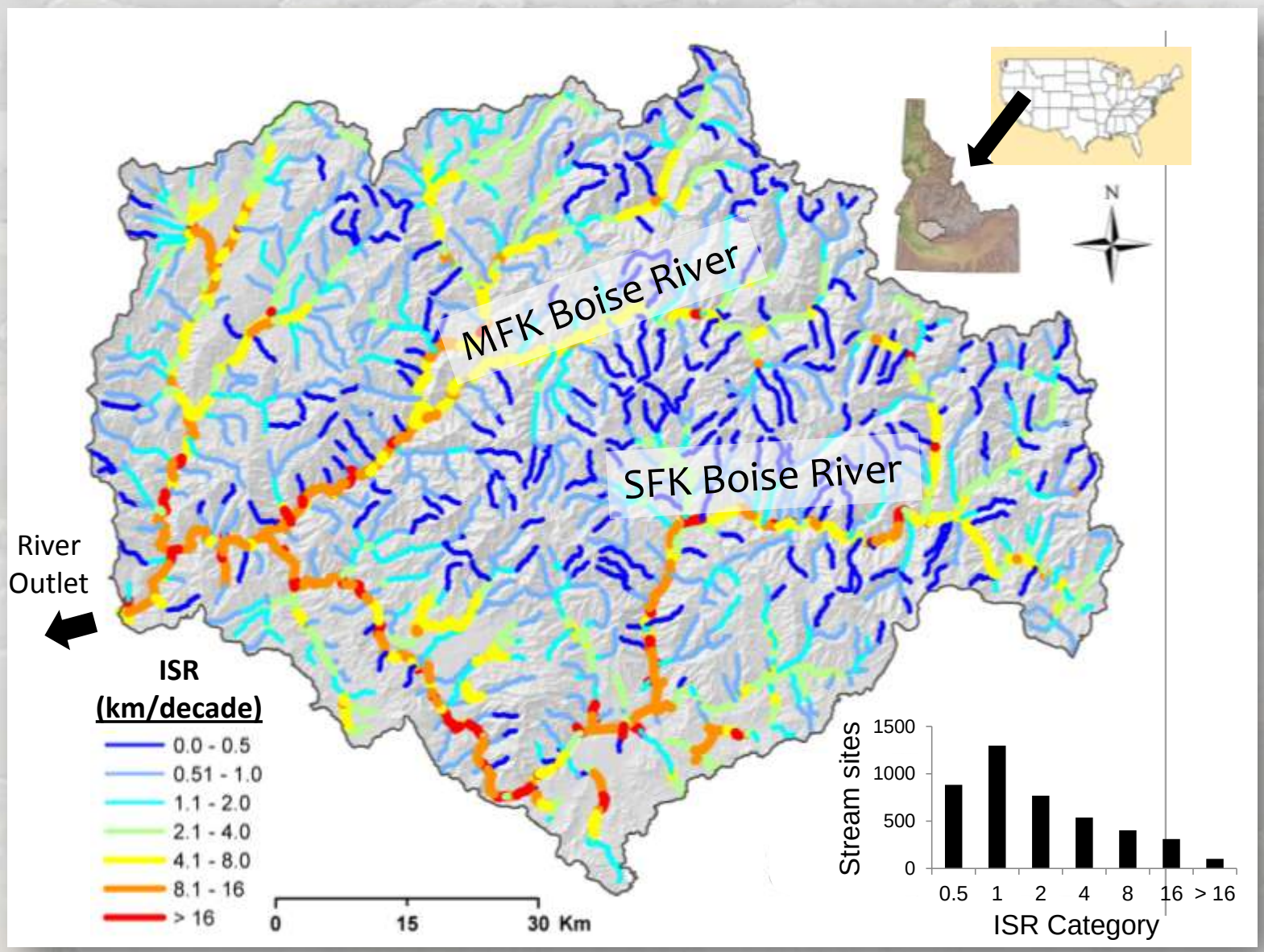
11.2 °C isotherm

Climate Velocity is How Fast Isotherms Shift Across the Earth's Surface



Loarie et al. 2009. *Nature* **462**:1052-1055.

Climate Velocity Map for River Network



Isaak & Rieman. 2012. *Global Change Biology* **19**, doi: 10.1111/gcb.12073

Mainstem Fisheries Will See First & Most Pronounced Thermal Impacts

High Water Temperature In Grande Ronde Kills 239 Adult Spring Chinook

Columbia Basin Bulletin, August 14, 2009 (PST)

