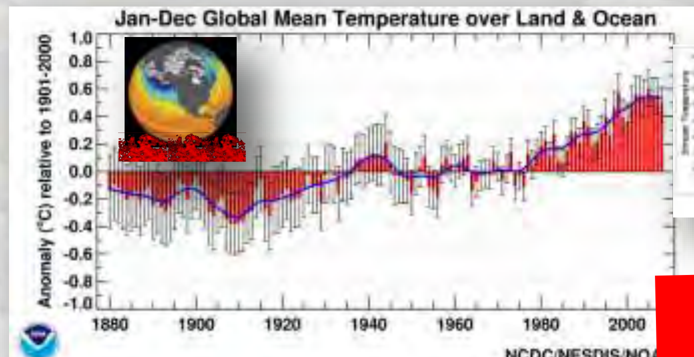
Climate Change & The Future of Isolated Trout Populations:

Can the PNW bull trout experience inform CRCT conservation?

Dan Isaak, US Forest Service



General outline:

1) 21st-Century model predictions for Rocky Mountain trout

2) 20th-Century observed patterns in climate & trout populations

3) Better spatial data to assist decision making. (the BIG DATA approach, the local monitoring approach)

4) Key future uncertainties (resolvable & not)

Parallel Structure to New Overview Paper…

Feature:
FISHERIES MANAGEMENT

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

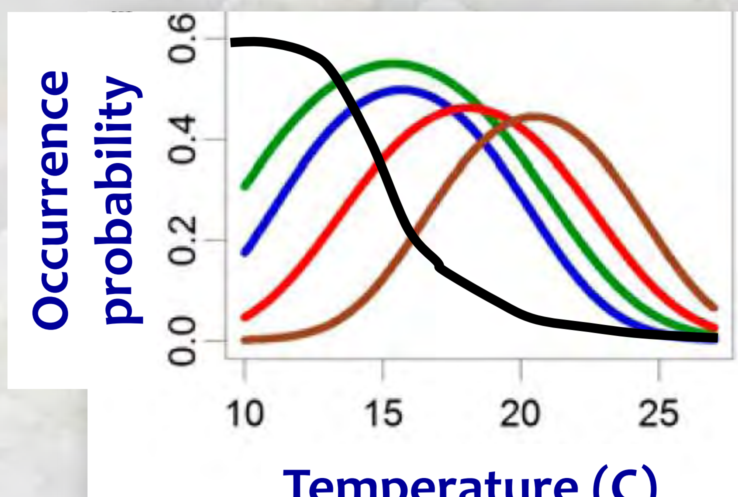
Isaak, … Roberts, … Fausch. 2012.
Fisheries **37**: 542-556.

Two conservation species

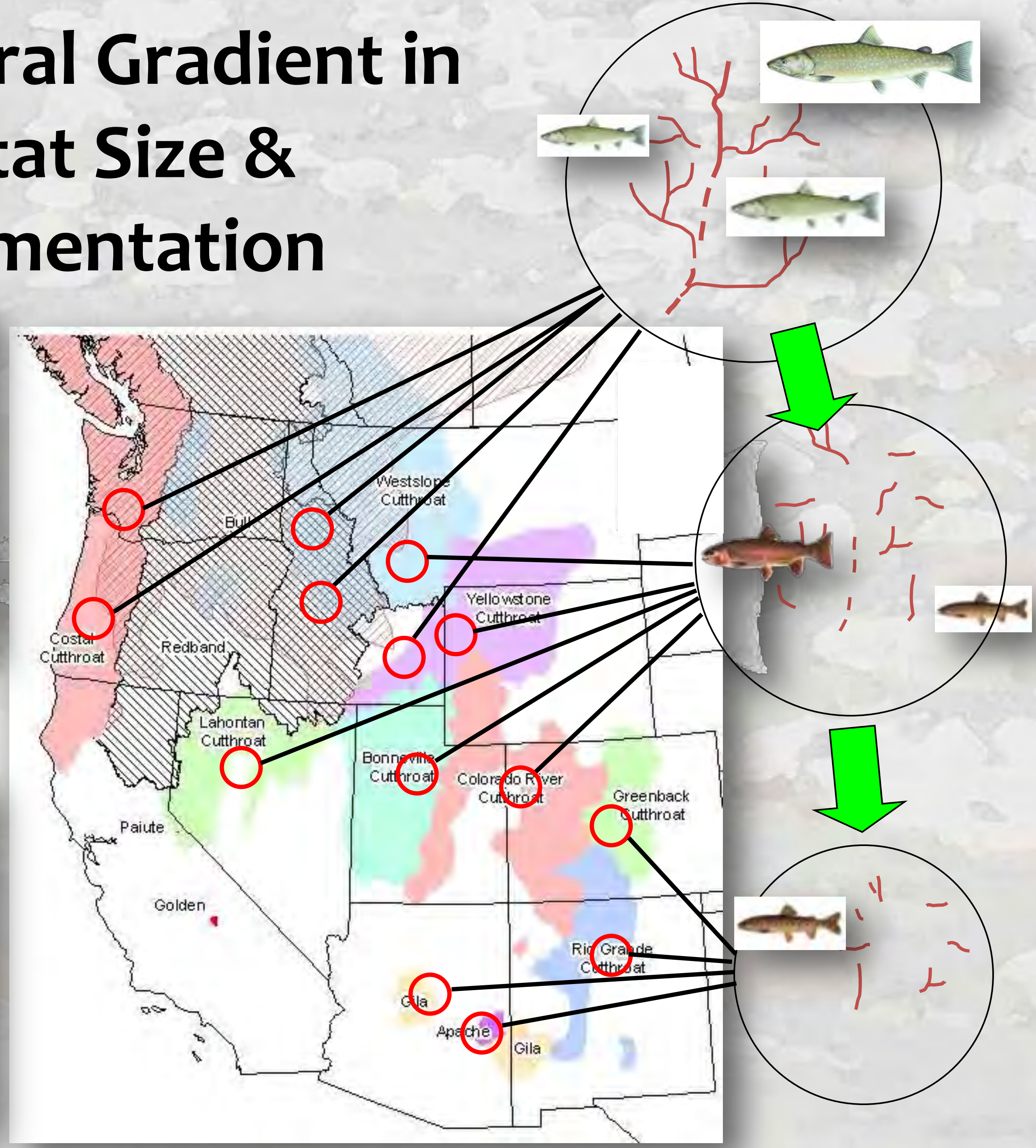
Five case history areas

Vs

Extensive	Habitat fragmentation?	Moderate
No	Fluvial fish?	Yes
Spring	Spawning period?	Fall
Wide	Thermal niche?	Narrow

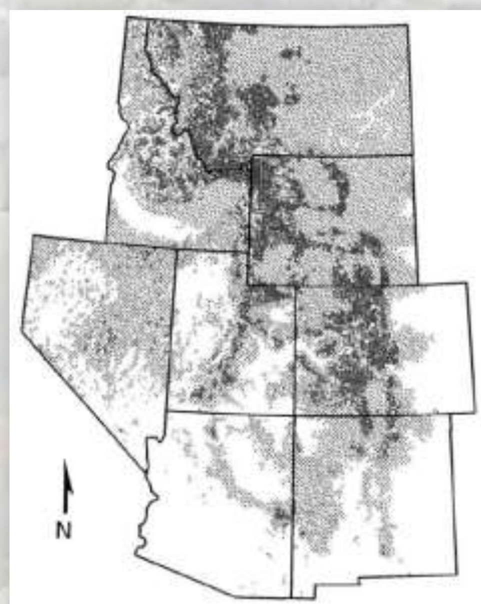


Natural Gradient in Habitat Size & Fragmentation

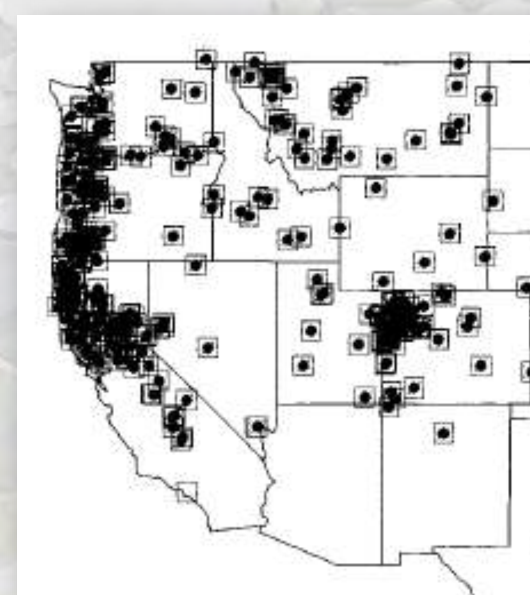


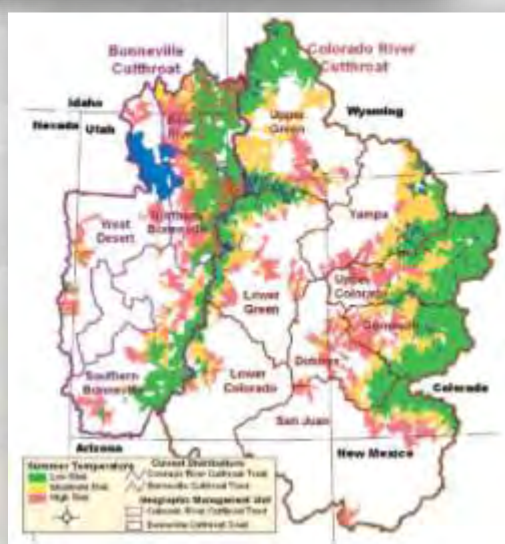
Bioclimate Models for Trout

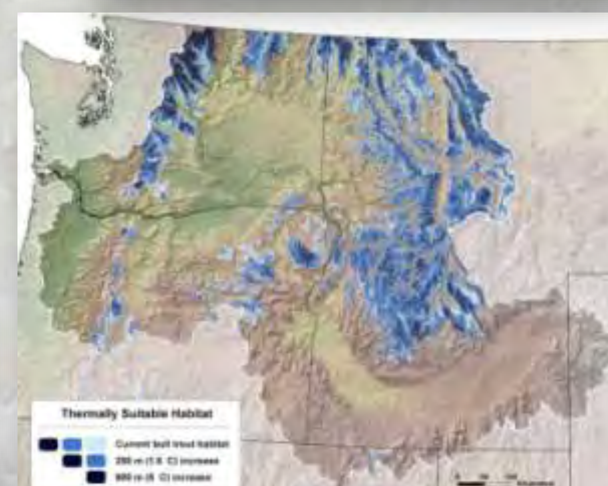
Rockies are model central!



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

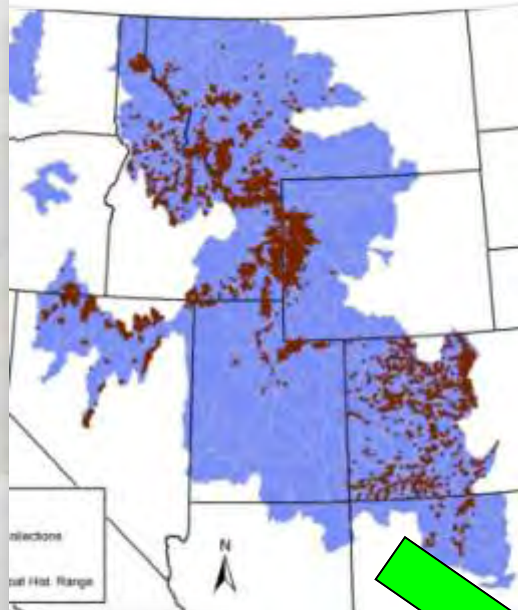




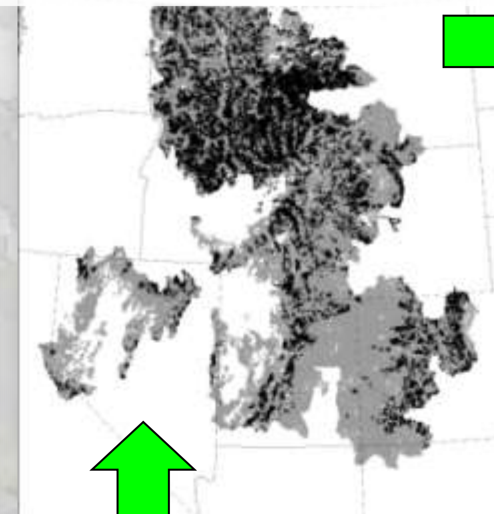


Most Recent Trout Climate Assessment

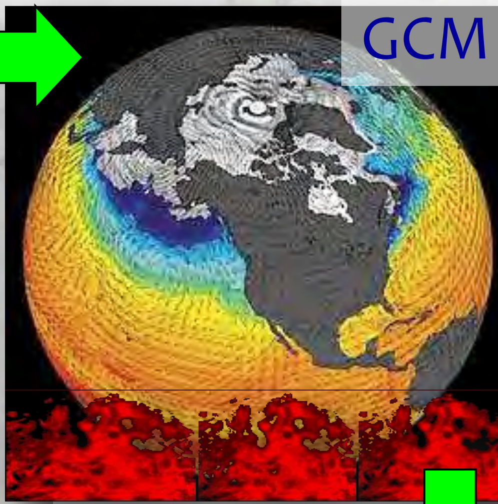
Fish survey database
~10,000 sites



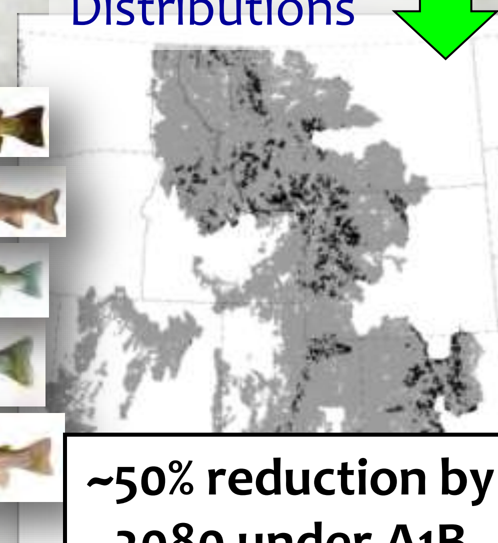
Historic Distributions



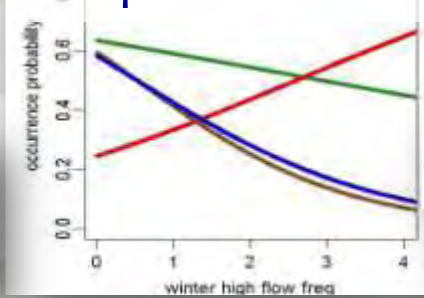
GCM



Future A1B
Distributions



Species-Specific
Habitat
Response Curves

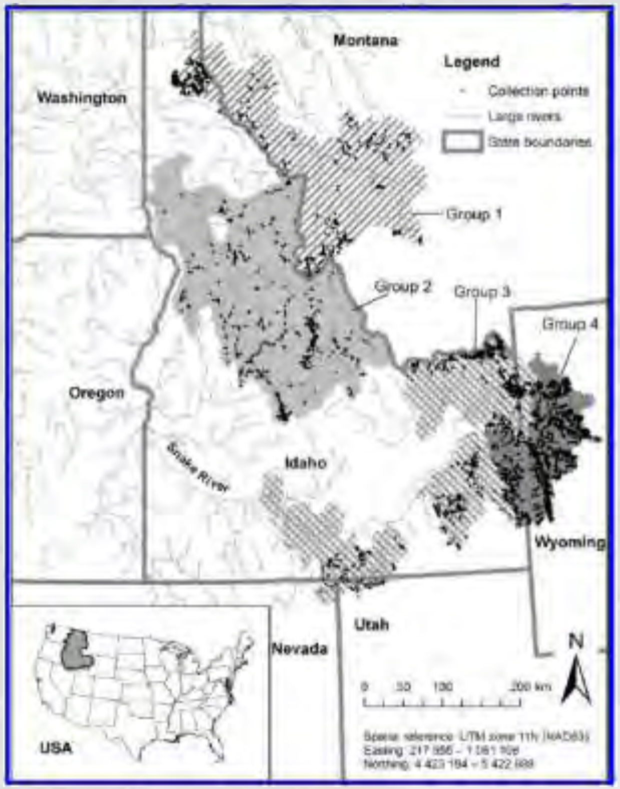


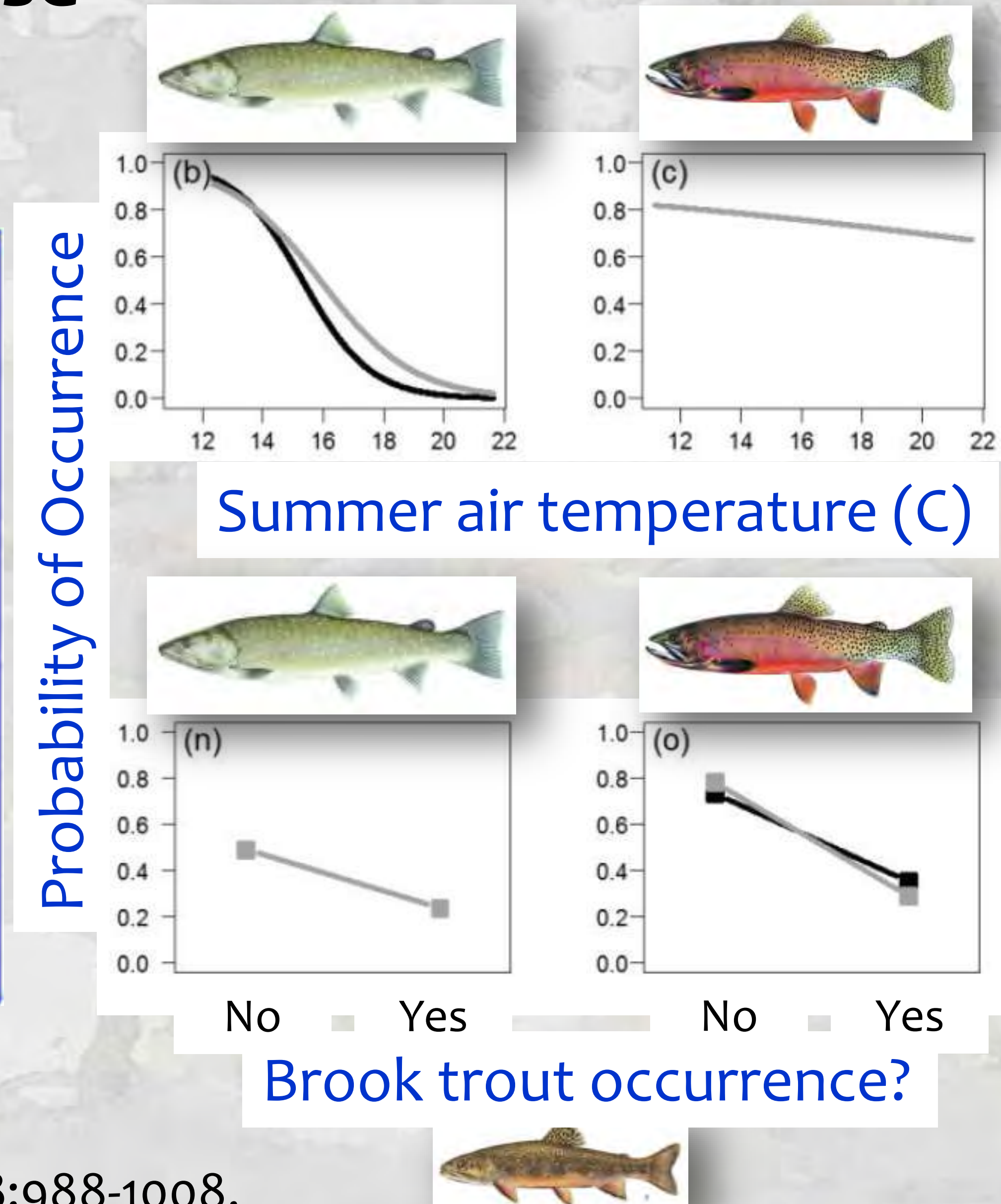
~50% reduction by 2080 under A1B

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

Mechanisms of Inter-specific Variation in Climate Response

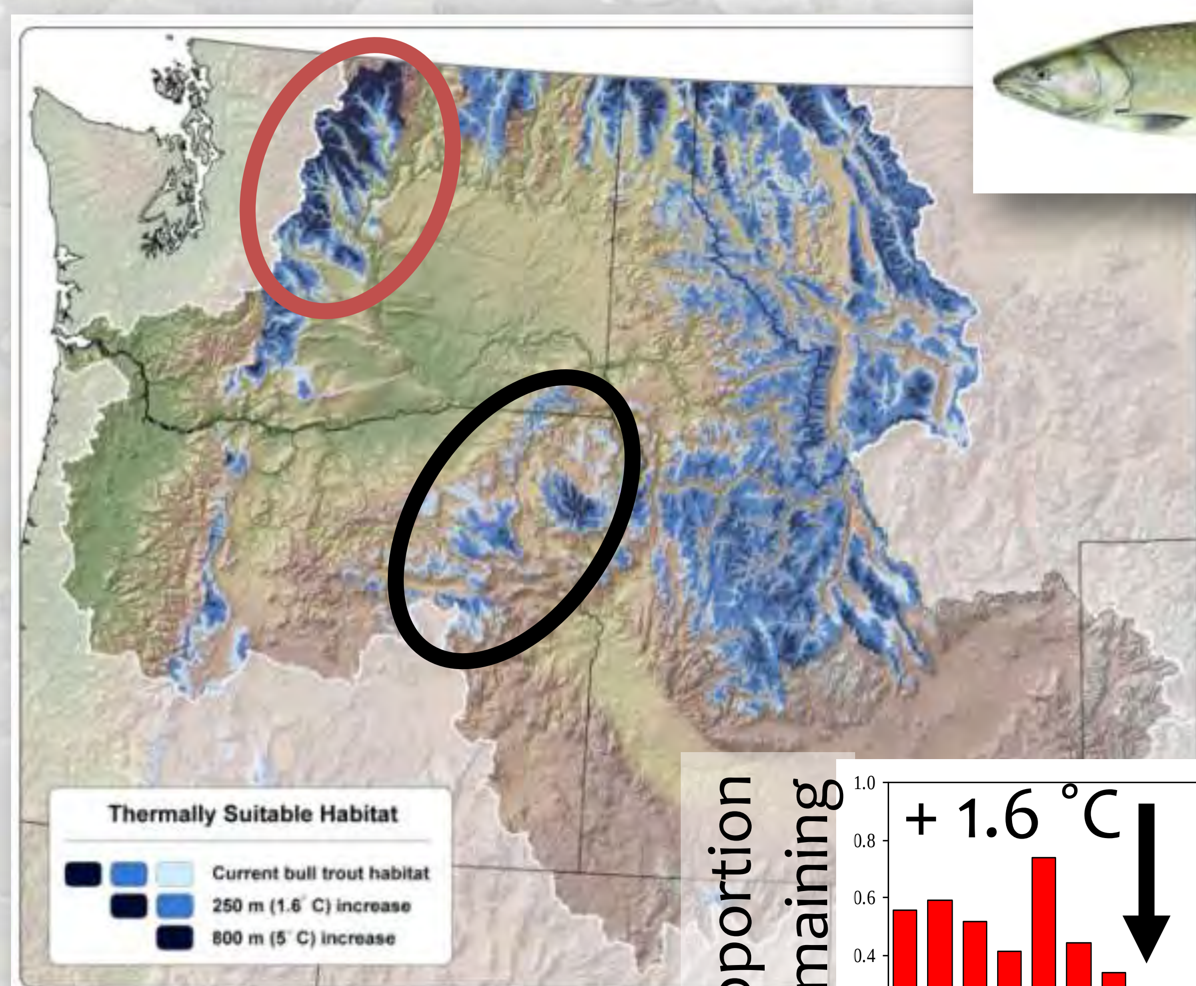
Fish survey database 4,165 sites

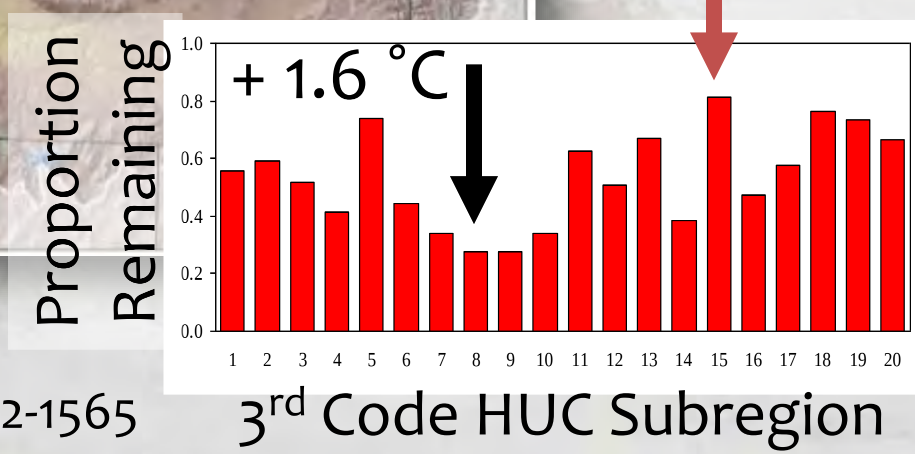




Wenger et al. 2011. *CJFAS* **68**:988-1008.