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

Wednesday, September 29, 2004
Fishing

PRINT SHARE

denverpost.com

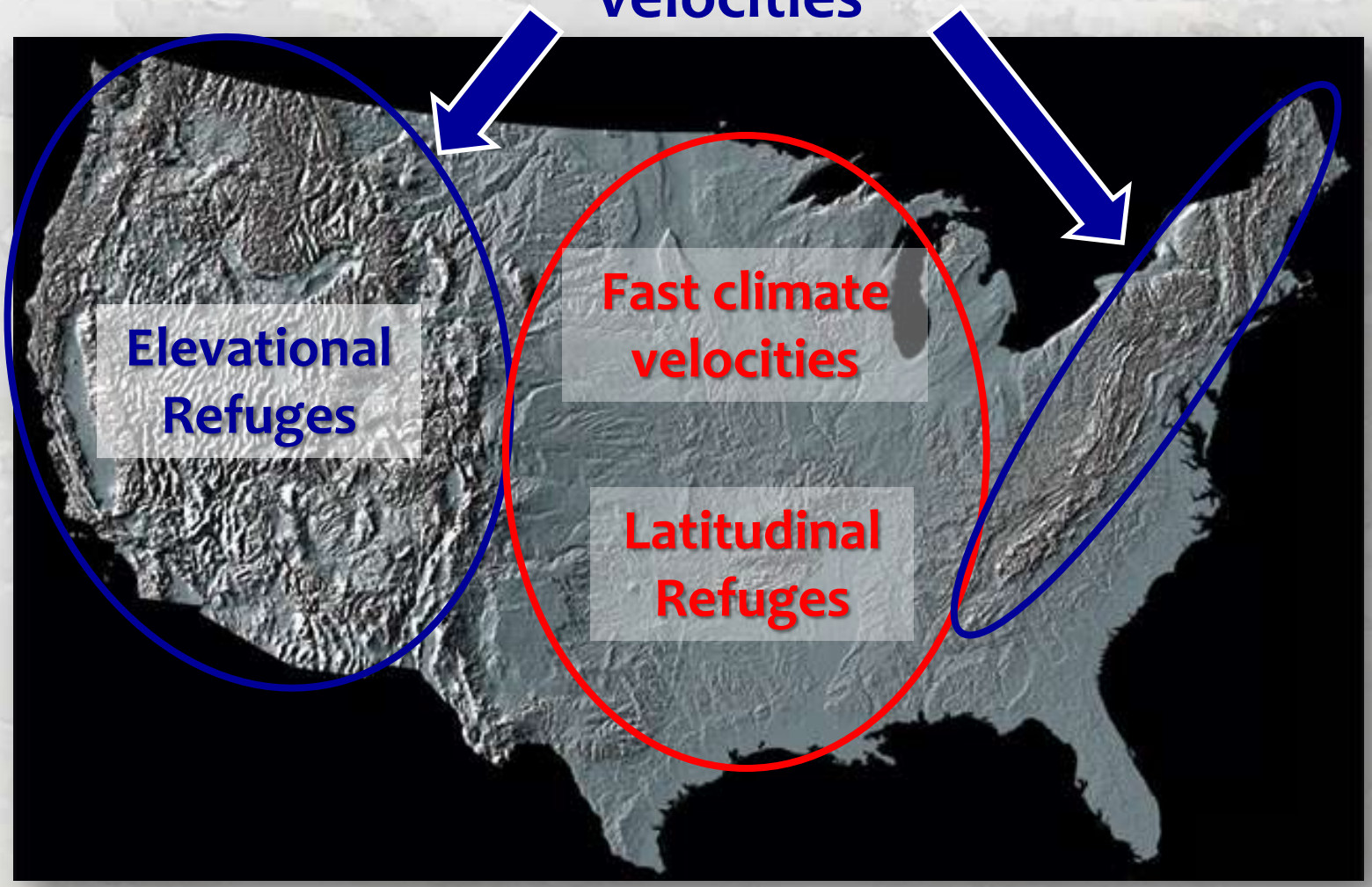
FISHING

Heat causing fishing closures

PRINT EMAIL
0 COMMENTS

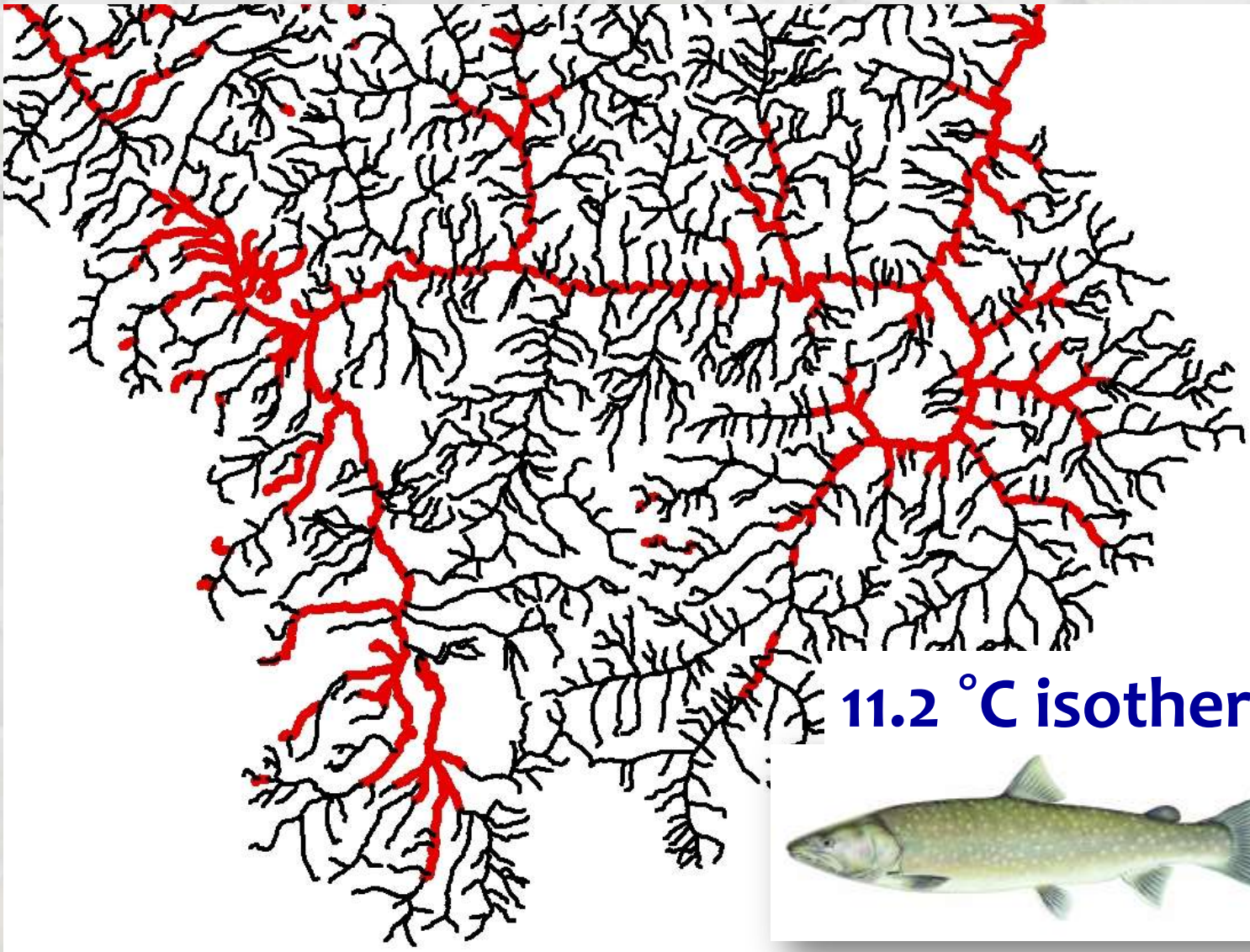
July 3, 2012

Topography & Climate Vulnerability



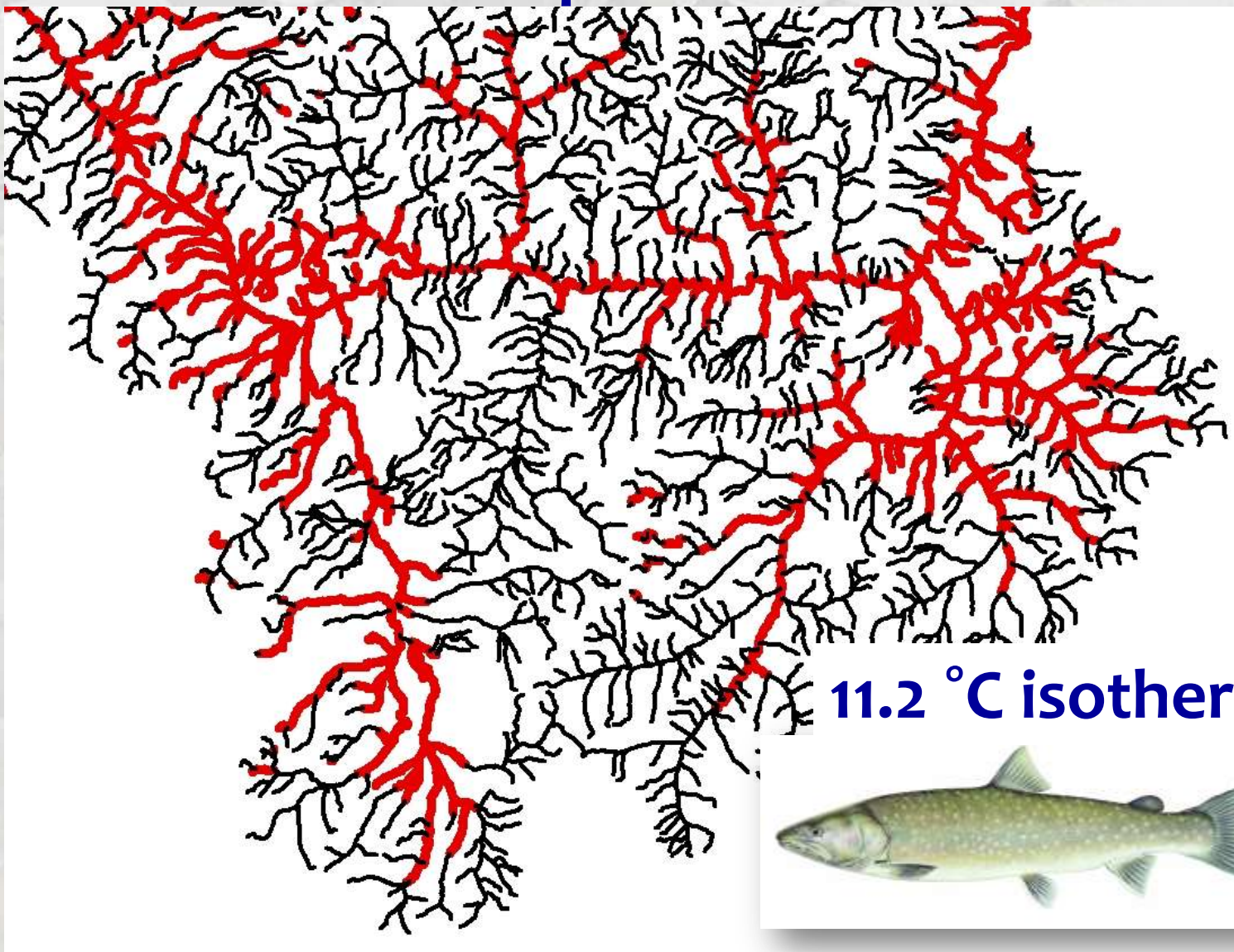
Spatial Variation in Habitat Loss

2002-2011 historical scenario



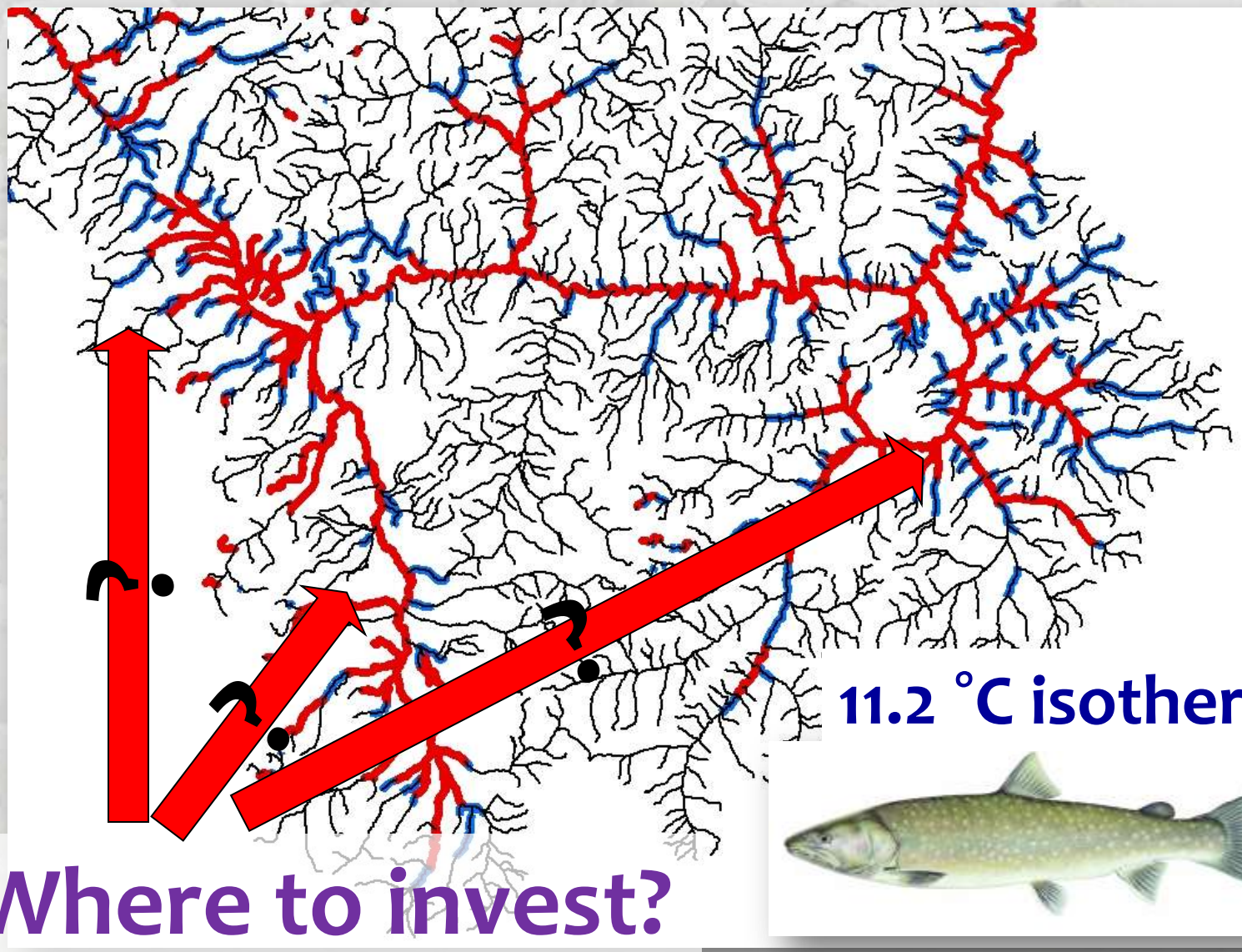
Spatial Variation in Habitat Loss

+1°C stream temperature scenario



Difference Map Shows Vulnerable Habitats

+1°C stream temperature scenario



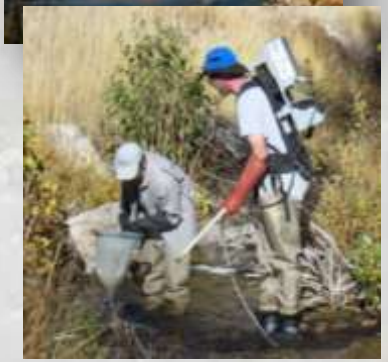
11.2 °C isotherm

Where to invest?

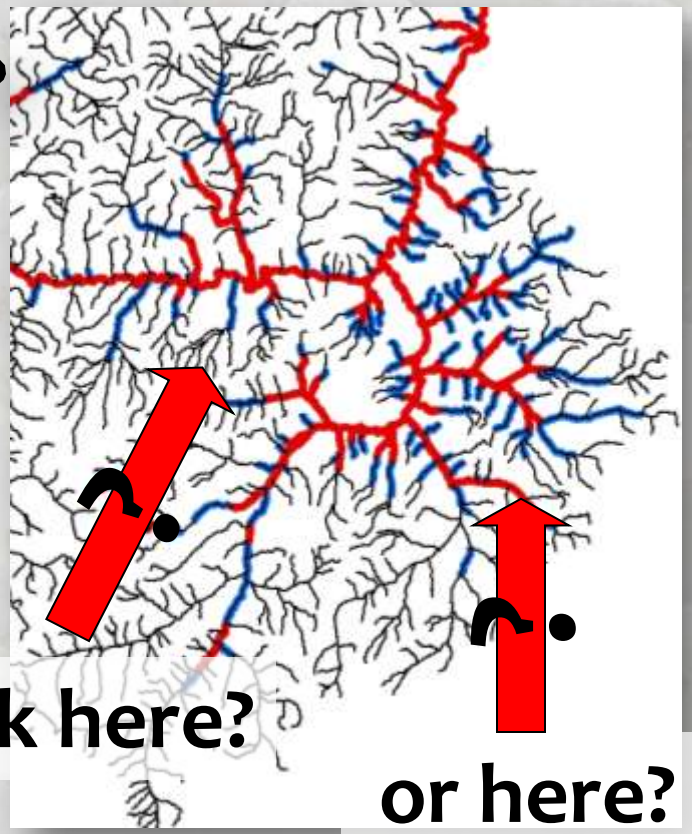
Strategic Prioritization of Restoration Actions is Possible

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







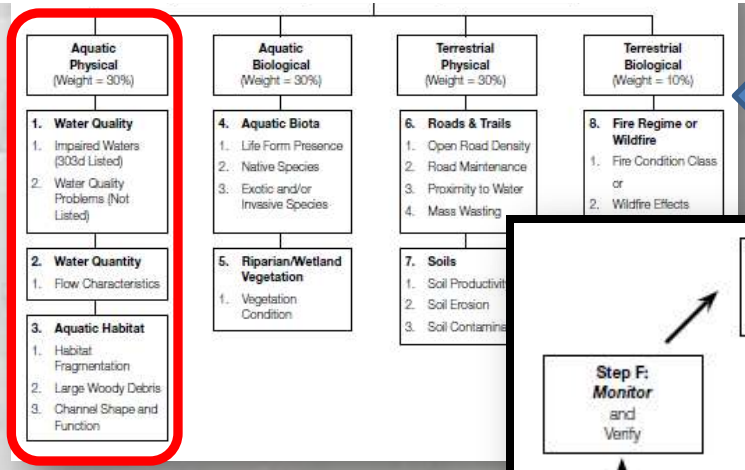


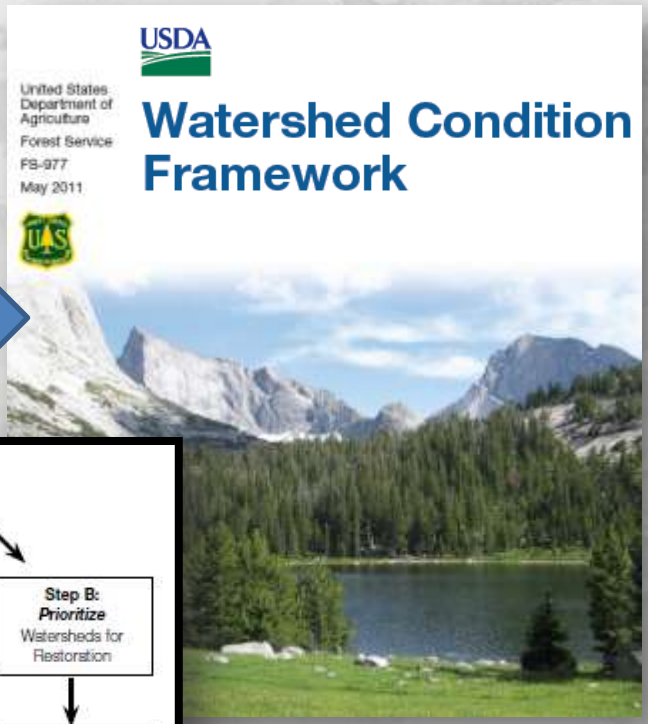
Work here?