Context Matters: Spatial Variation in Habitat Loss



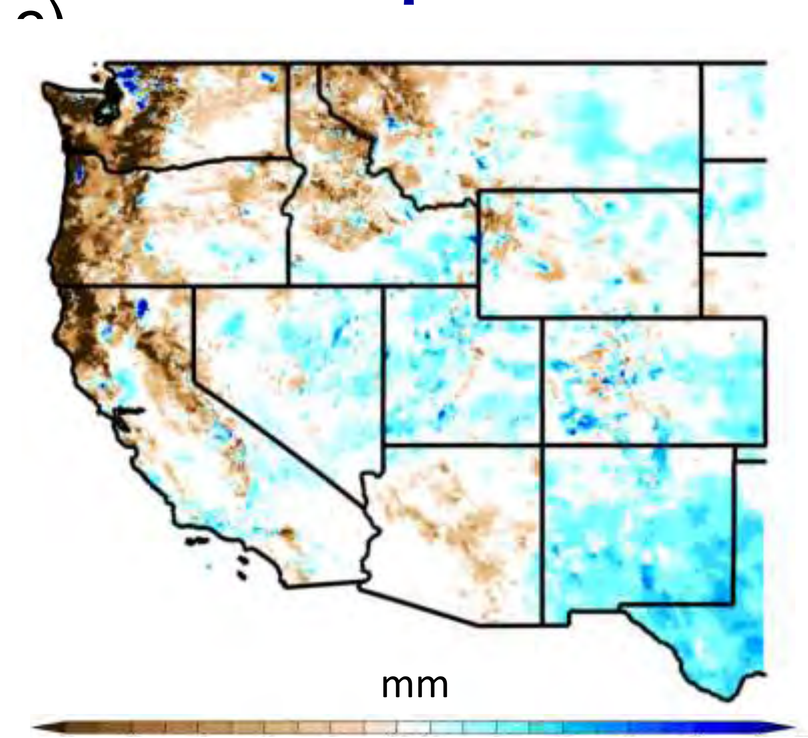


Rieman et al. 2007. *TAFS* **136**:1552-1565

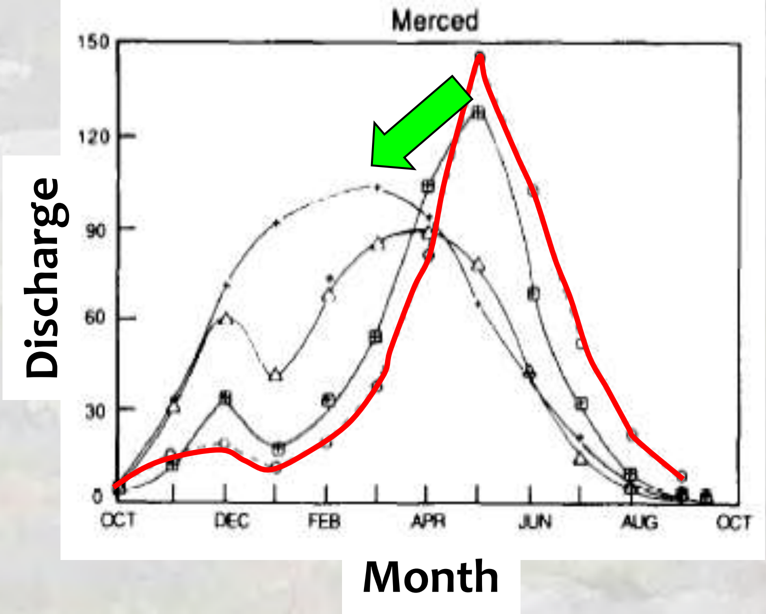
C

-4 -3 -2 -1 0 1 2 3 4

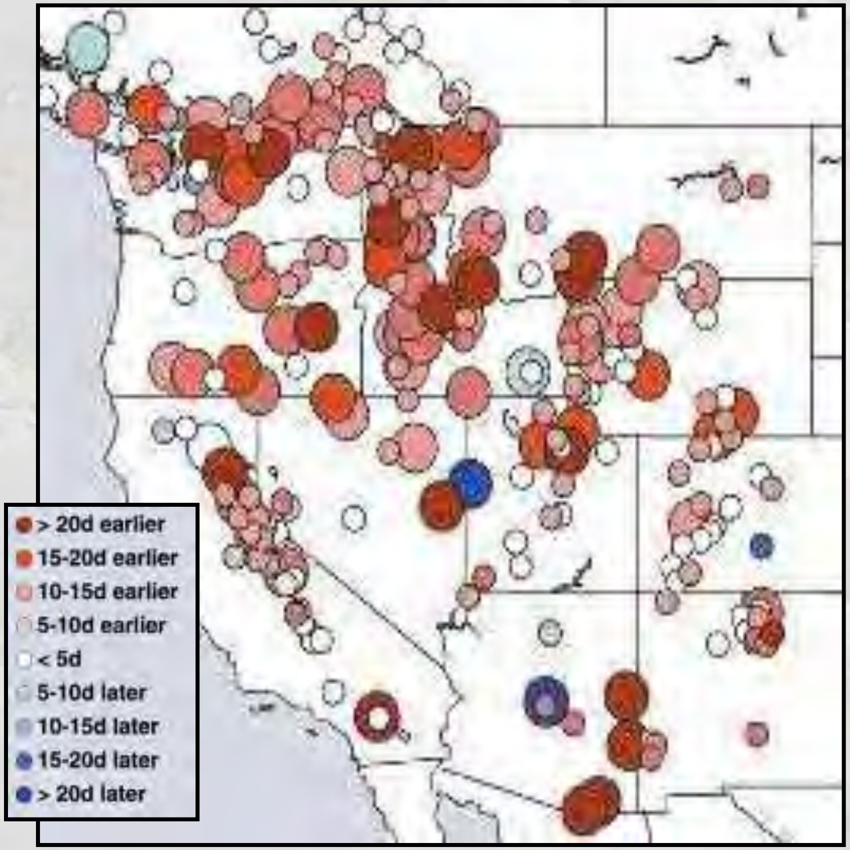
Precipitation



Observed Trends in Runoff Timing
(1948-2000)



Earlier snowmelt & river runoff

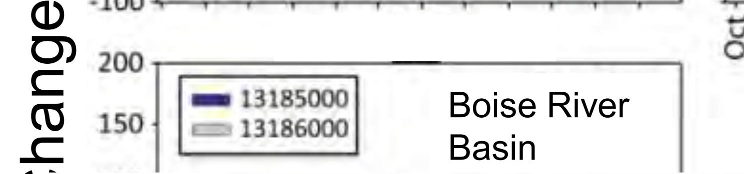


Stewart et al. 2005

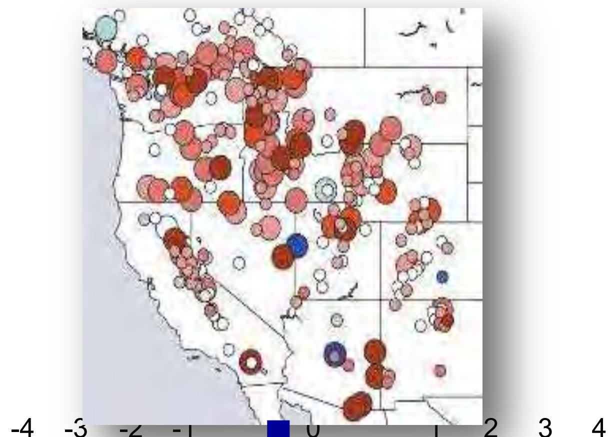
Runoff Interaction with

ds

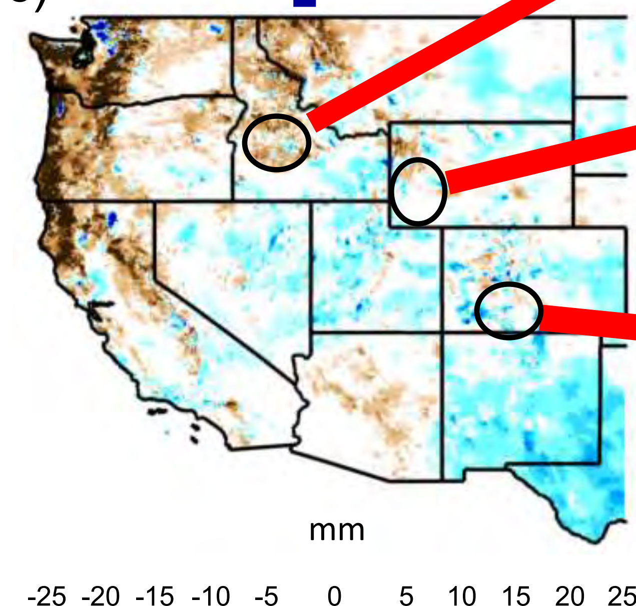
lows

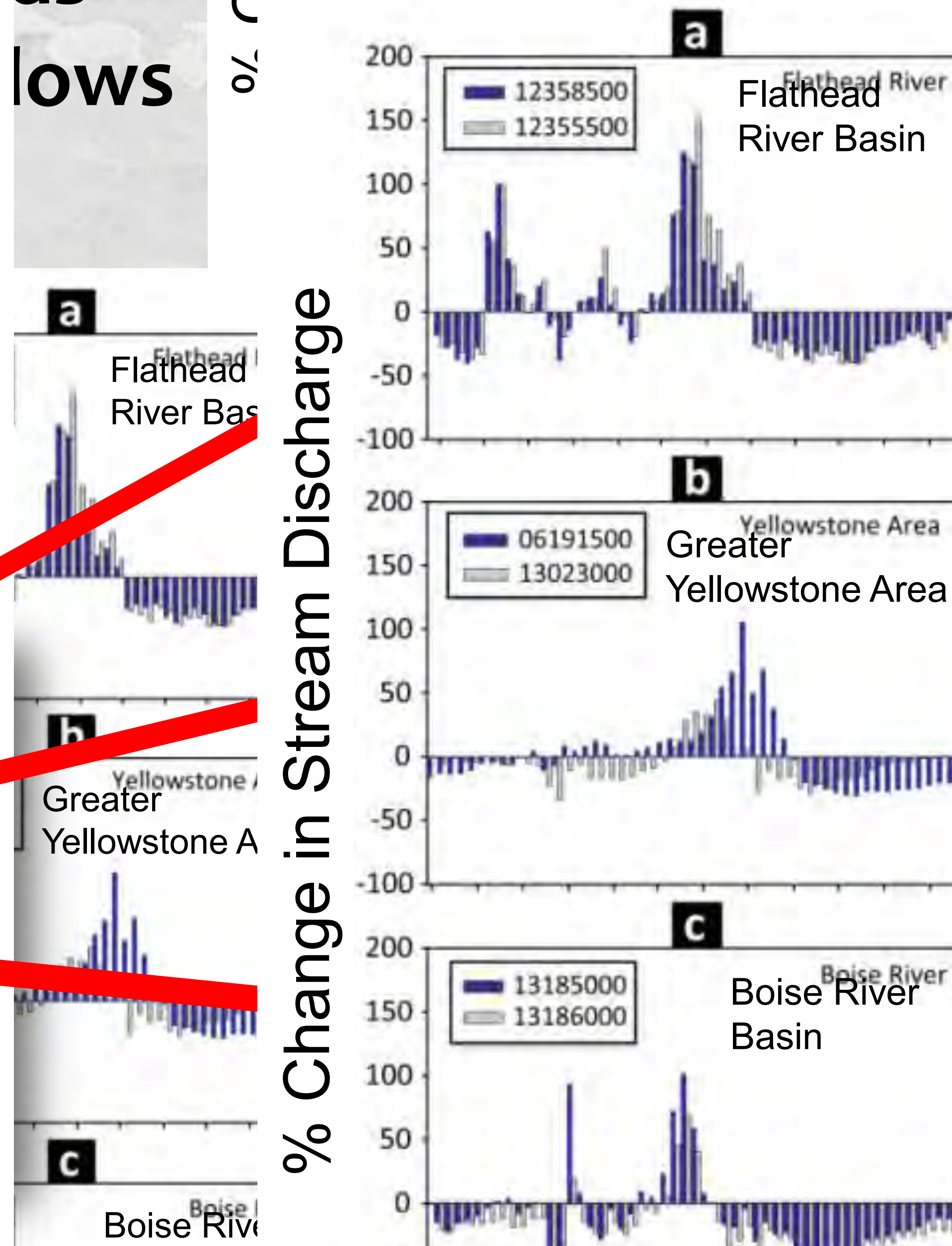


b)

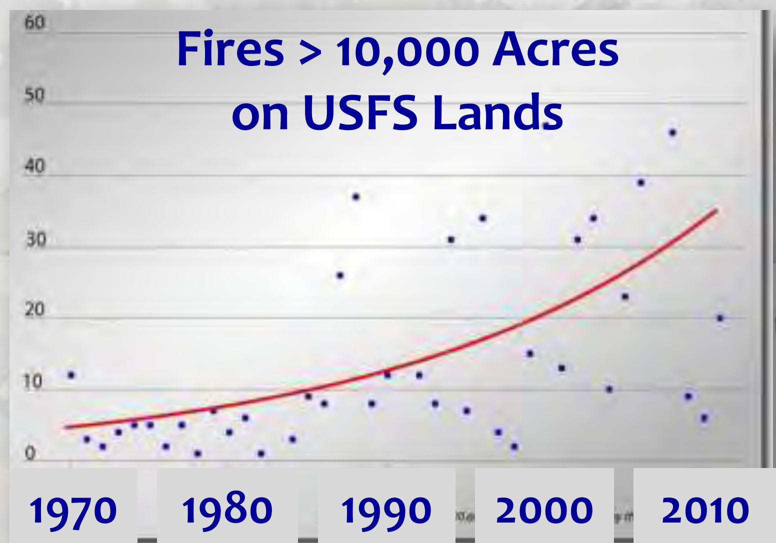


c)