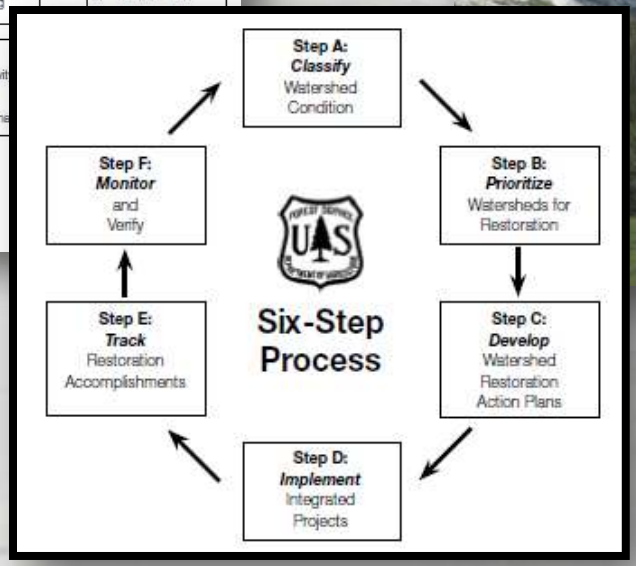
or here?

Integrate with…

Watershed Condition Indicators





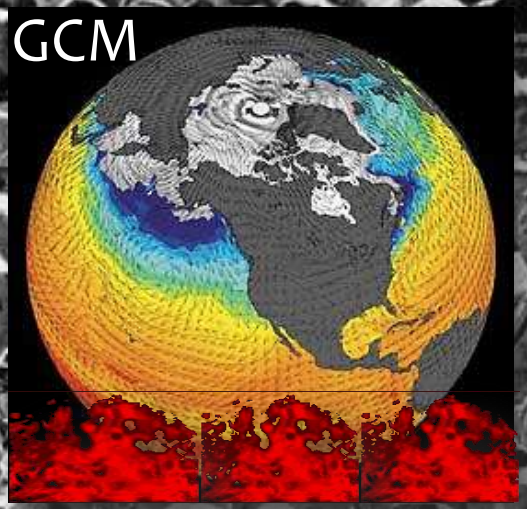


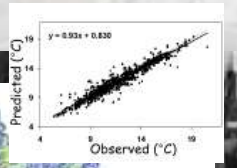
Forest Plan Revisions

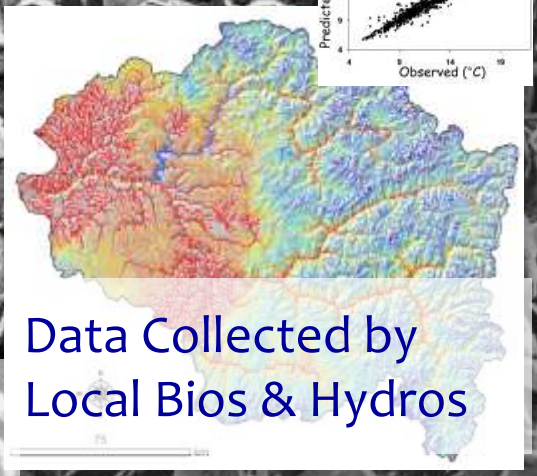
USDA United States Department of Agriculture
Forest Service
Northern Region
March 2007

Proposed
Land Management Plan
Clearwater National Forest

NorWeST is a "Crowd-Sourced" Model Developed from Everyone's Data



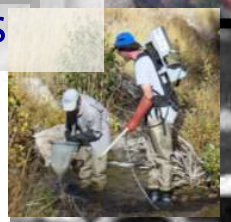




Data Collected by Local Bios & Hydros

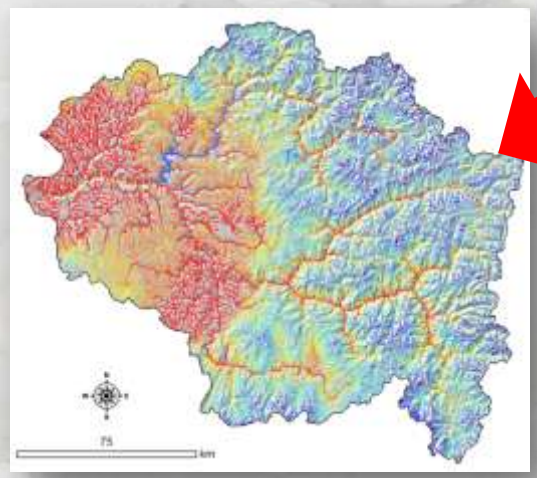
Coordinated, Interagency Responses?

Management Actions

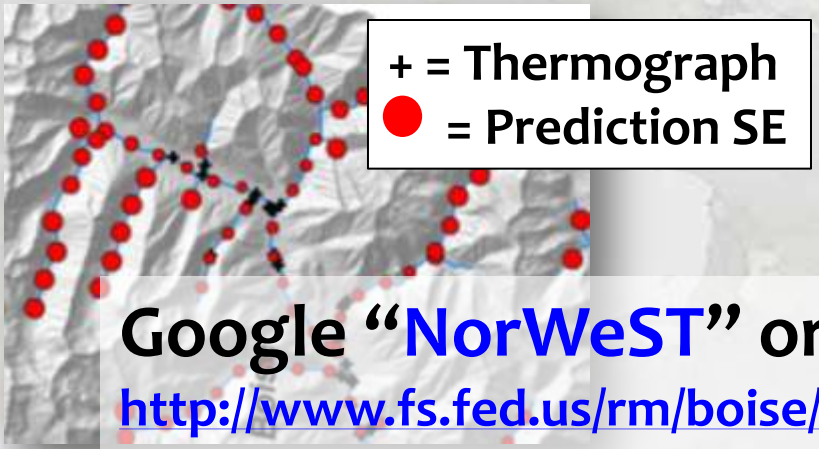


NorWeST Website Distributes Scenarios & Other Temperature Products as GIS Layers

1) GIS shapefiles of stream temperature scenarios



2) GIS shapefiles of stream temperature model prediction precision



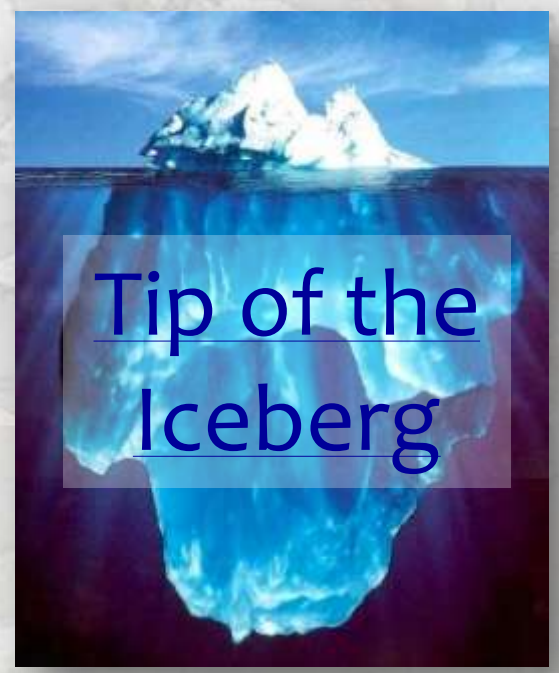
3) Temperature data summaries

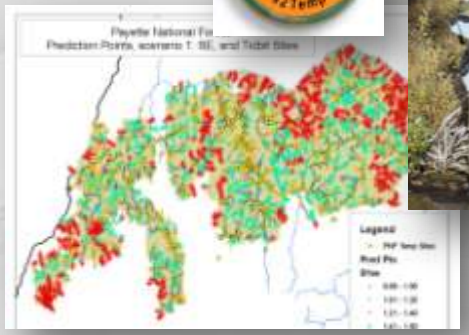
Google "NorWeST" or go here…

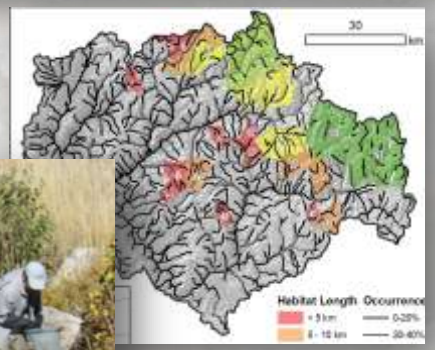
http://www.fs.fed.us/rm/boise/AWAE/projects/NorWeST.shtml

NorWeST Facilitating Related Projects

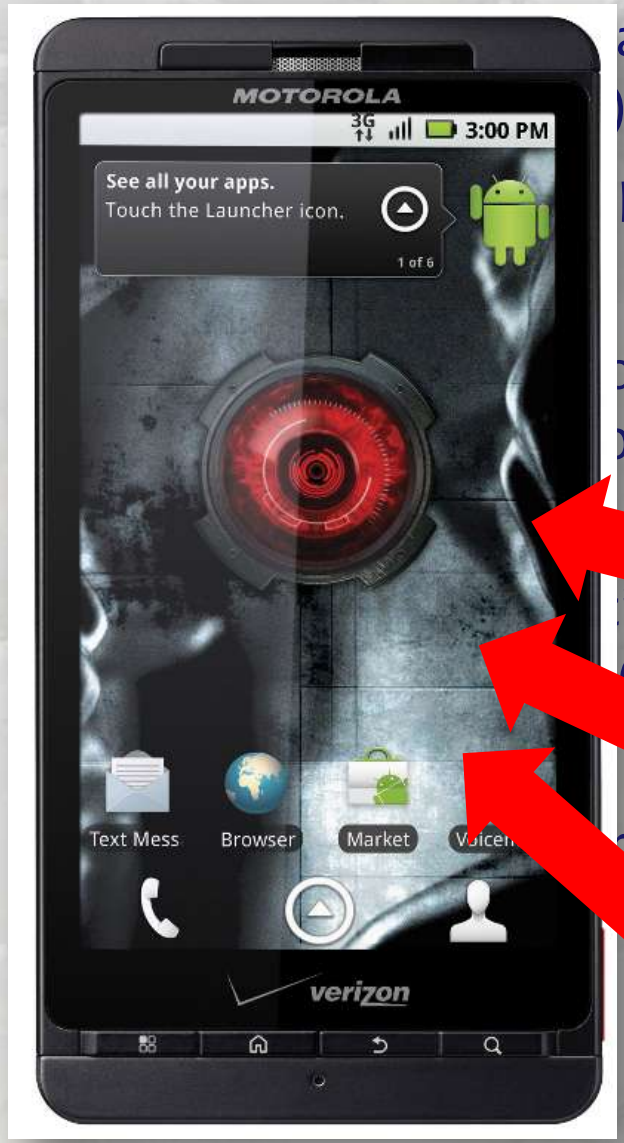
- Regional bull trout climate vulnerability assessment (J. Dunham)
- Cutthroat & bull trout climate decision support tools (Peterson et al., 2013)
- Landscape-scale bull trout monitoring protocol (Isaak et al. 2009)
- Consistent thermal niche definitions & more accurate bioclimatic models for trout & nongame fishes (S. Wenger, R. Al-Chokhachy, In Prep.)
- Efficient stream temperature monitoring designs