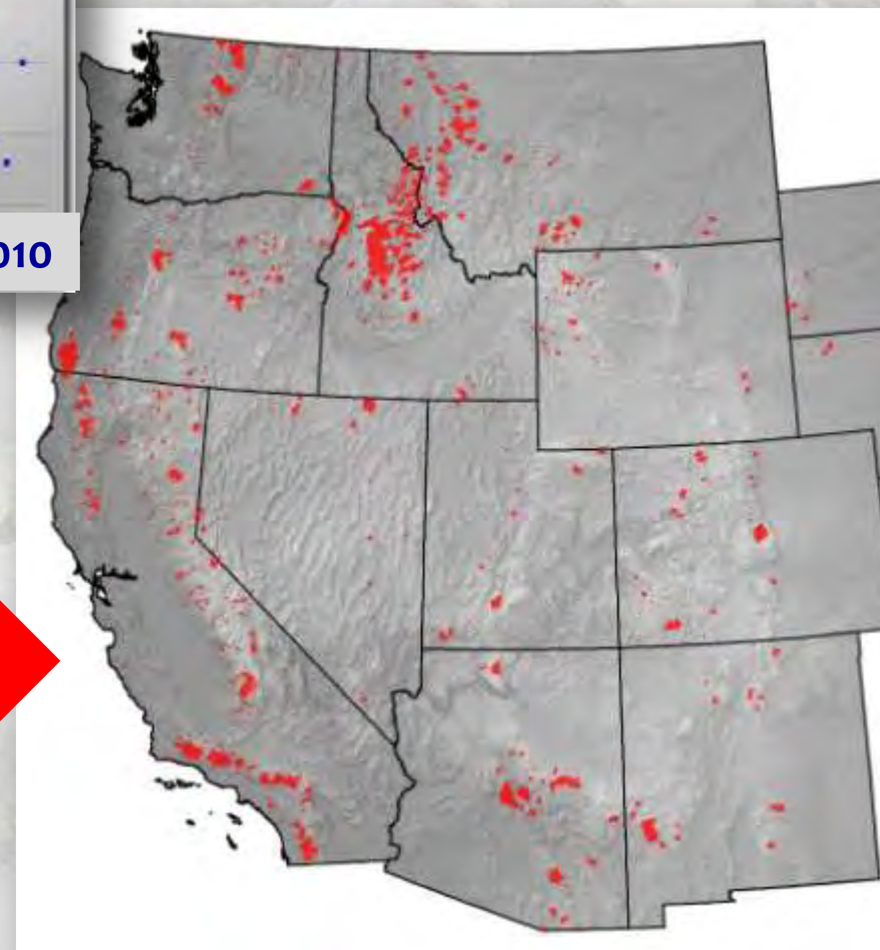




Wildfires Increasing Westwide



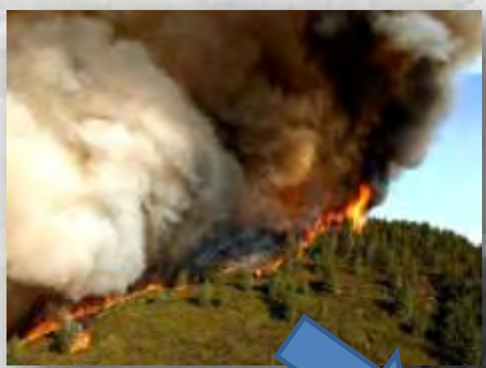
Fires from 2001 - 2007
on USFS Lands

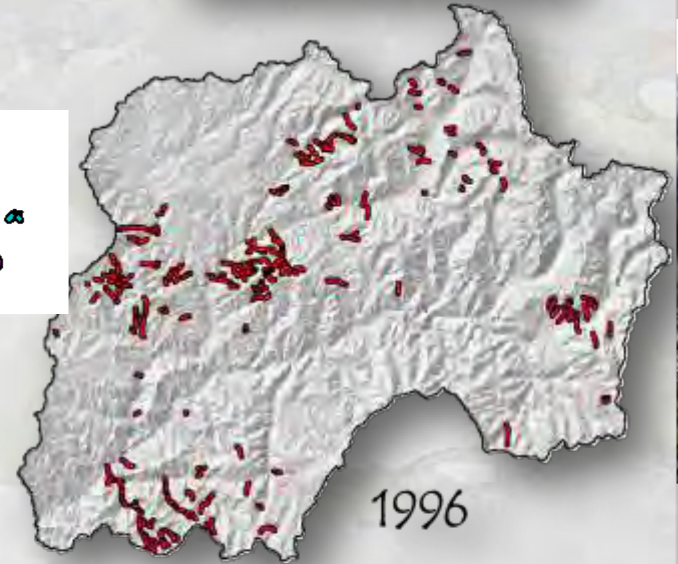


National Research Council. 2011

Sediment Regimes

Fire & Disturbance

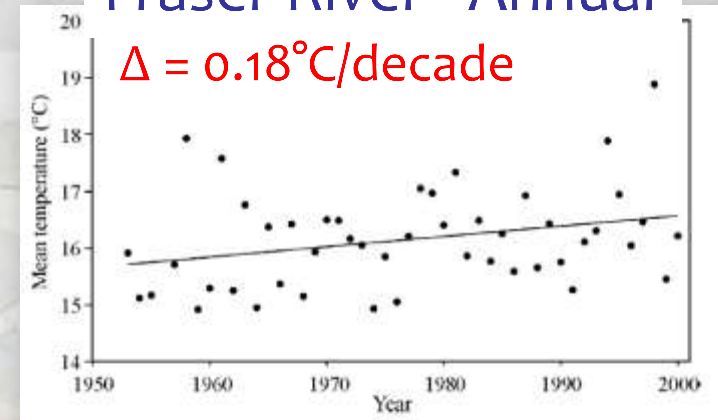




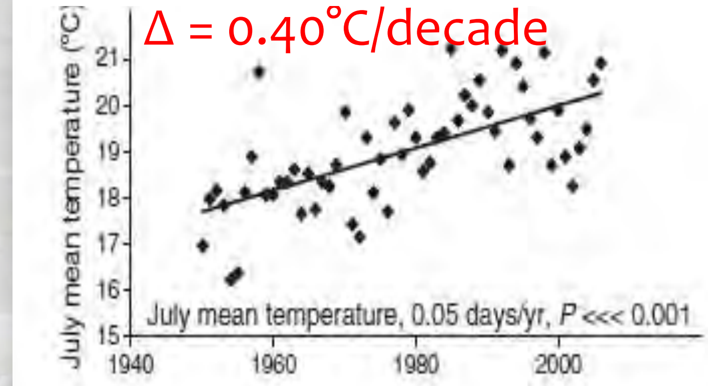
Burned & debris flow

Temperature Trends In Northwest Rivers

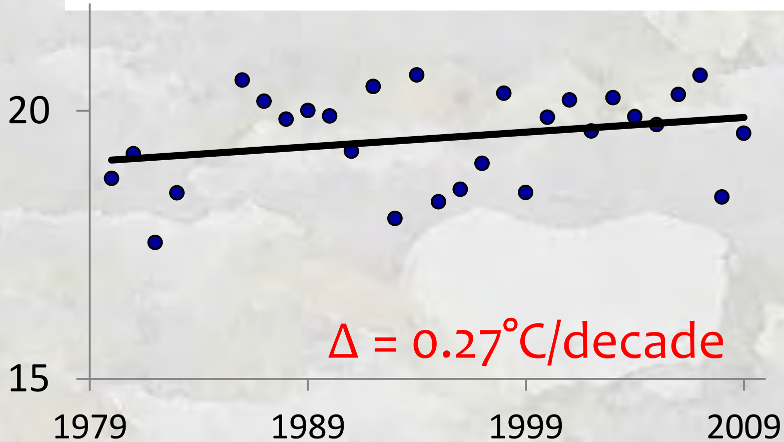
Fraser River - Annual



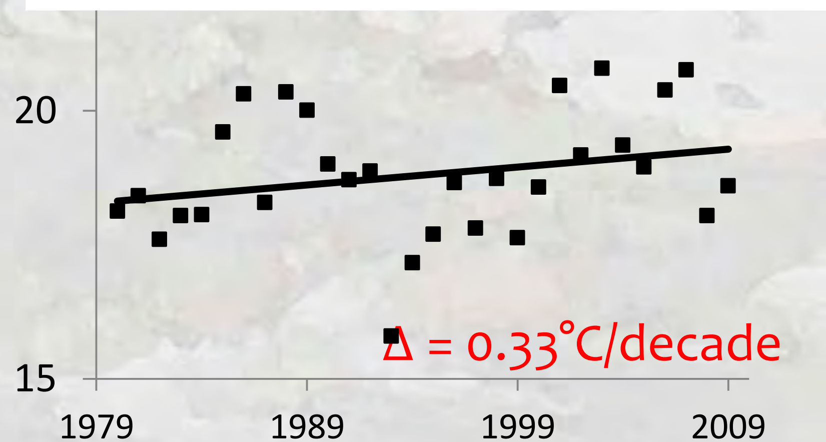
Columbia River - Summer



Snake River, ID - Summer



Missouri River, MT - Summer



Factors Confounding Stream Warming = Urbanization + Reservoirs

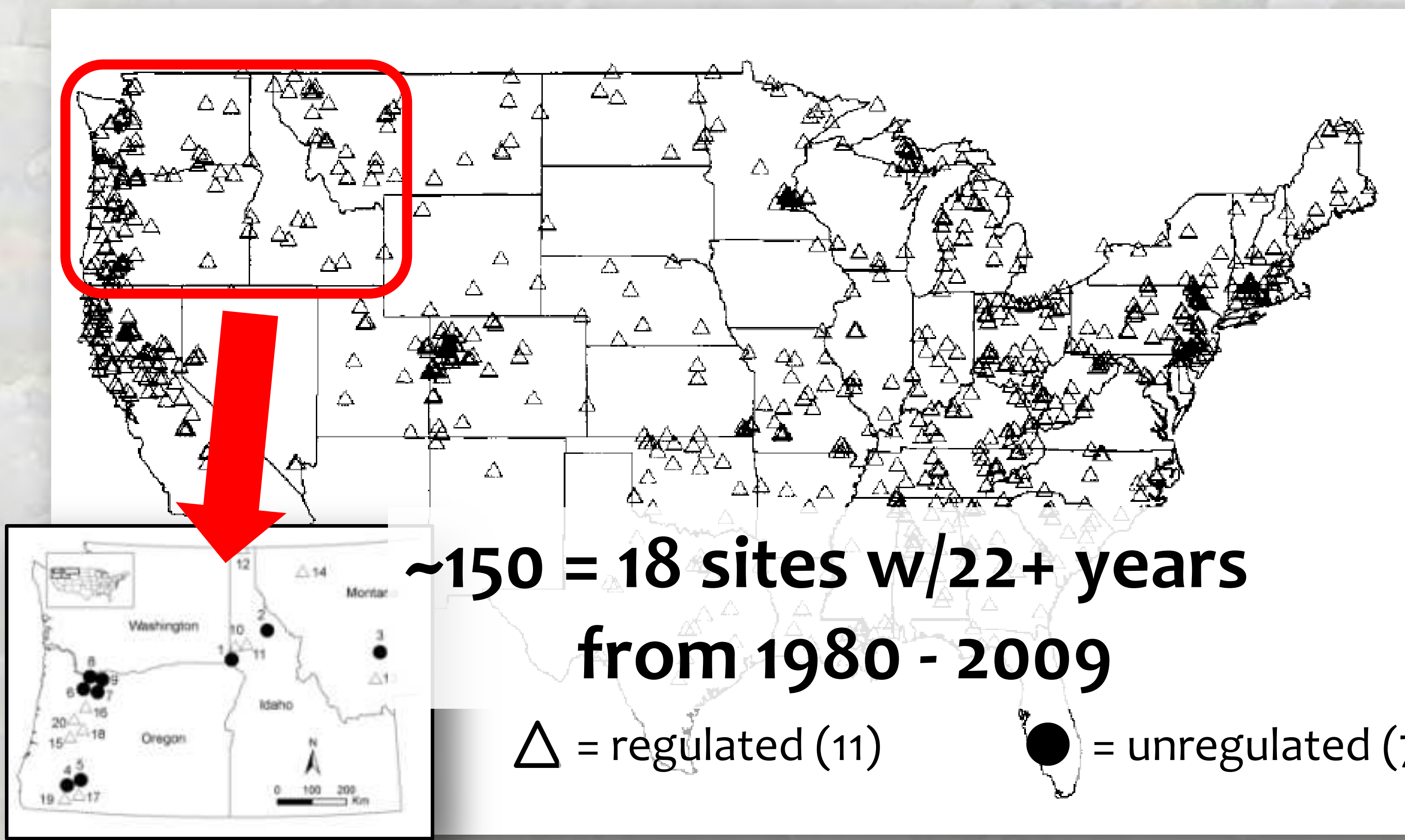
Rising stream and river temperatures in the United States

Sujay S Kaushal[1*], Gene E Likens[2], Norbert A Jaworski[3], Michael L Pace[2†], Ashley M Sides[1], David Seekell[4], Kenneth T Belt[5], David H Secor[1], and Rebecca L Wingate[1]

Kaushal et al. 2010. *Frontiers in Ecology & the Environment*

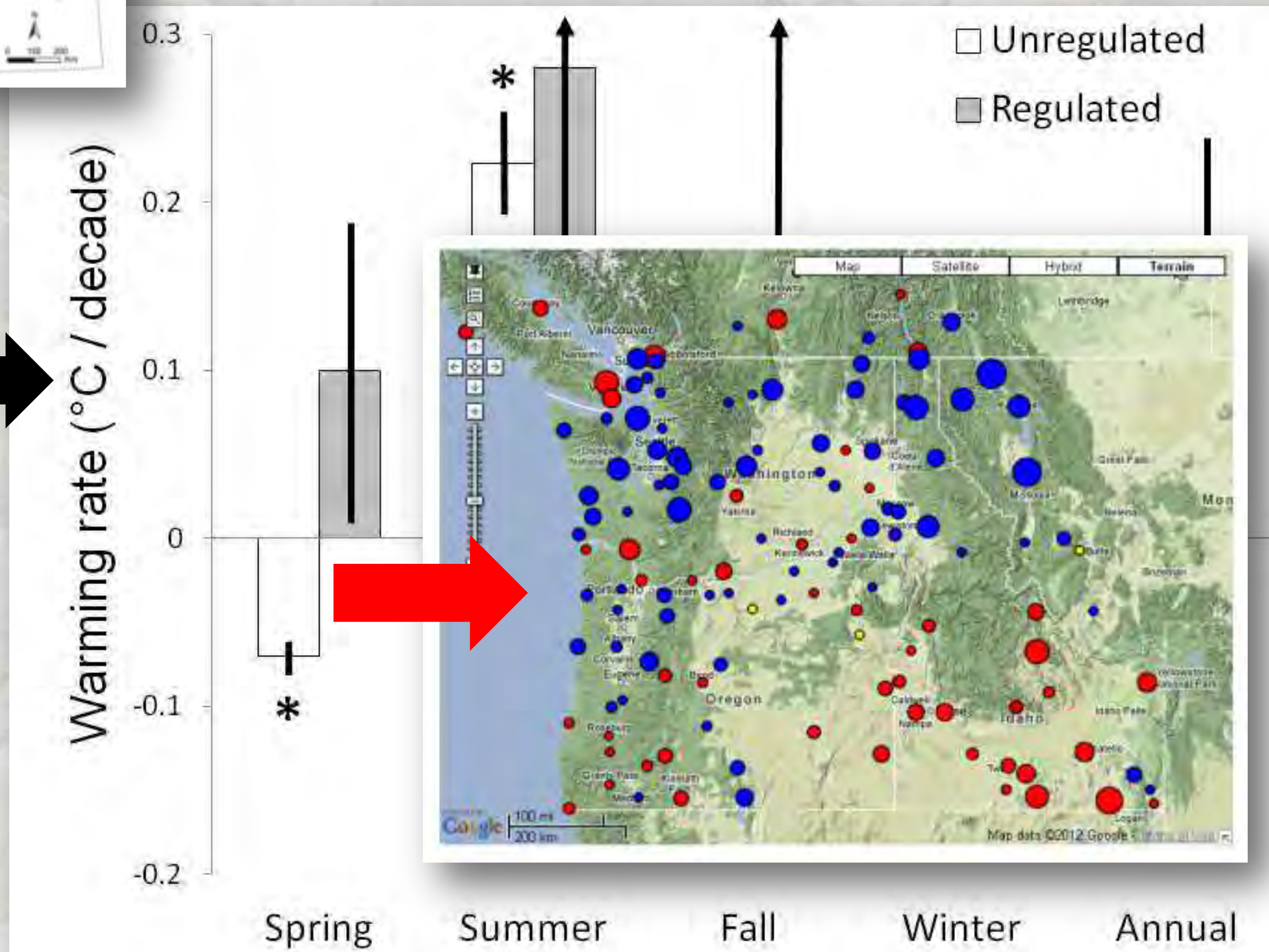
Are There “Pristine” Sites with Long-term Data to Serve as Climate Sentinels?