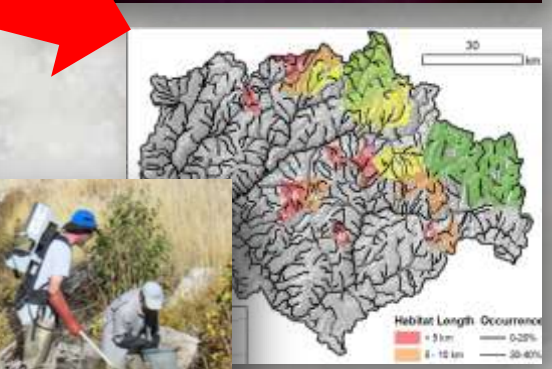




NorWeST Facilitating Related Projects



"Apps" Run on a Consistent Data Network



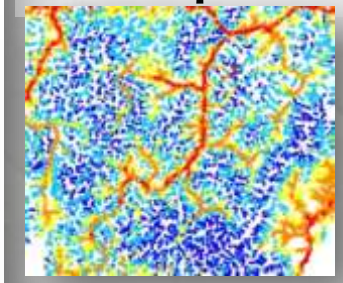
Real-time Access to Stream Spatial Data Anytime, Anywhere

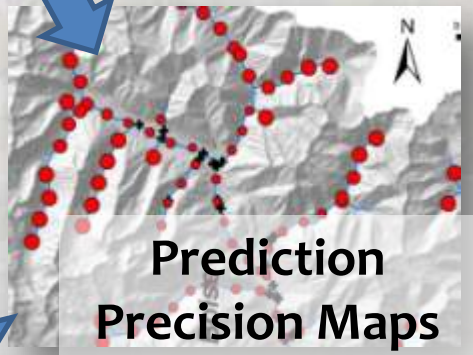
Smartphones as field computers

ArcGIS app

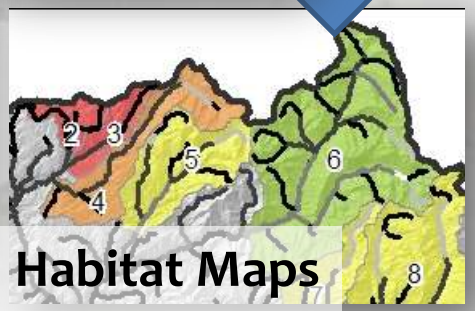
ESRI

Temperature Maps





Prediction Precision Maps

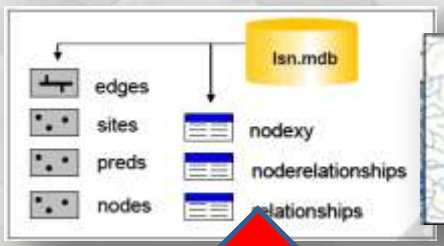


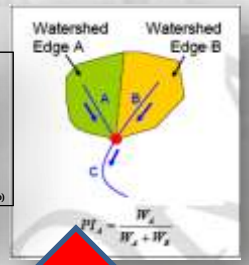
Habitat Maps

GoogleMaps

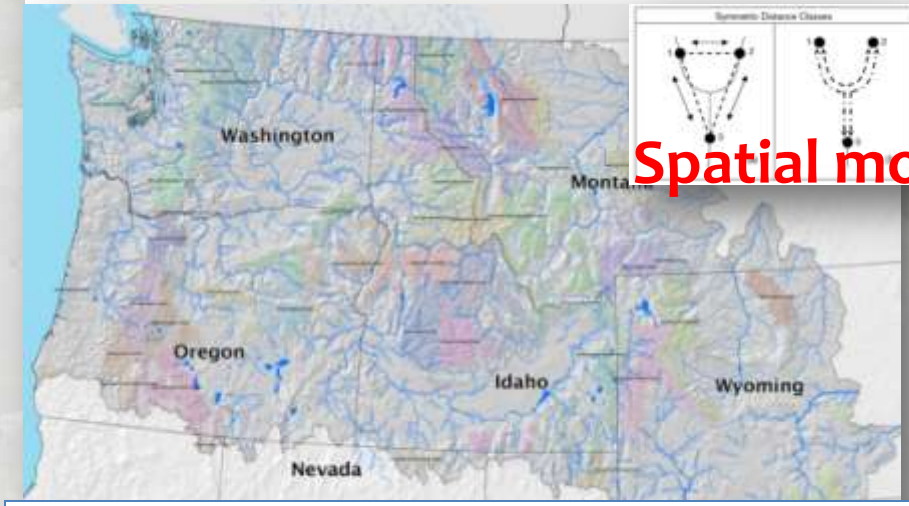
An InterNet for Stream Data

GIS infrastructure now exists…





Great Northern
LANDSCAPE CONSERVATION COOPERATIVE



Spatial models

~~1G~~ ~~LTE~~

1G LCC

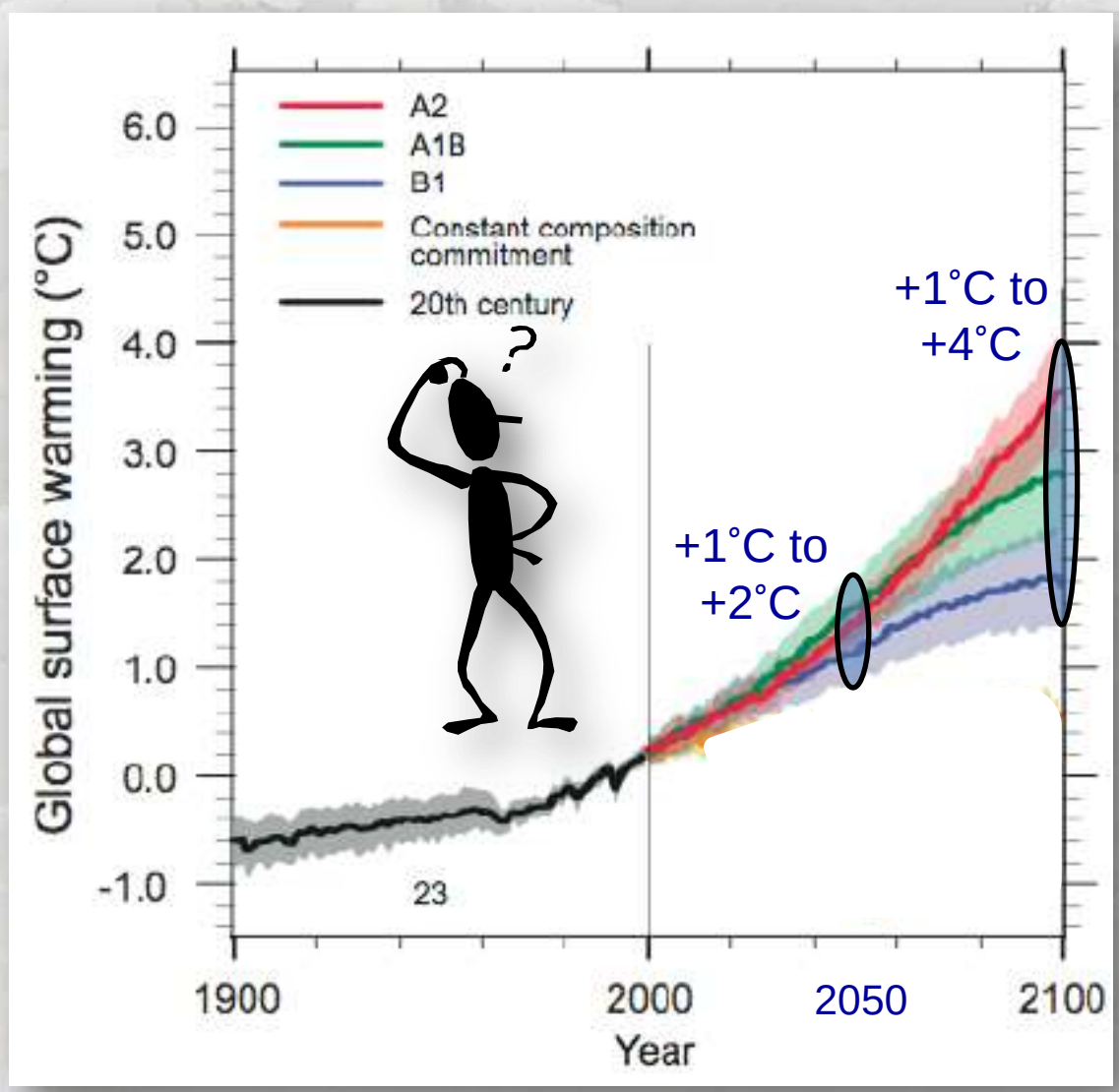
Accurate & consistent scaling of information

55 National Forests
350,000 stream kilometers

Boise Spatial Streams Group

Significant Unknowns:

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



A2?

A1B?

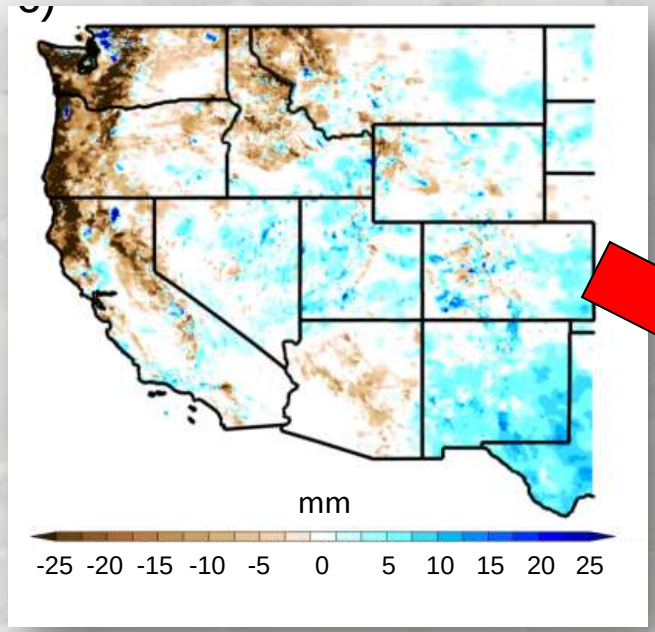
B1?

IPCC 2007

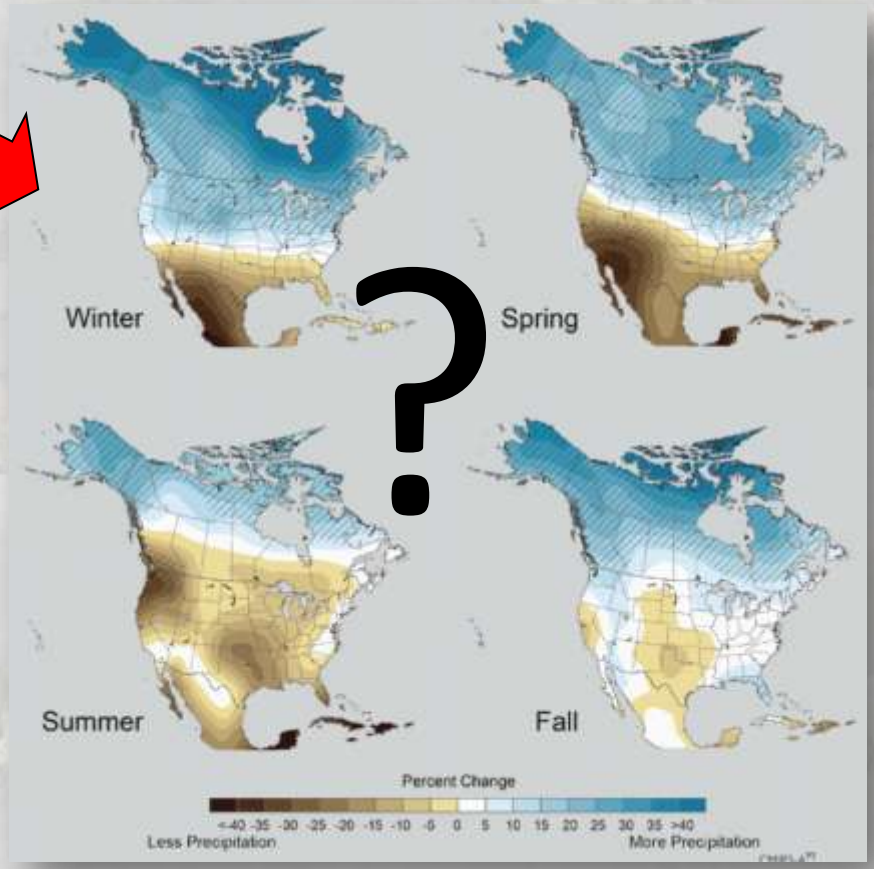
Significant Unknowns:

Is it Going to Get Wetter or Dryer?