764 USGS gages have some temperature data



USGS NWIS Database (http://waterdata.usgs.gov/nwis)

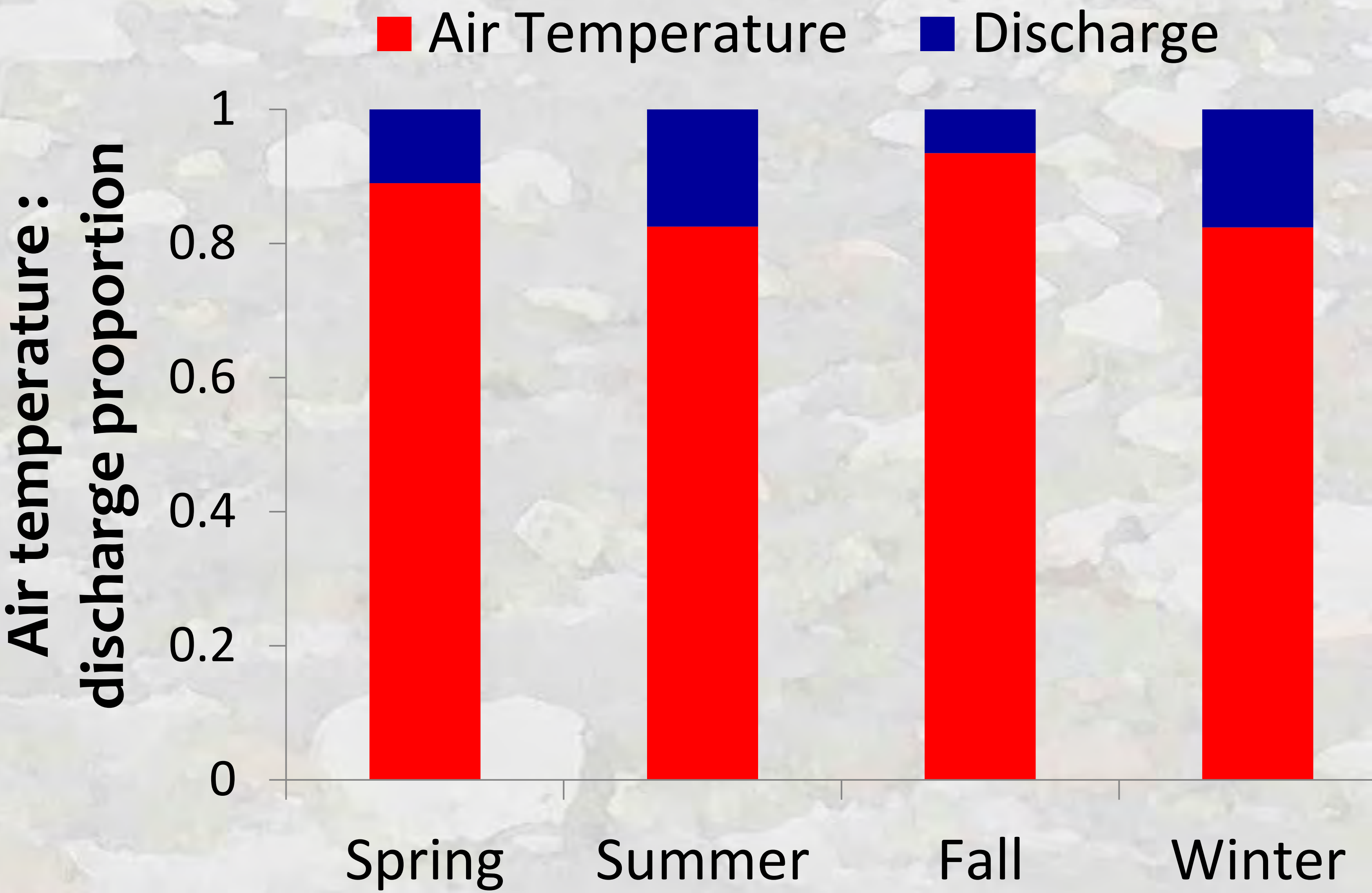
Seasonal Trends In Northwest Stream Temperatures (1980-2009)



Isaak et al. 2011. *Climatic Change* **113**:499-524.

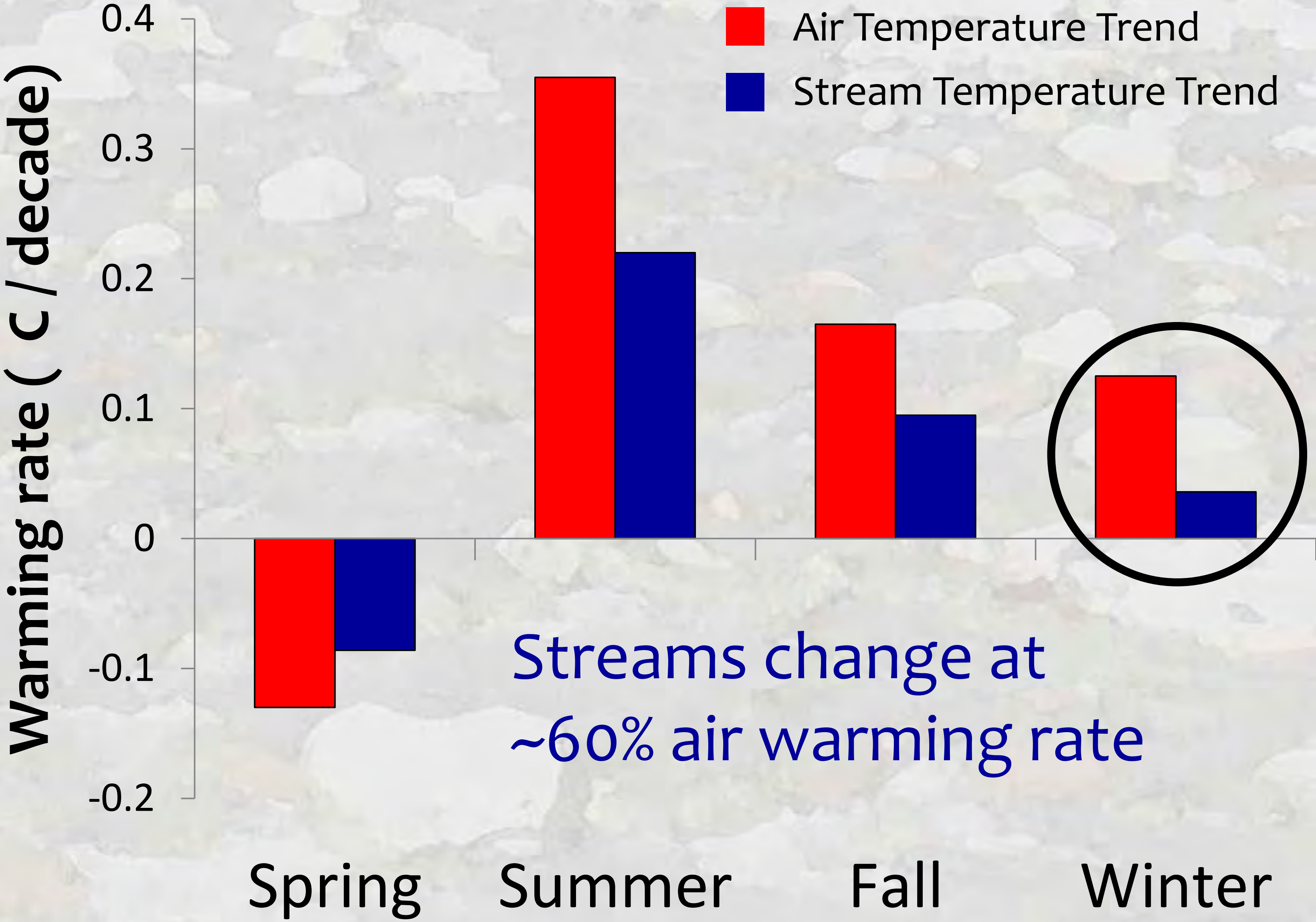
What's causing it?

Attribution of Stream Warming Trends



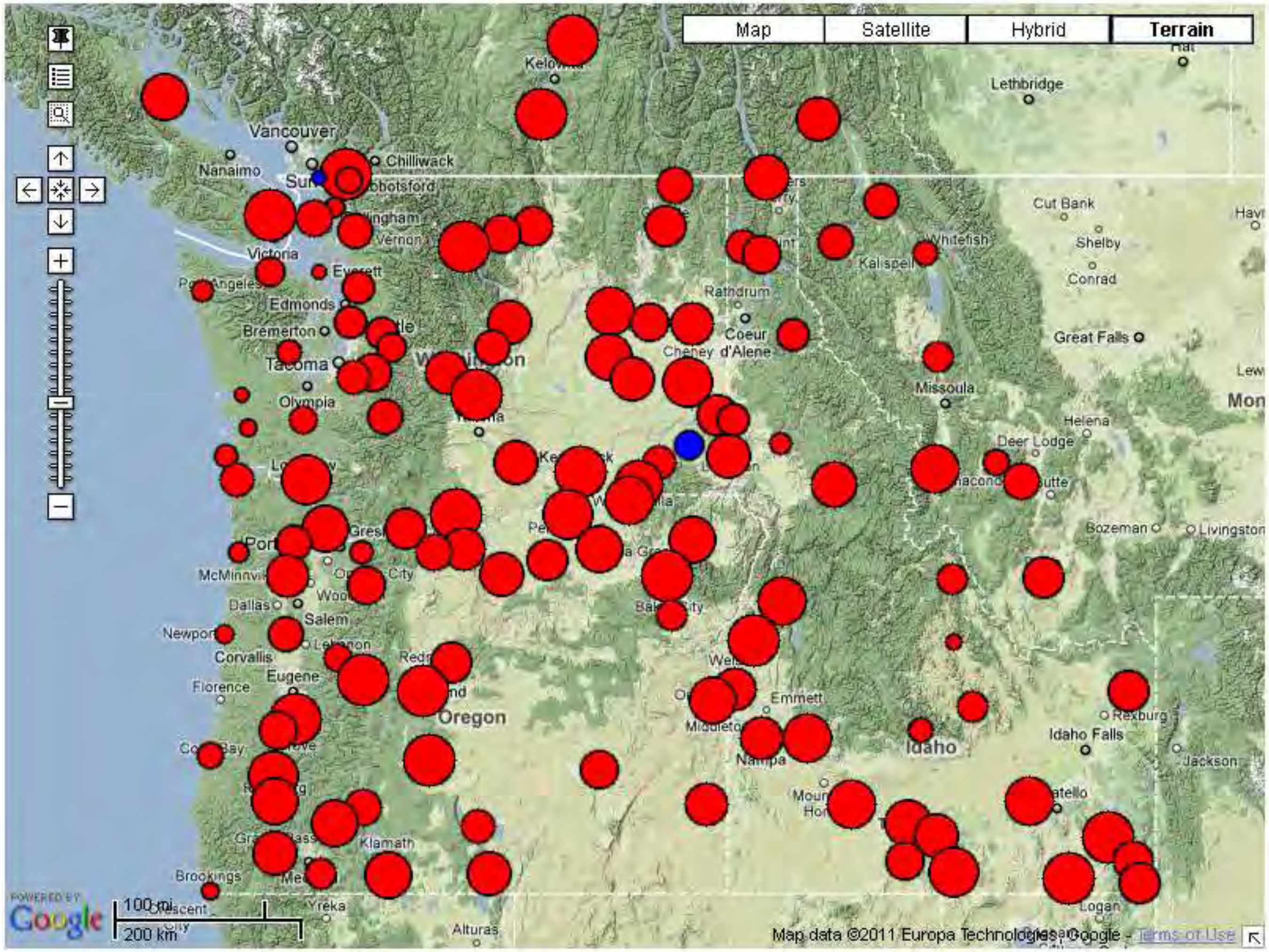
Isaak et al. 2011. *Climatic Change* **113**:499-524.

Streams are Tracking Air Temperatures



Air Trends as Stream Temperature Surrogates?

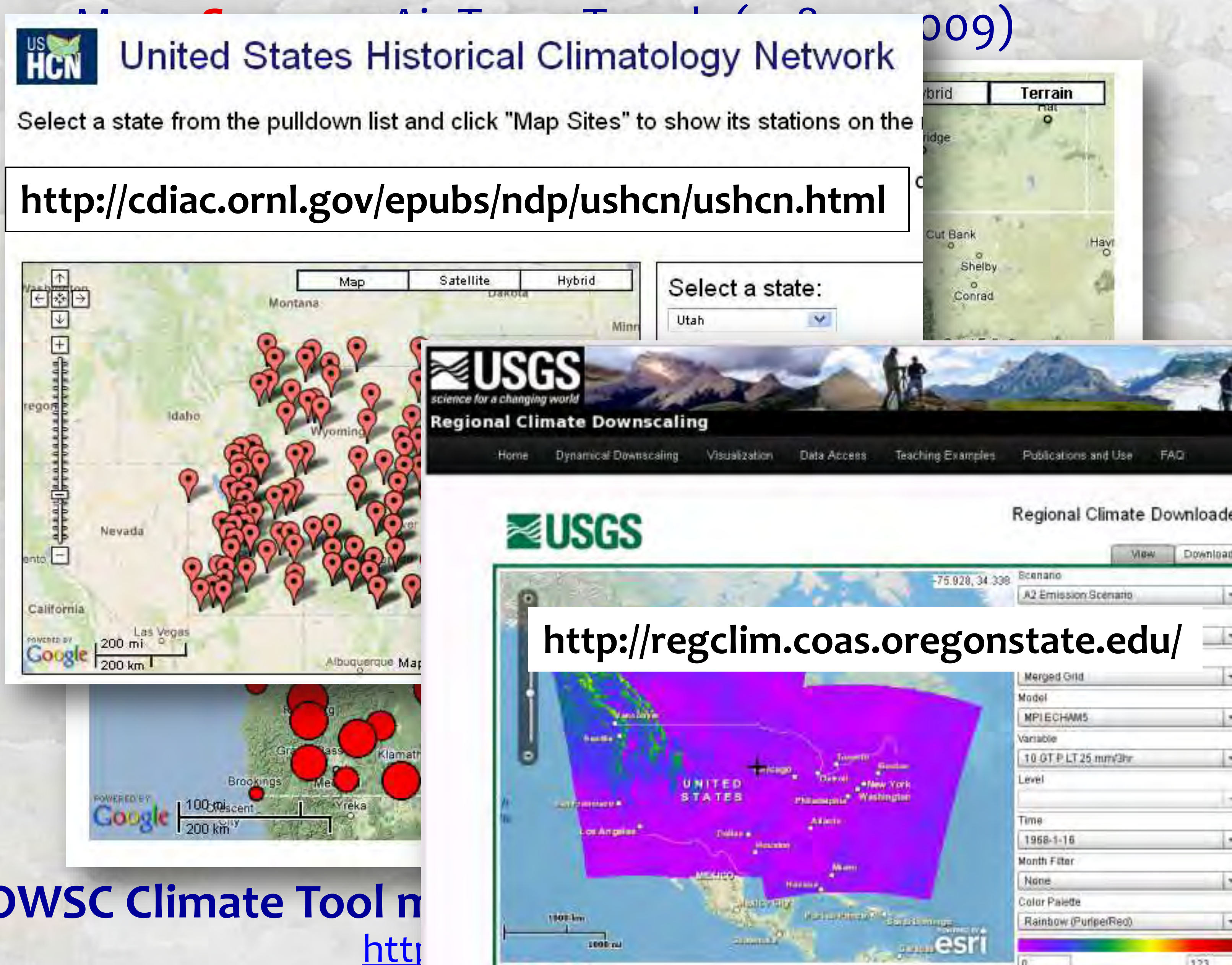
Mean **Summer** Air Temp Trends (1980 – 2009)



OWSC Climate Tool map

http://www.climate.washington.edu/trendanalysis/

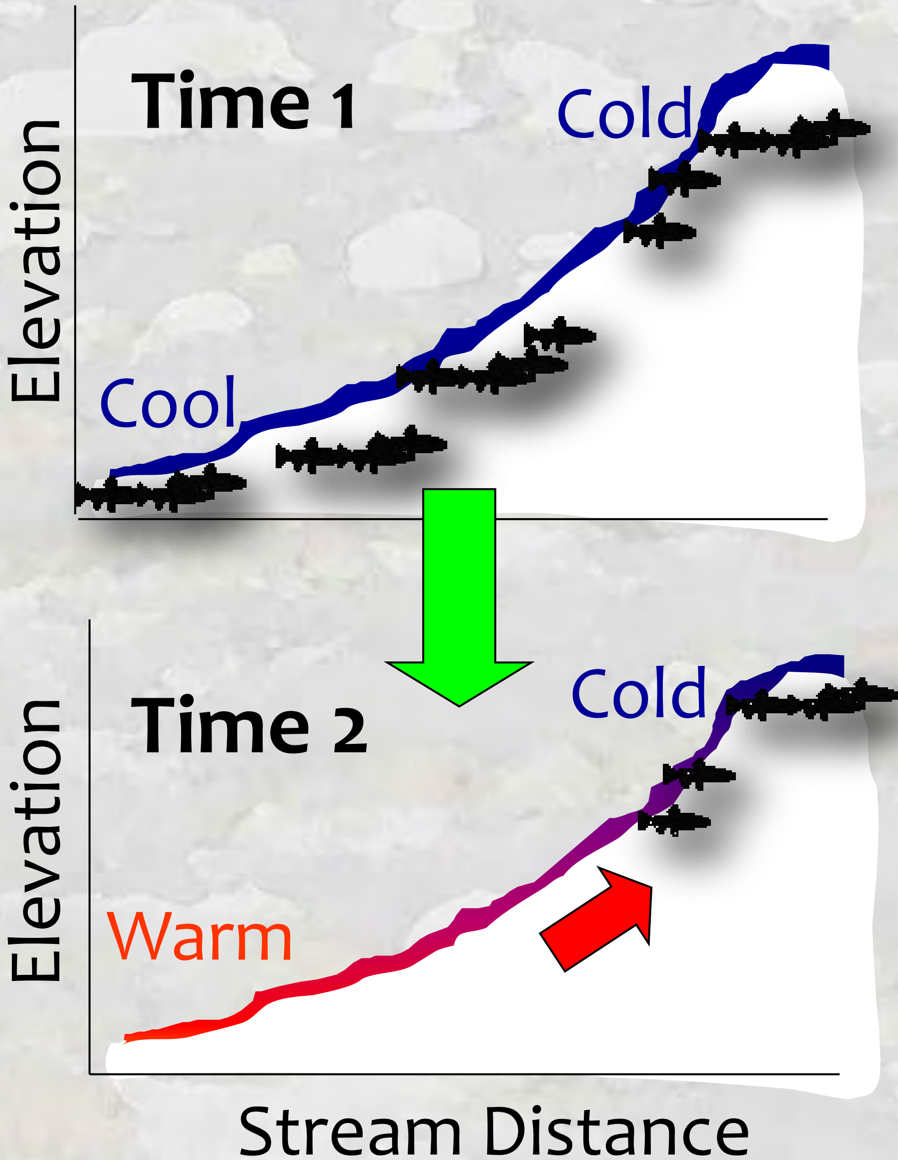
Air Trends as Stream Temperature Surrogates?



OWSC Climate Tool m

http

How Are Trout Populations Responding?

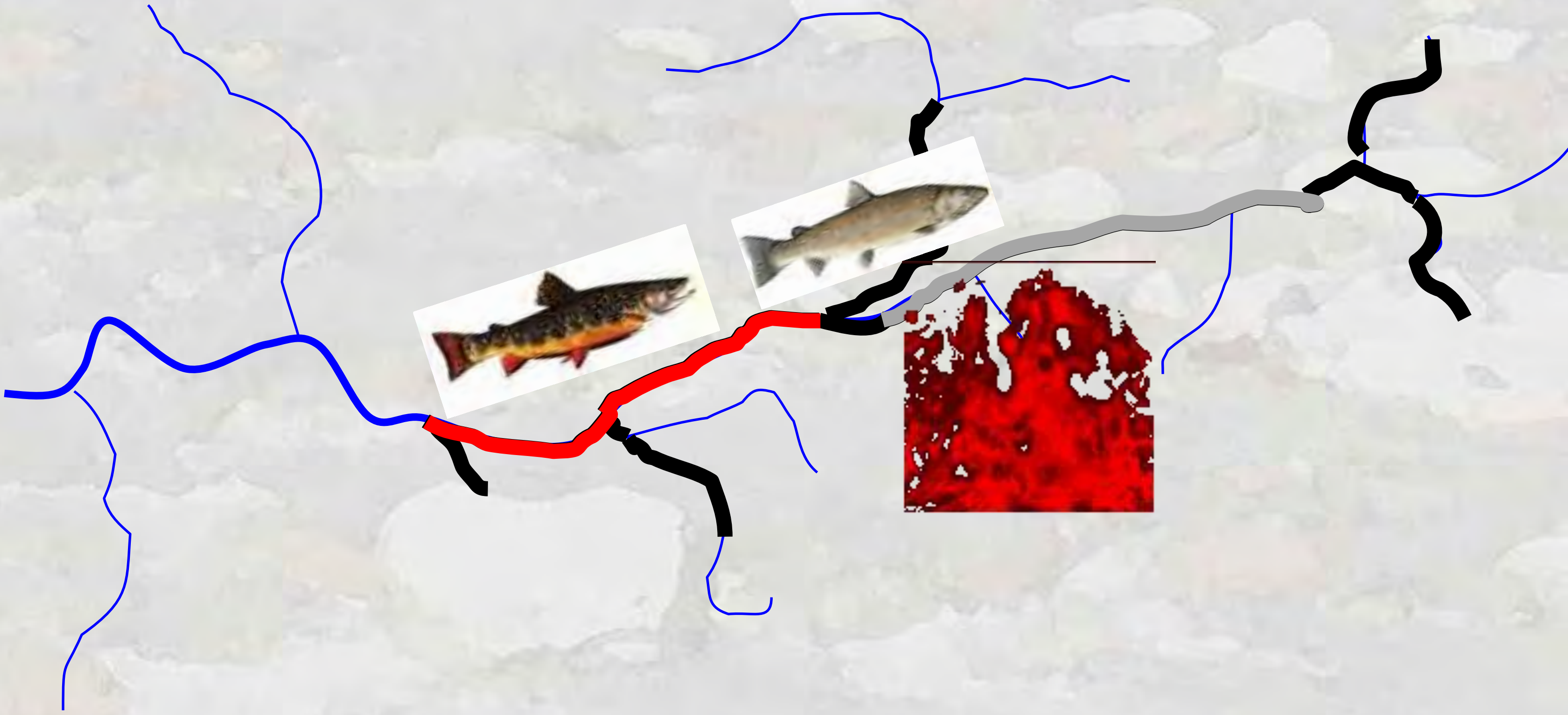


Average distribution shift across taxa =
6.1 km/decade poleward OR
6.1 m/decade higher

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

The Bull Trout Vise

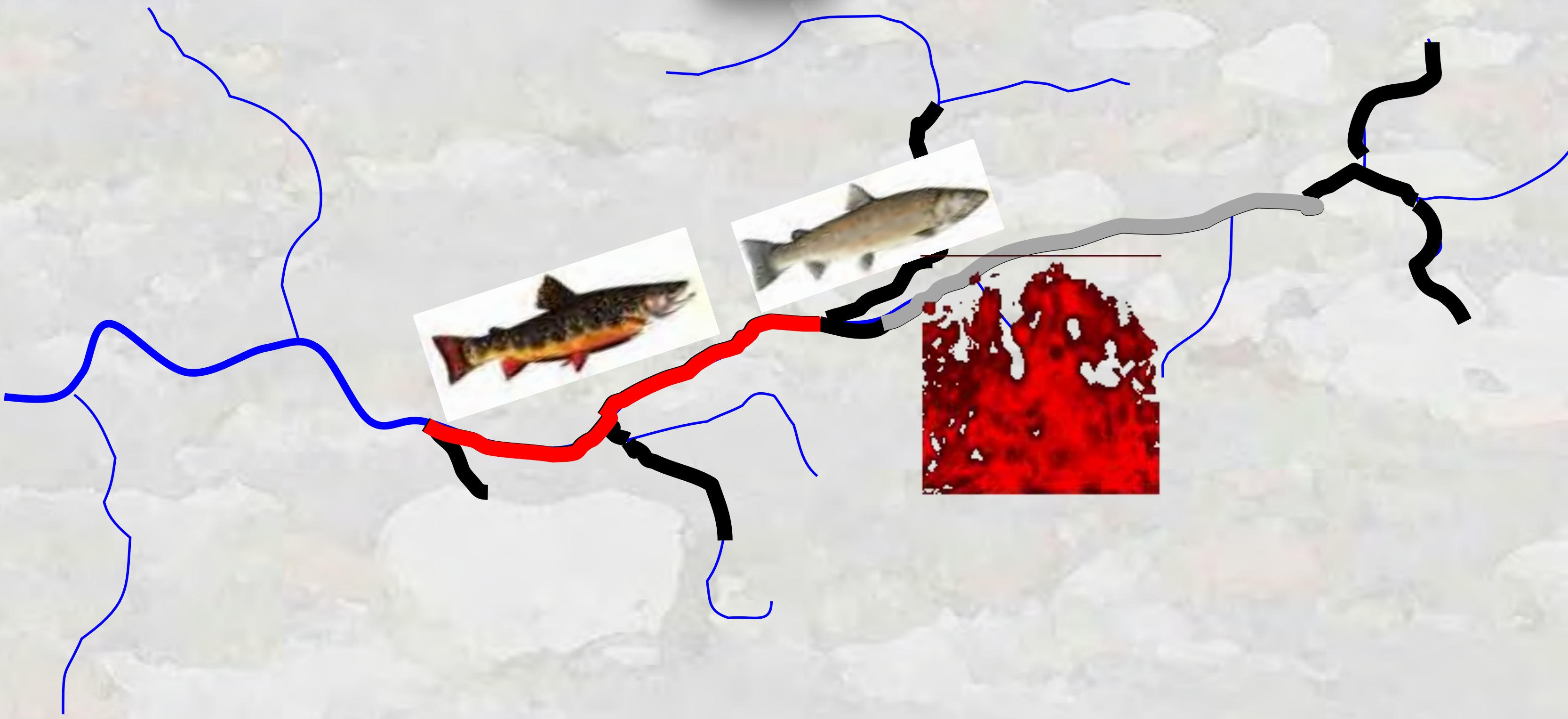
Warmer temperatures
Reduced summer flows
Fire & debris flows
Winter flooding
Non-native invasions



The Bull Trout Vise

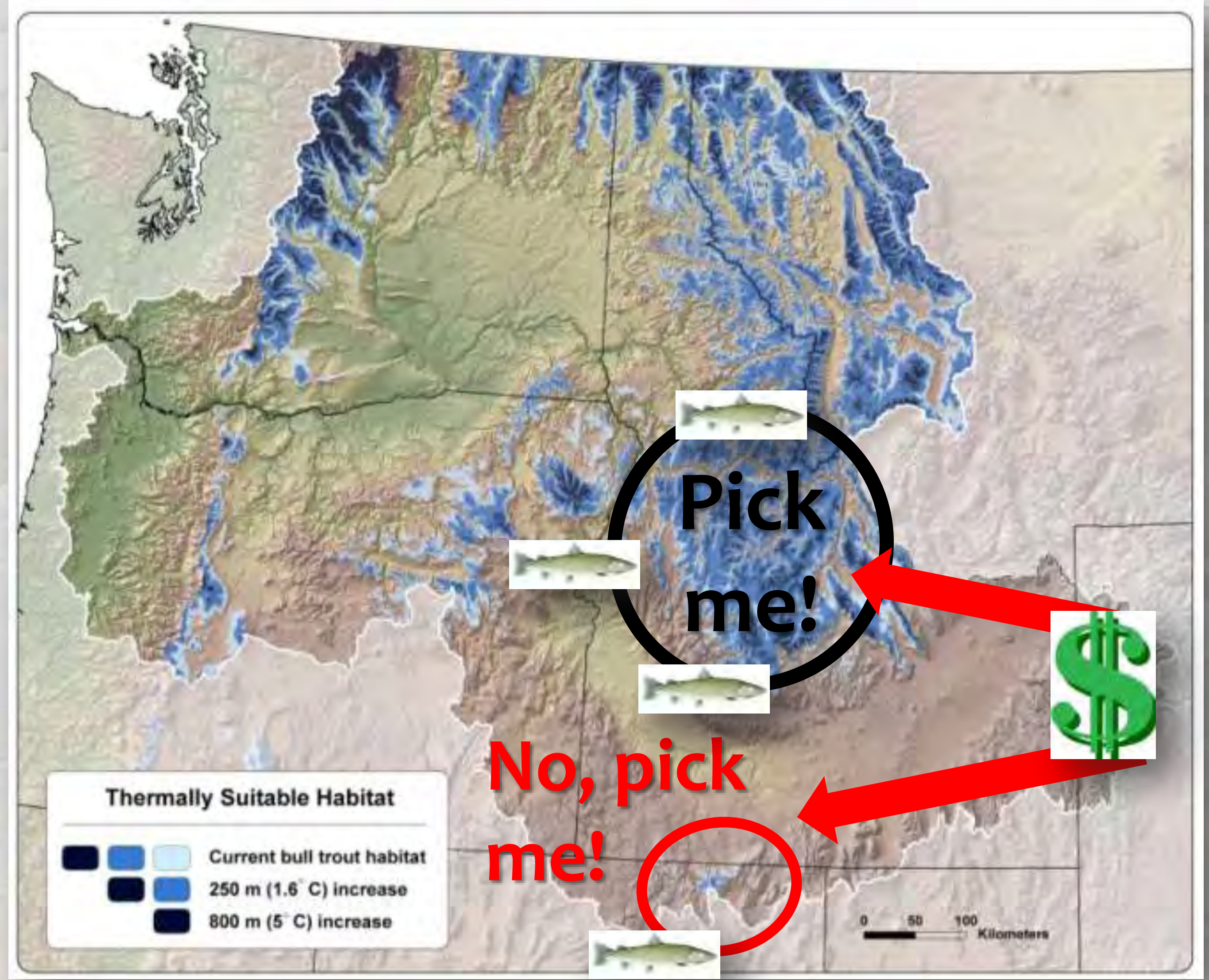
- Warmer temperatures
- Reduced summer flows ?
- Fire & debris flows !
- Winter flooding
- Non-native invasions !