Precipitation trends (1950-2009)



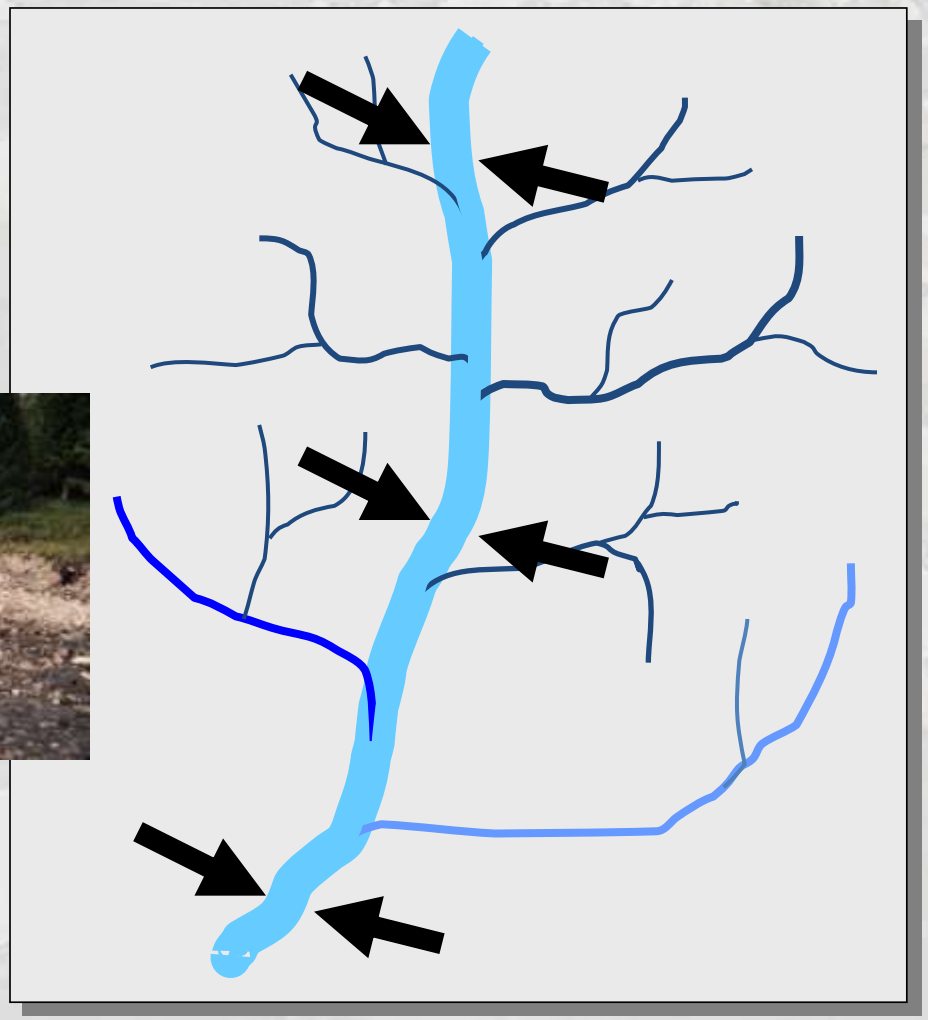
Future trends (2080-2099)?



Past may not be a prelude in this case…

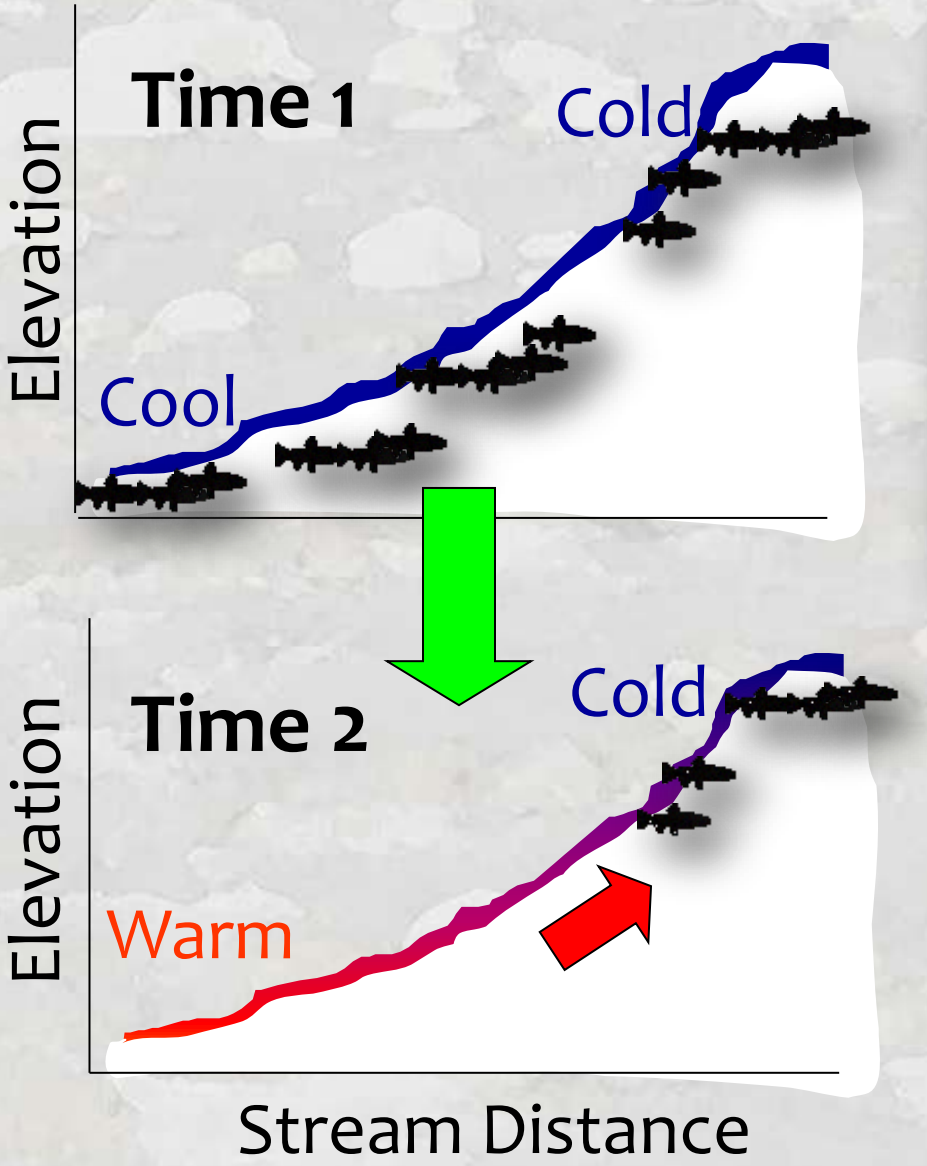
U.S. Climate Change Science Program. 2009

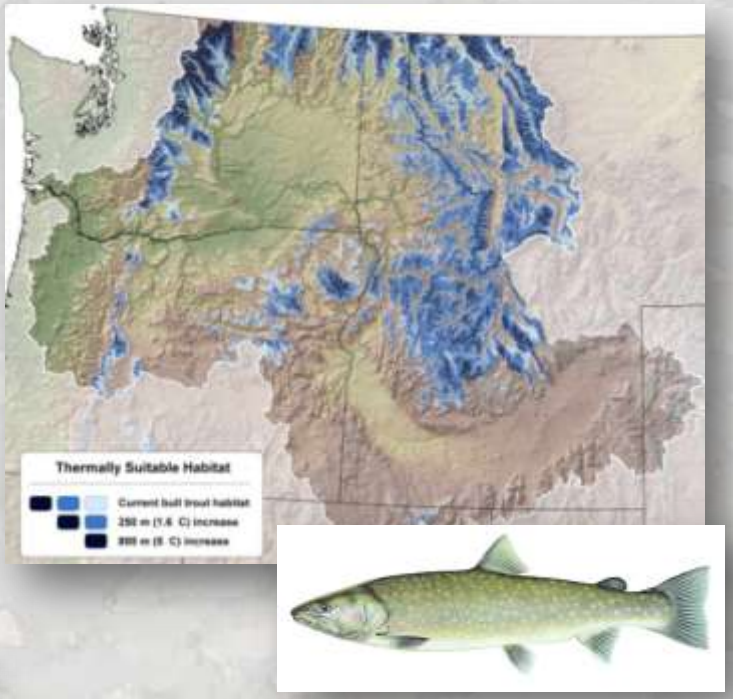
Precipitation Declines = Habitat Reductions & Fragmentation



Significant Unknowns:

How Fast Are Fish Distributions Shifting?





Average distribution shift across taxa =

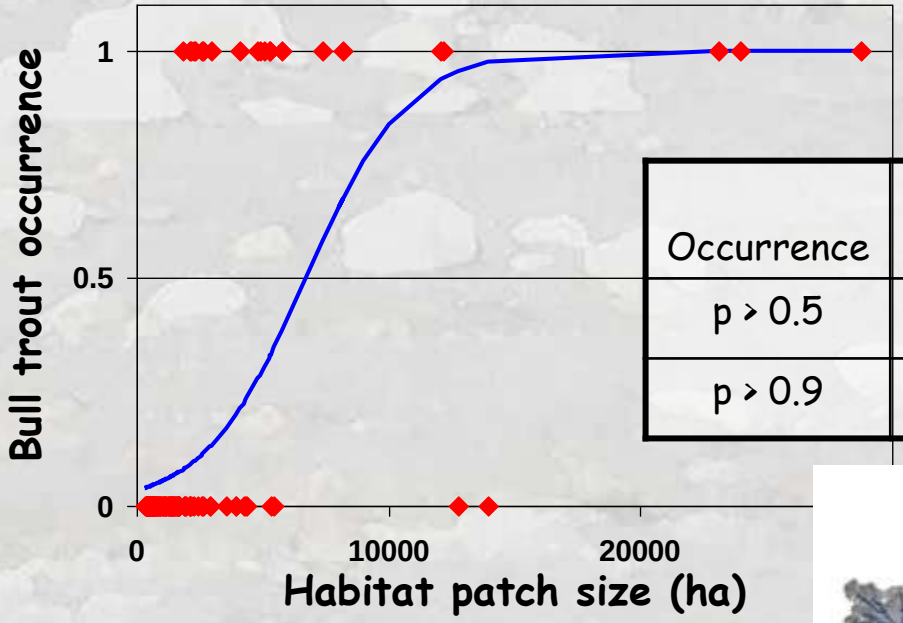
6.1 km/decade poleward OR

6.1 m/decade higher

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

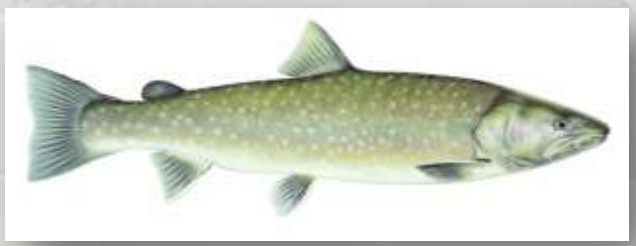
Significant Unknowns:

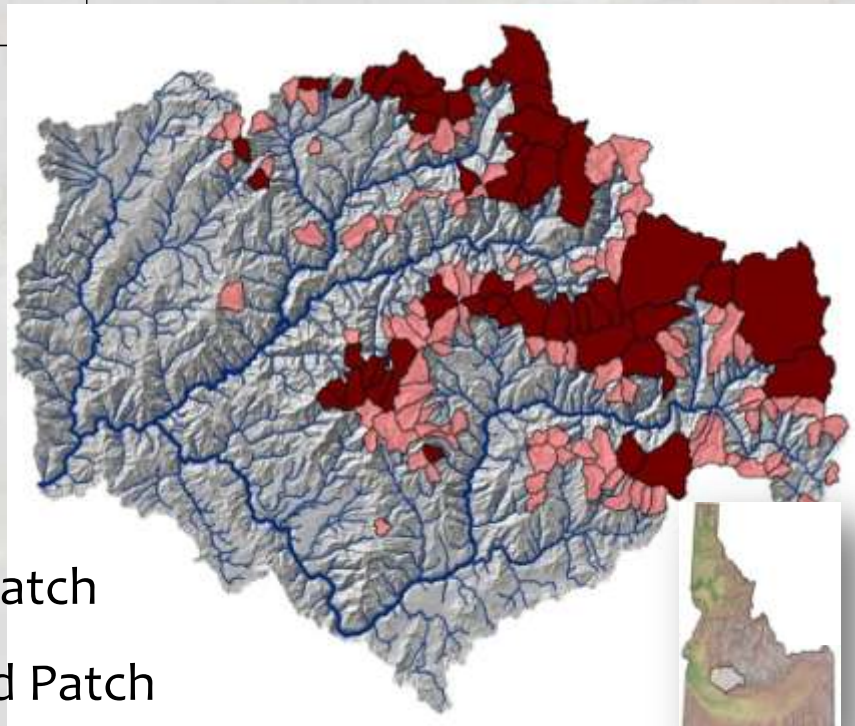
How Much Habitat is Needed to Persist?



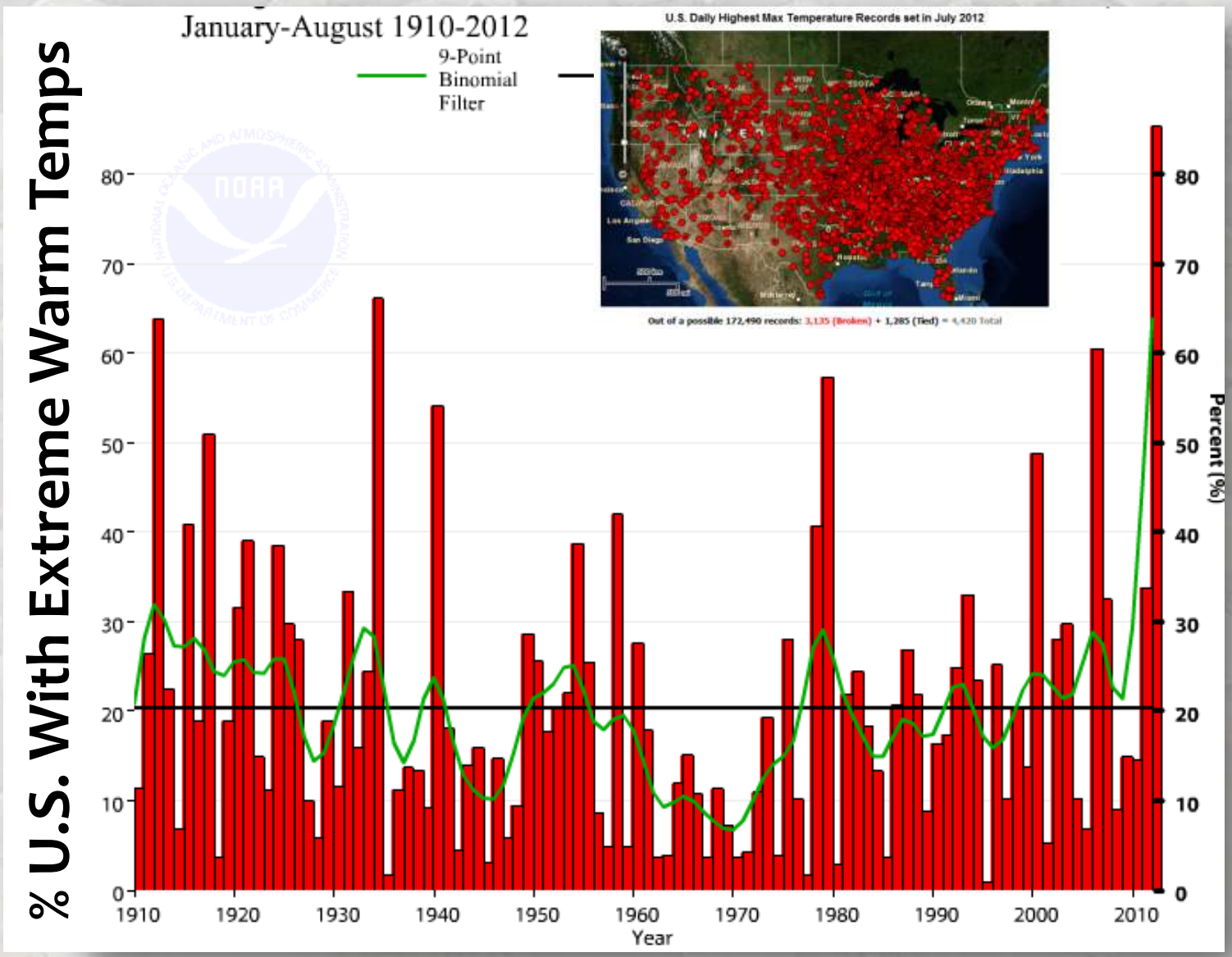
Rieman & McIntyre 1995
Isaak et al. 2010

Occurrence	Watershed area (ha)	Stream length (km)
p > 0.5	~3,000	~13
p > 0.9	~10,000	~40



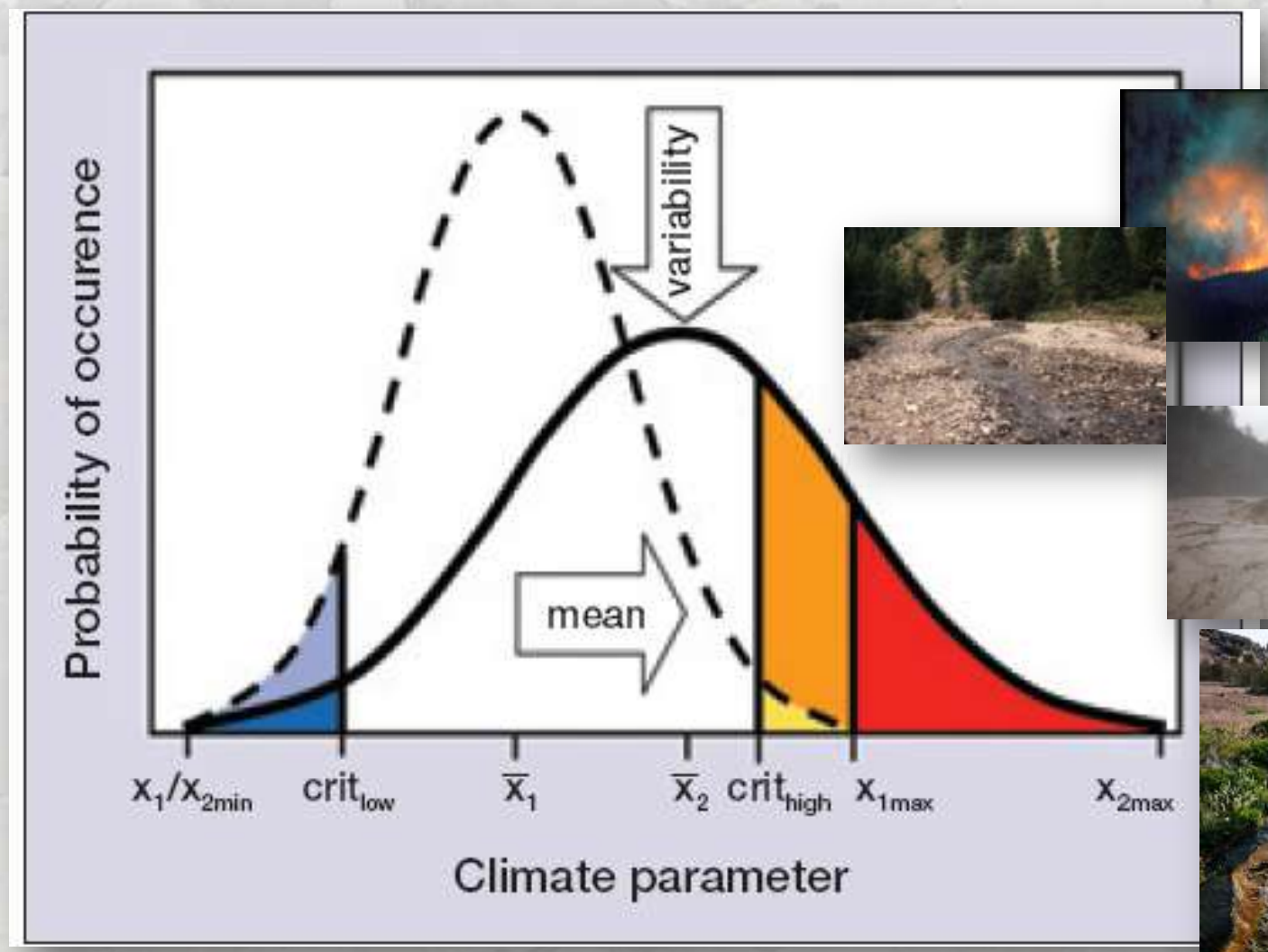


Extremes May Become More Extreme…



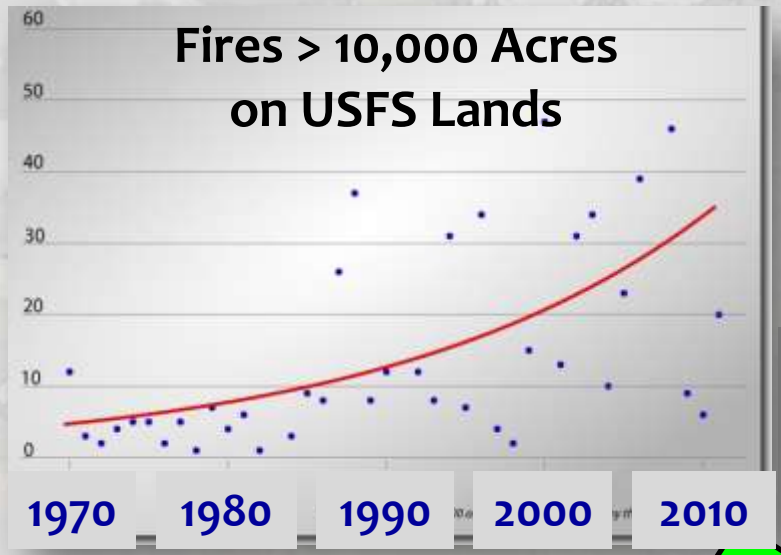
http://www.ncdc.noaa.gov/extremes/cei/graph/1c/ytd

Number of Climatic "Events" May Increase Dramatically

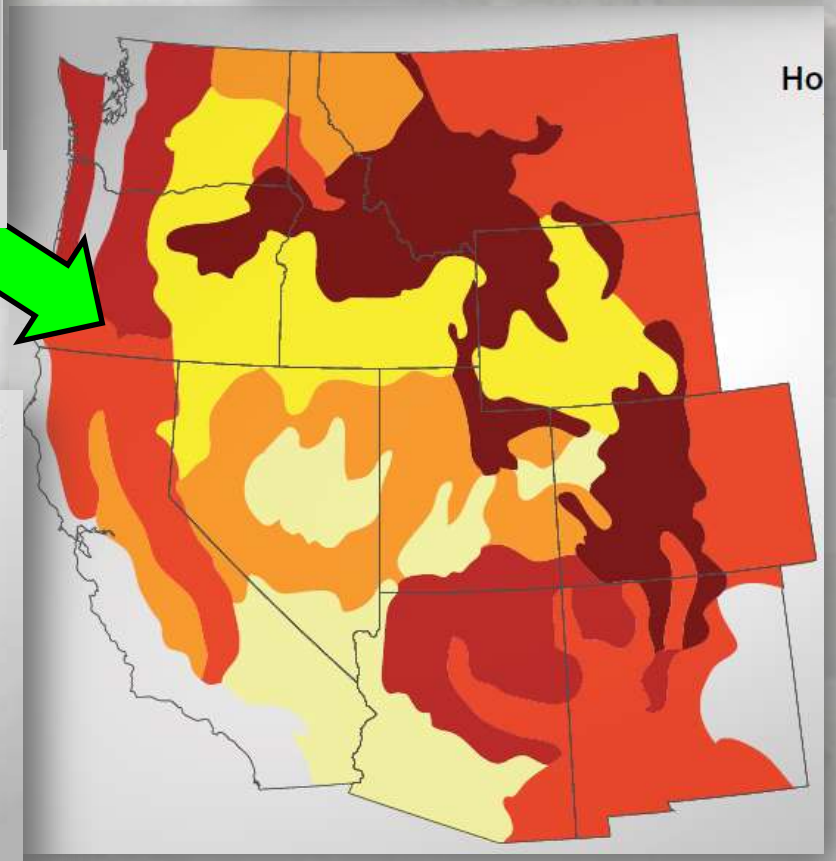


Jentsch et al. 2007

More & Bigger Wildfires



If +1.0 °C...

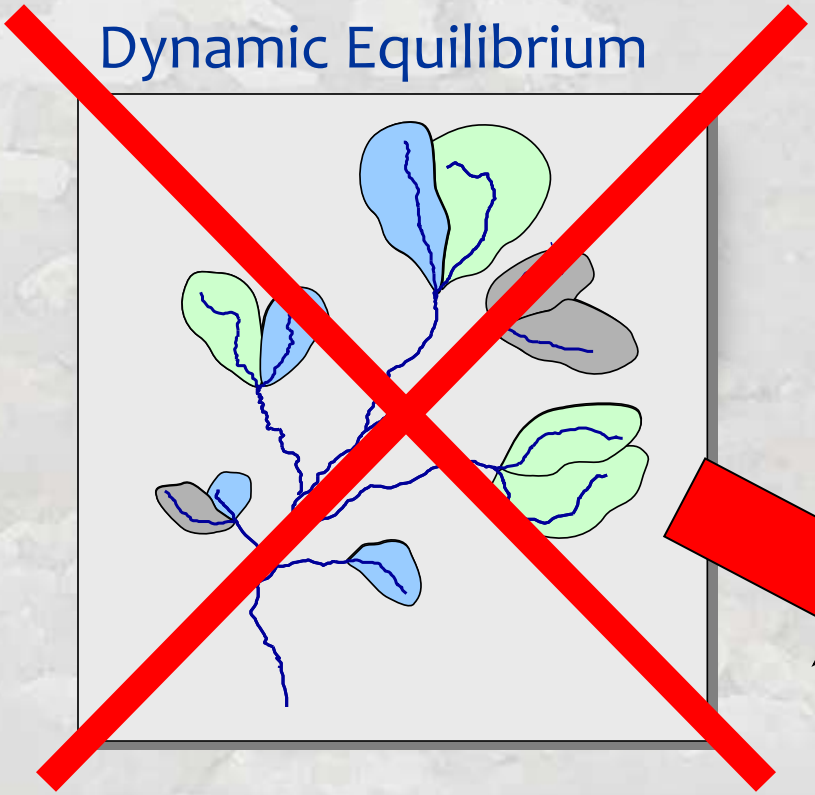


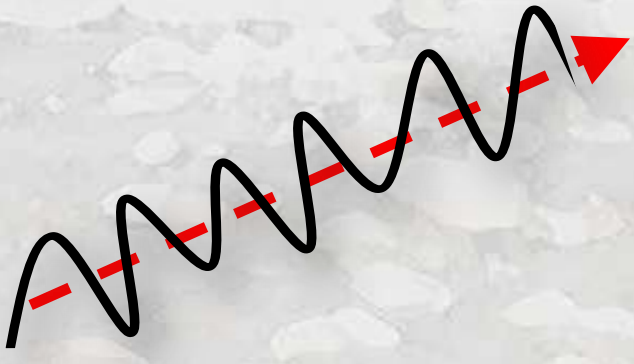
National Research Council 2011

Significant Unknowns:

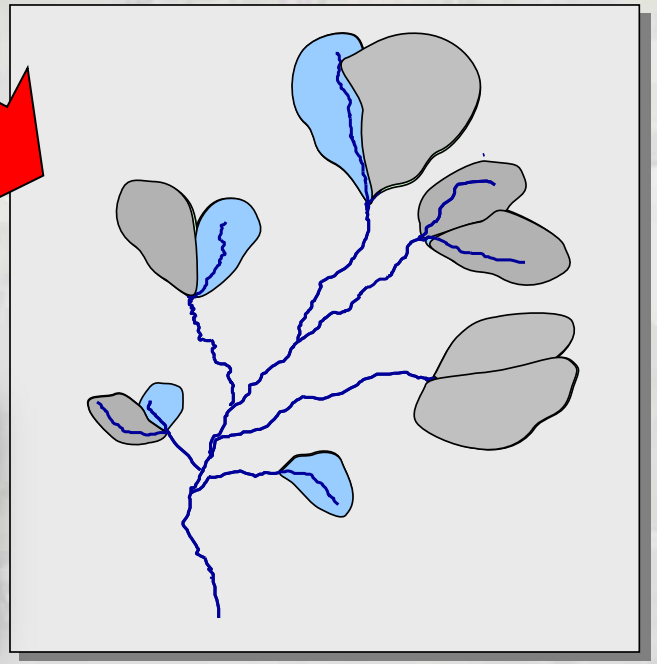
Can We Adjust Our Mindsets?

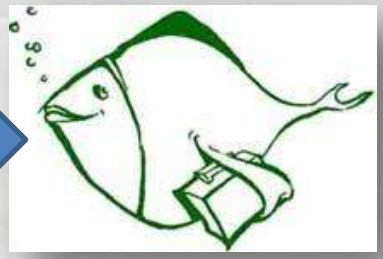
Dynamic Equilibrium



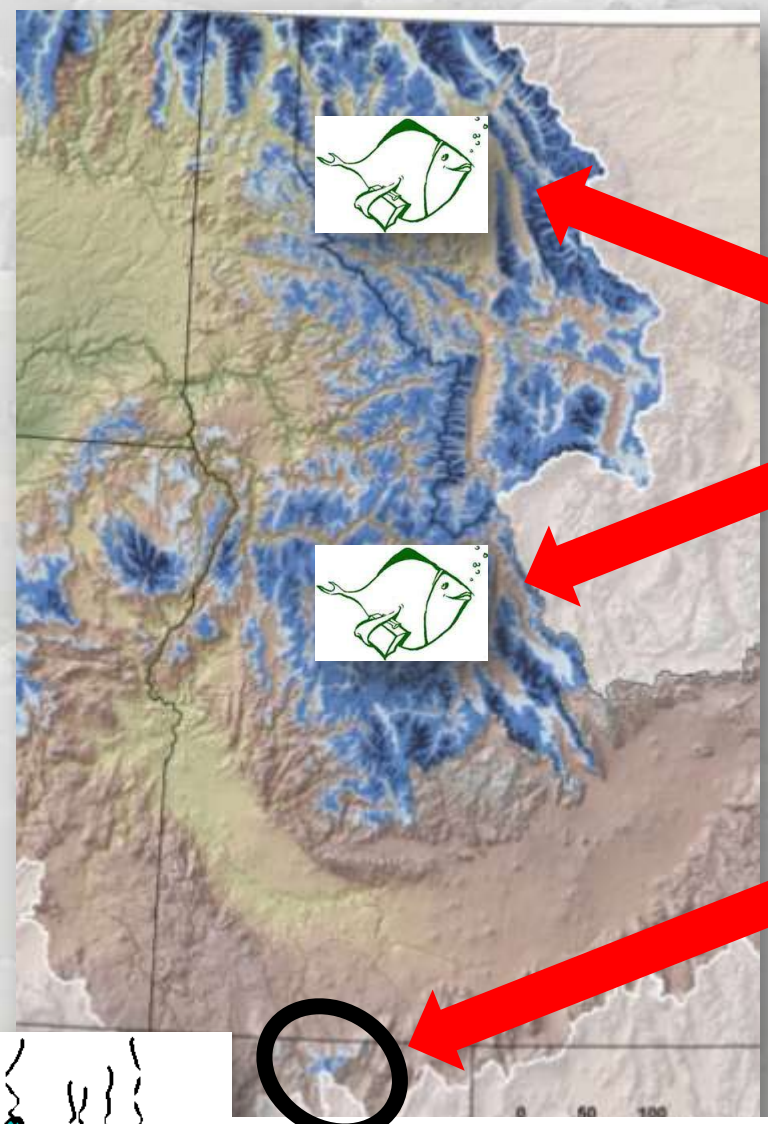


Dynamic Dis-Equilibrium





Can we Make Hard Choices & Let Some Populations Go?



Resilient Populations

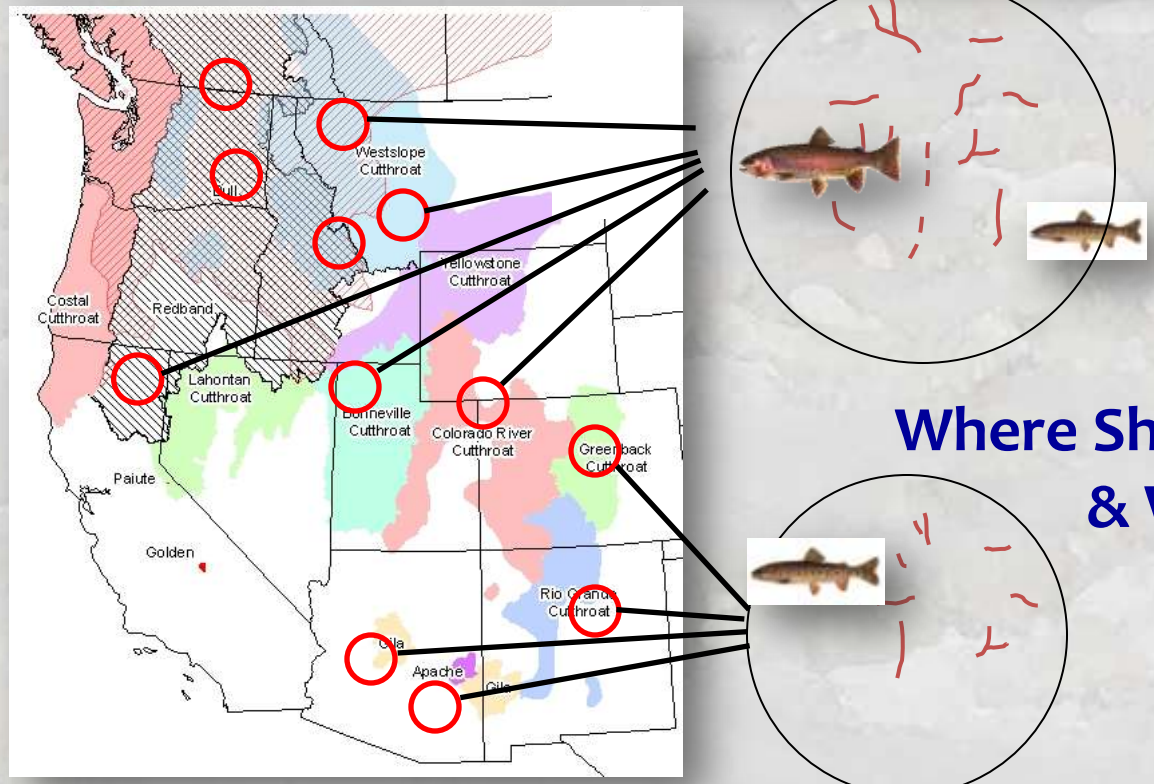
Lost Cause

Sorry Charlie

Do We Need Fish Conservation Reserves?