CRCT Vise?

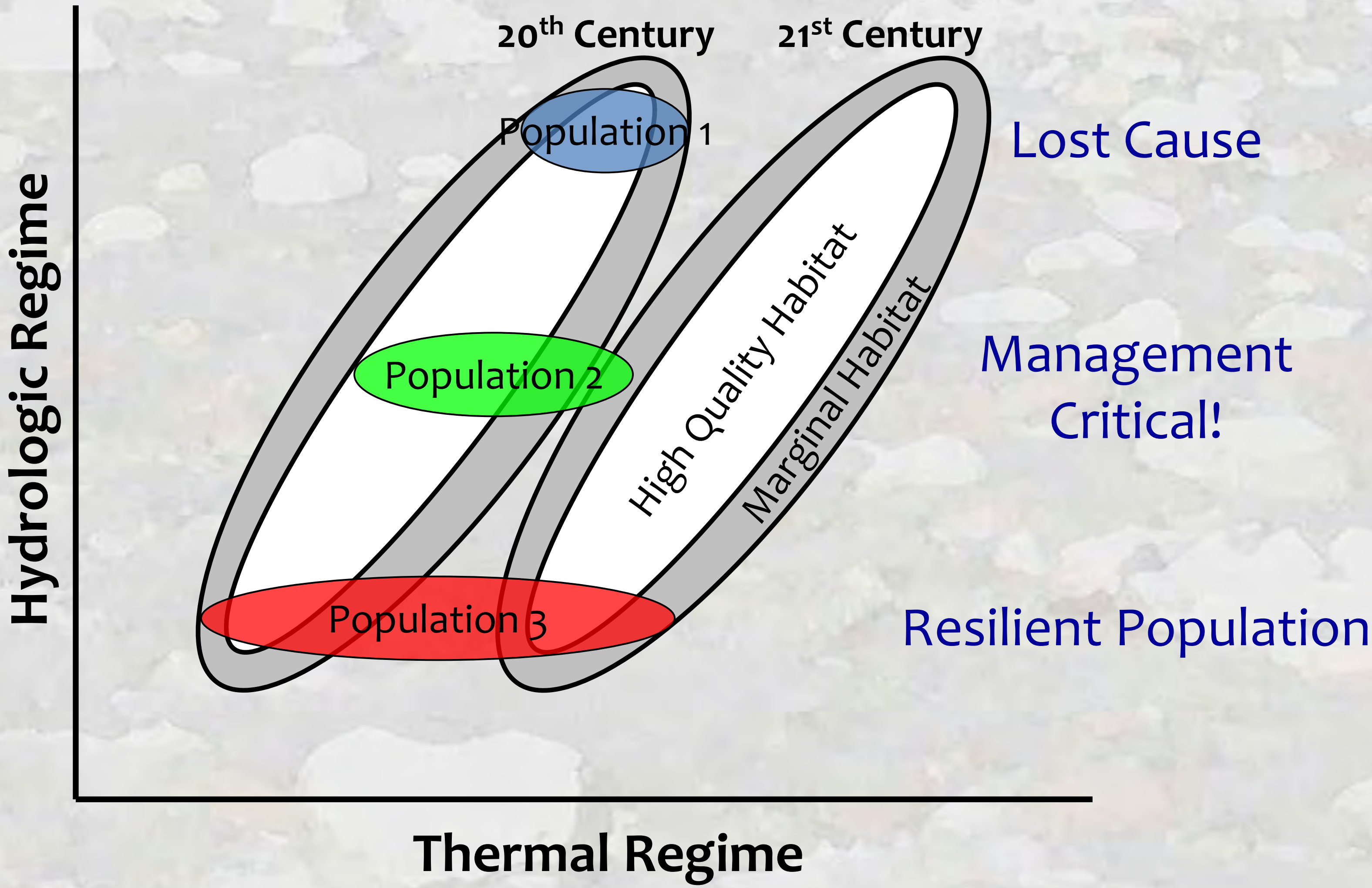


Lots of Uncertainties…

Where should scarce resources be spent?

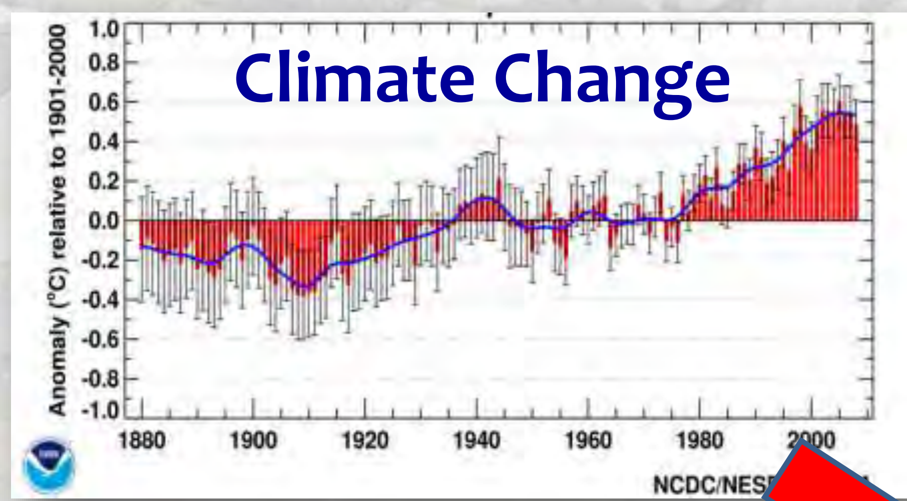


Where Can We Make a Difference?



Modified from Williams et al. 2007

More Pressure, Fewer Resources

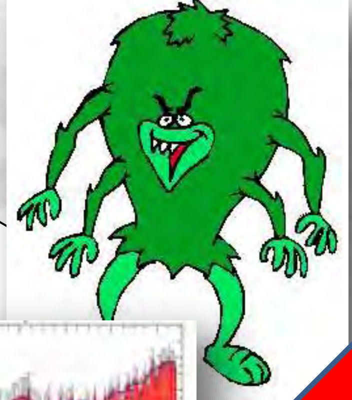


Urbanization & Population Growth

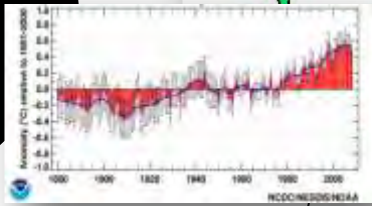
Shrinking Budgets

Need to do more with less

Climate Boogeyman



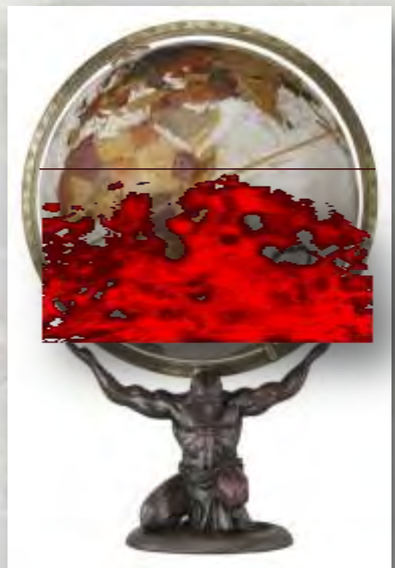
Onus?



Opportunity?

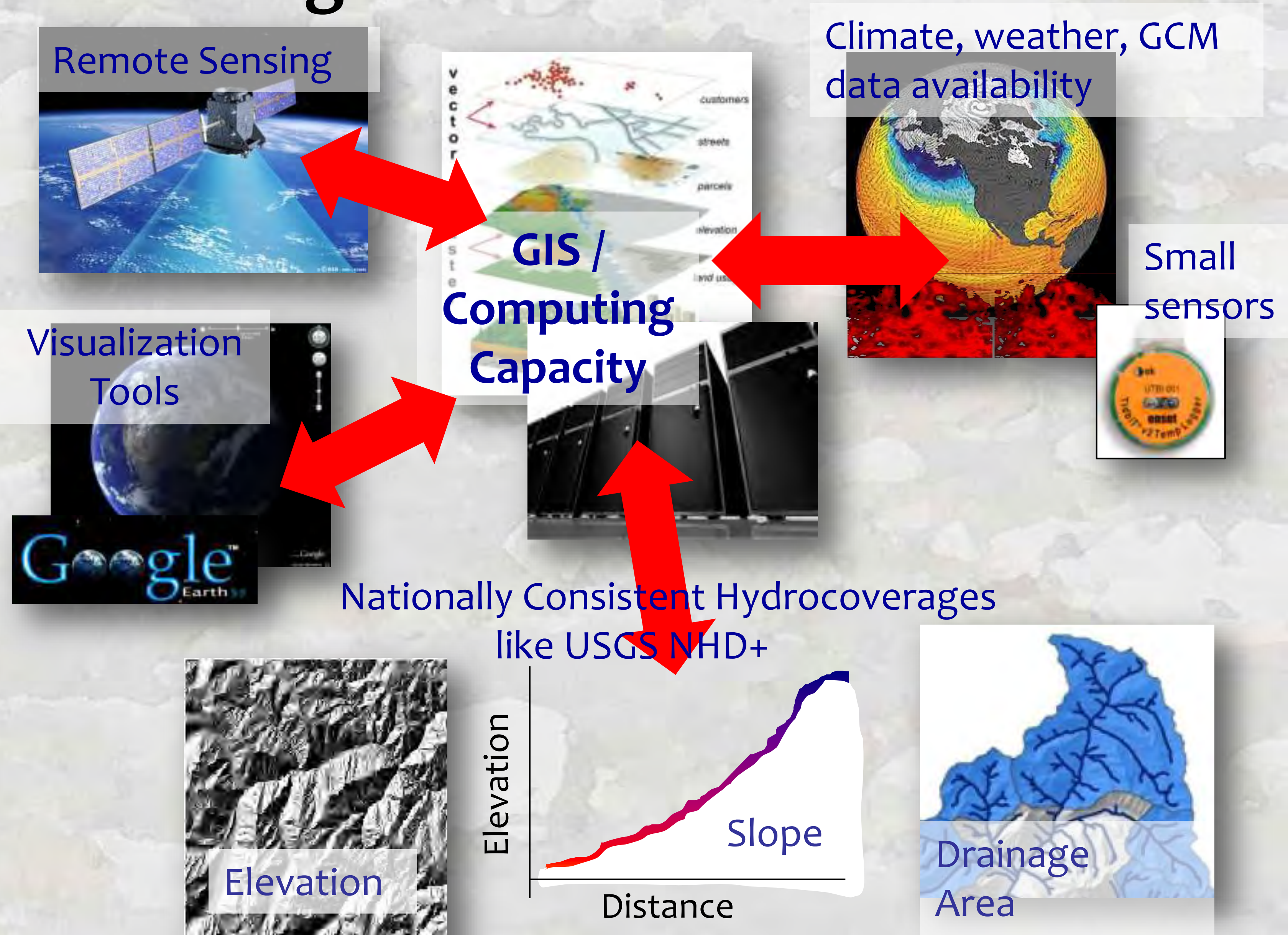
Analytical Capacity

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



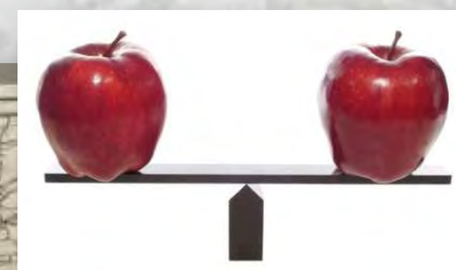
More Collaboration

Geospatial Tools for Accurate Regional Scale Stream Models



Accurate Spatial Information (a.k.a. “Maps”) Can Reduce Uncertainty

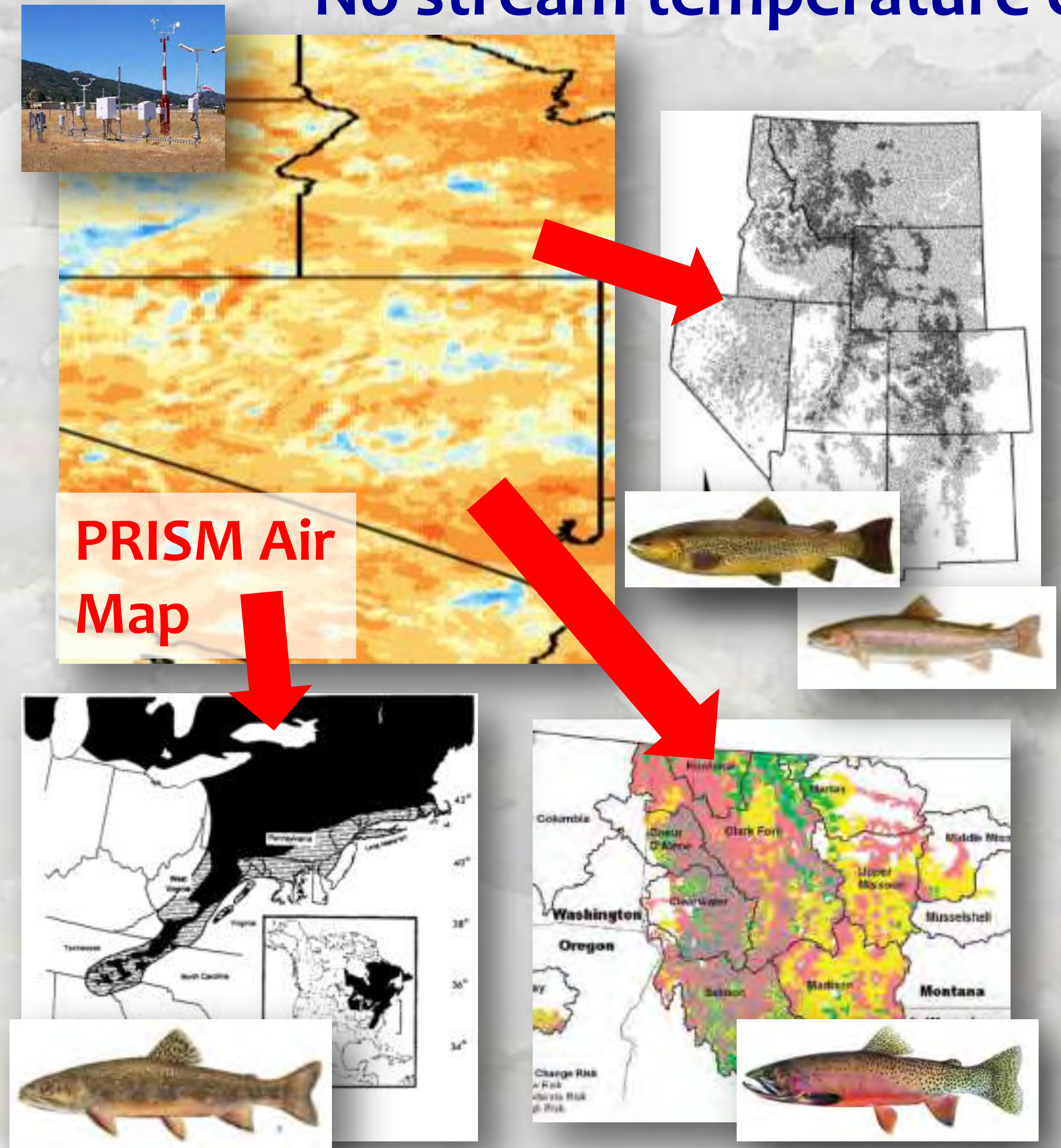
Maps are powerful tools, especially if they’re “smart”