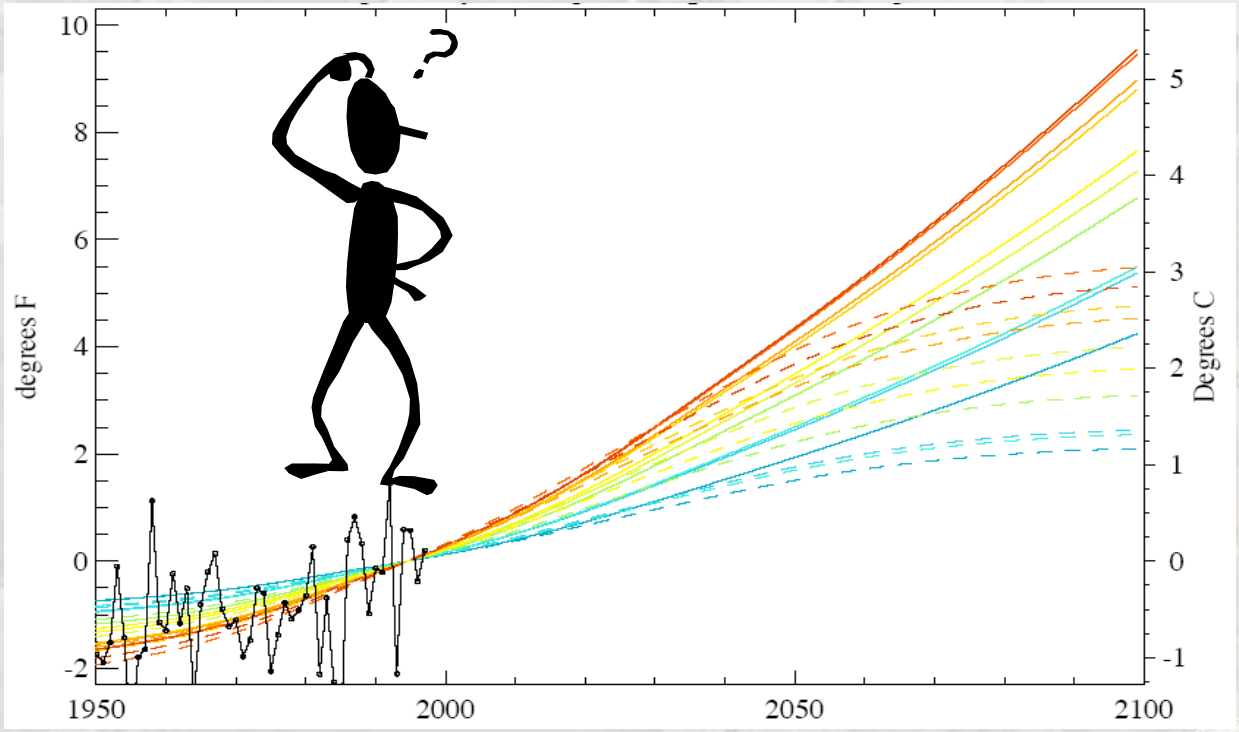
Native Fish Conservation Areas: A Vision for Large-Scale Conservation of Native Fish Communities

Jack E. Williams, Richard N. Williams, Russell F. Thurow, Leah Elwell, David P. Philipp, Fred A. Harris, Jeffrey L. Kershner, Patrick J. Martinez, Dirk Miller, Gordon H. Reeves, Christopher A. Frissell, and James R. Sedell

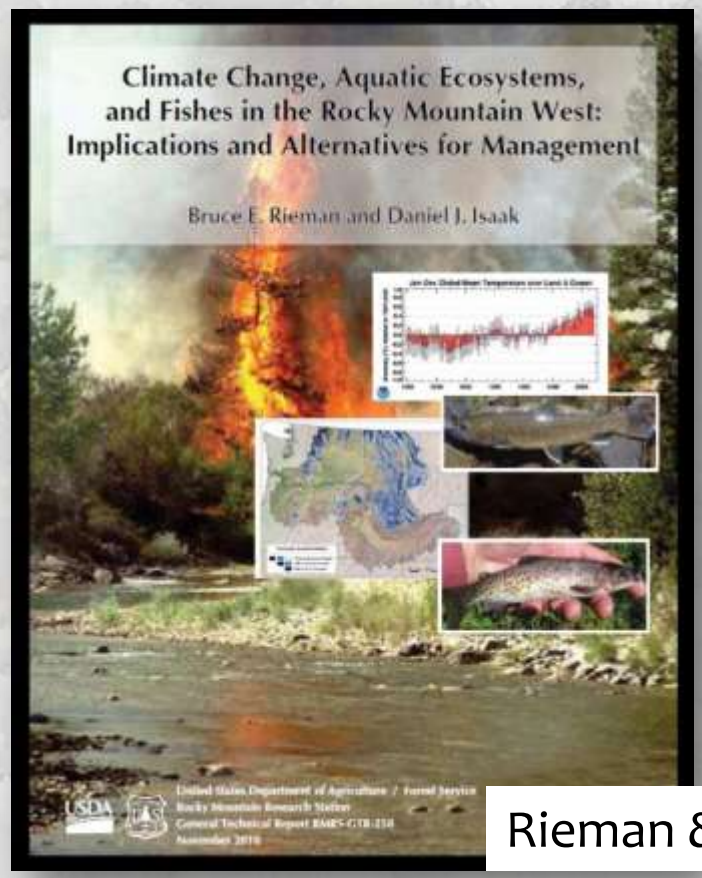


Where Should these Be?
& Which Species?

The Sooner We Act, The Bigger The Impact



Climate-Aquatics Syntheses…



Rieman & Isaak 2010.

Three Questions:

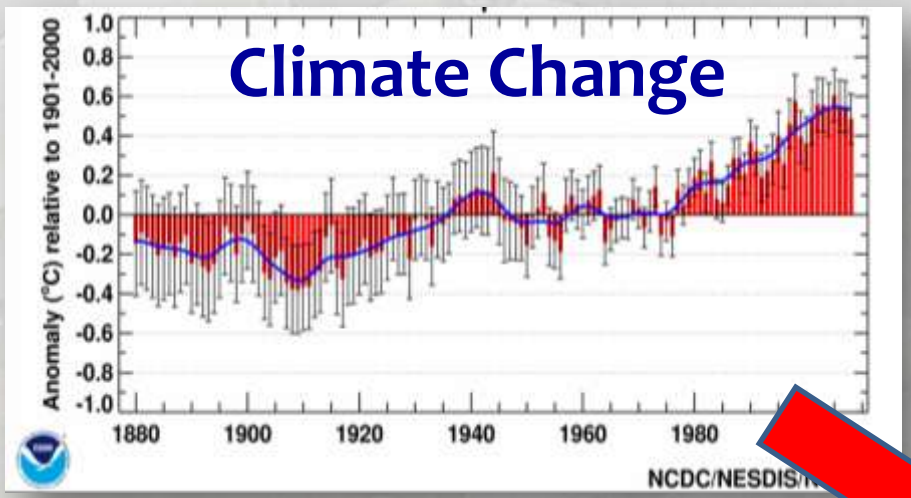
1) ***What is changing*** in the climate and related physical processes that may influence aquatic species and their habitats?
2) ***What are the implications*** for fish populations, aquatic communities and related conservation values?
3) ***What can we do about it?***

FEATURE
Socio-economics

The Past as Prelude to the Future for Understanding 21st-Century Climate Effects on Rocky Mountain Trout

Isaak et al. 2012. *Fisheries* **37**: 542-556.

Need to Do More With Less, but What If… We Did Much More?

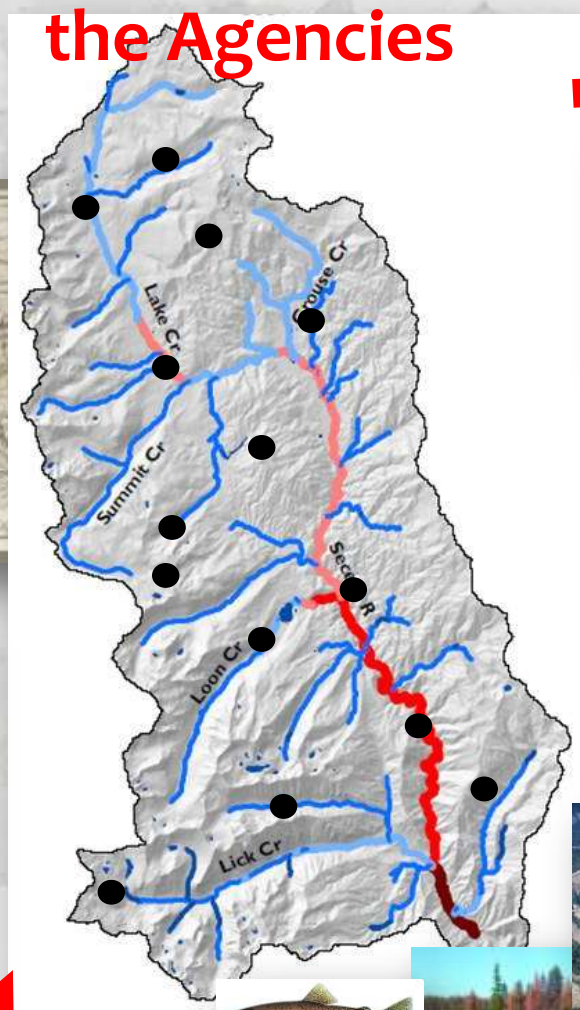


Urbanization & Population Growth

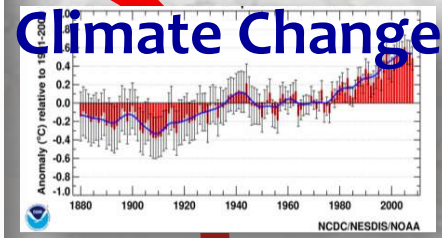
Shrinking Budgets

Connect the Dots to Map the Future

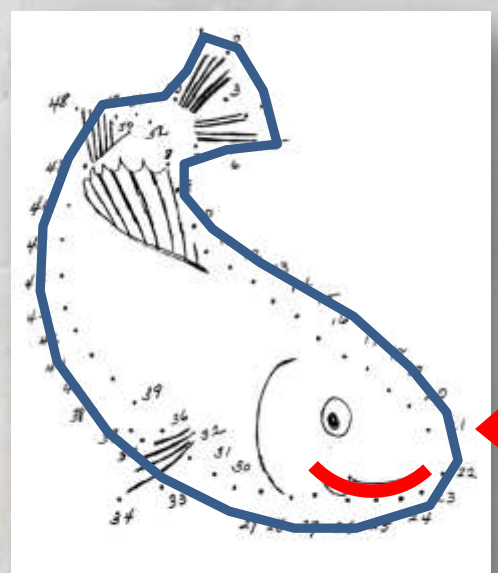
& the People & the Agencies

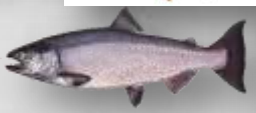


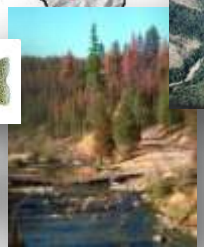
Climate Change



Urbanization & Population Growth







Land & Species Management


The End