Still catching up to Lewis & Clarke 200 years later…

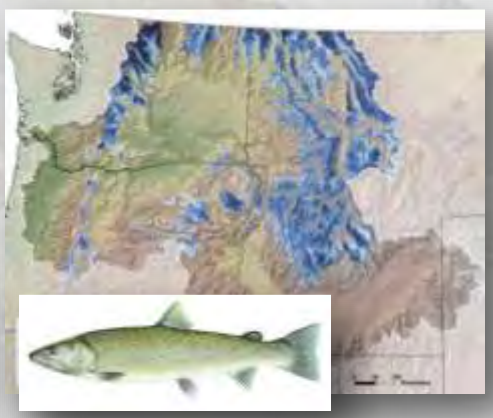
BioClimatic Assessments

No stream temperature component

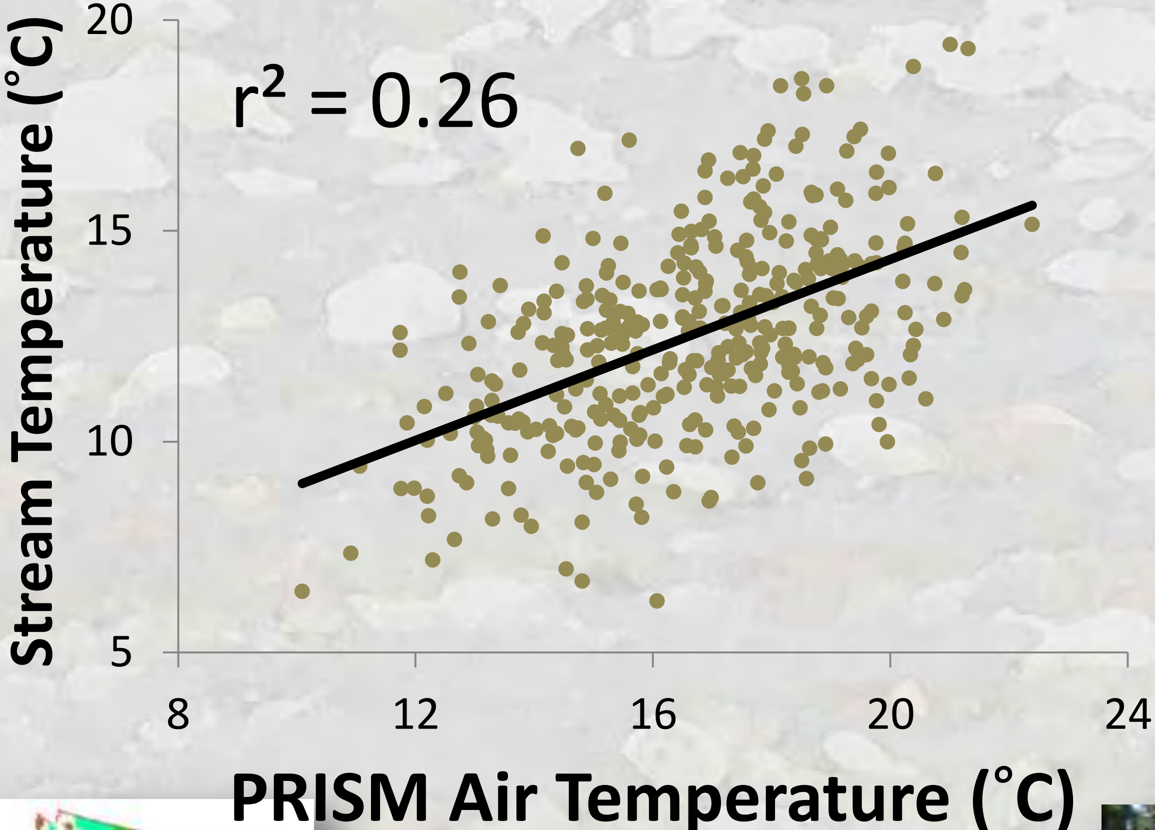


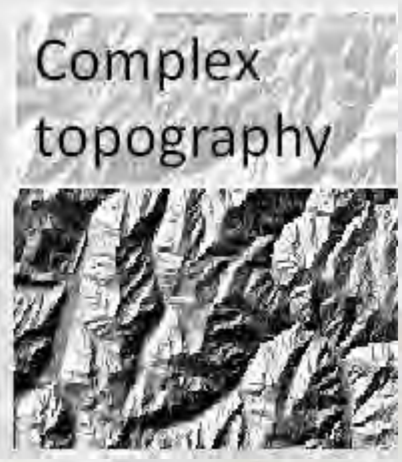
Air Temperatures…

- 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





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

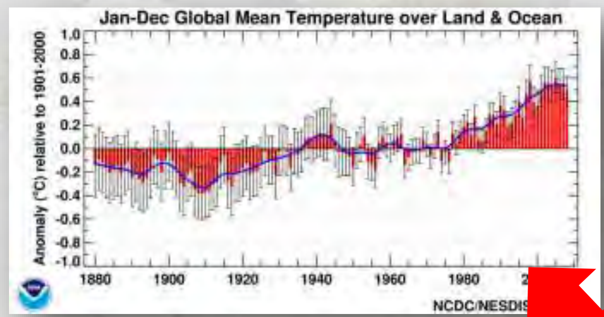
U.S. Forest Service

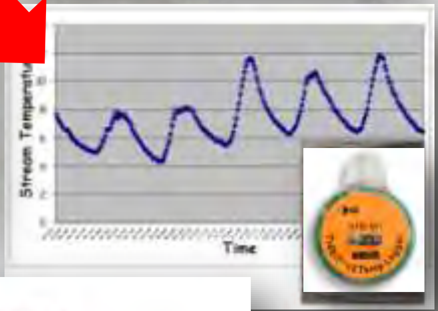
[1]Trout Unlimited

[2]CSIRO

[3]NOAA

[4]USGS





Great Northern
LANDSCAPE CONSERVATION COOPERATIVE

Lots of Temperature Data Out There…

Stealth Sensor Network

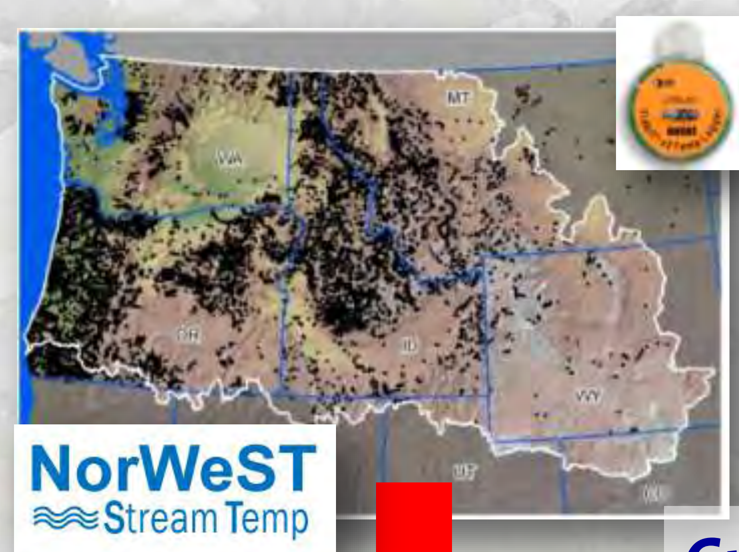
NorWeST Stream Temp

45,000,000+ hourly records
45,000+ summers measured
15,000+ unique stream sites

Stealth Sensor Network

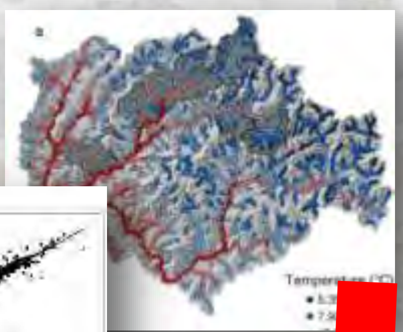
60+ agencies
350,000 stream km

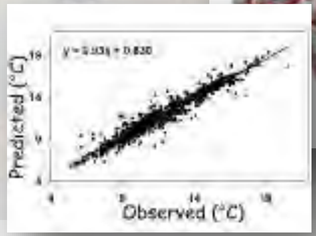
Regional Temperature Model



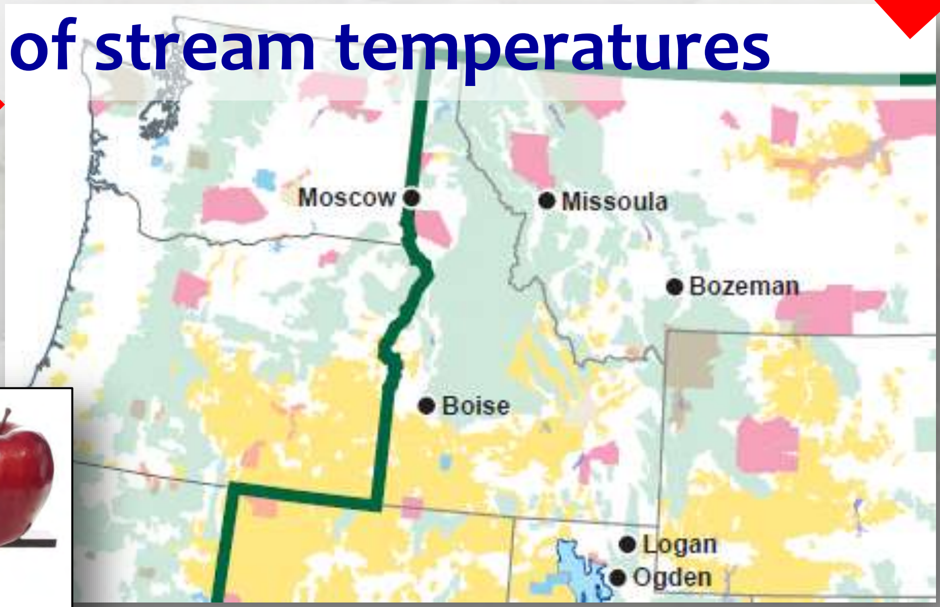
+

Accurate temperature models

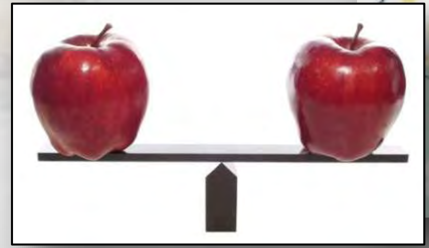




Cross-jurisdictional "maps" of stream temperatures

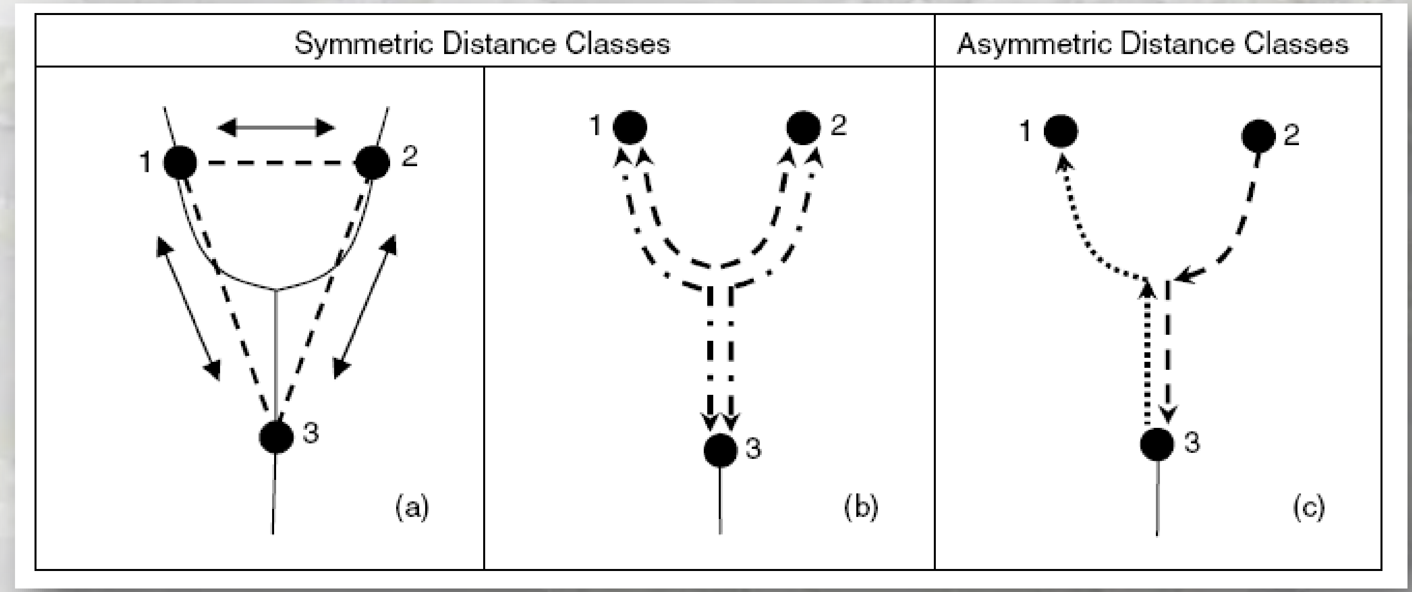


Consistent datum for strategic assessments across 350,000 stream kilometers



Spatial Statistical Stream Models

Valid means of interpolation between sample locations on networks… finally!



Advantages:

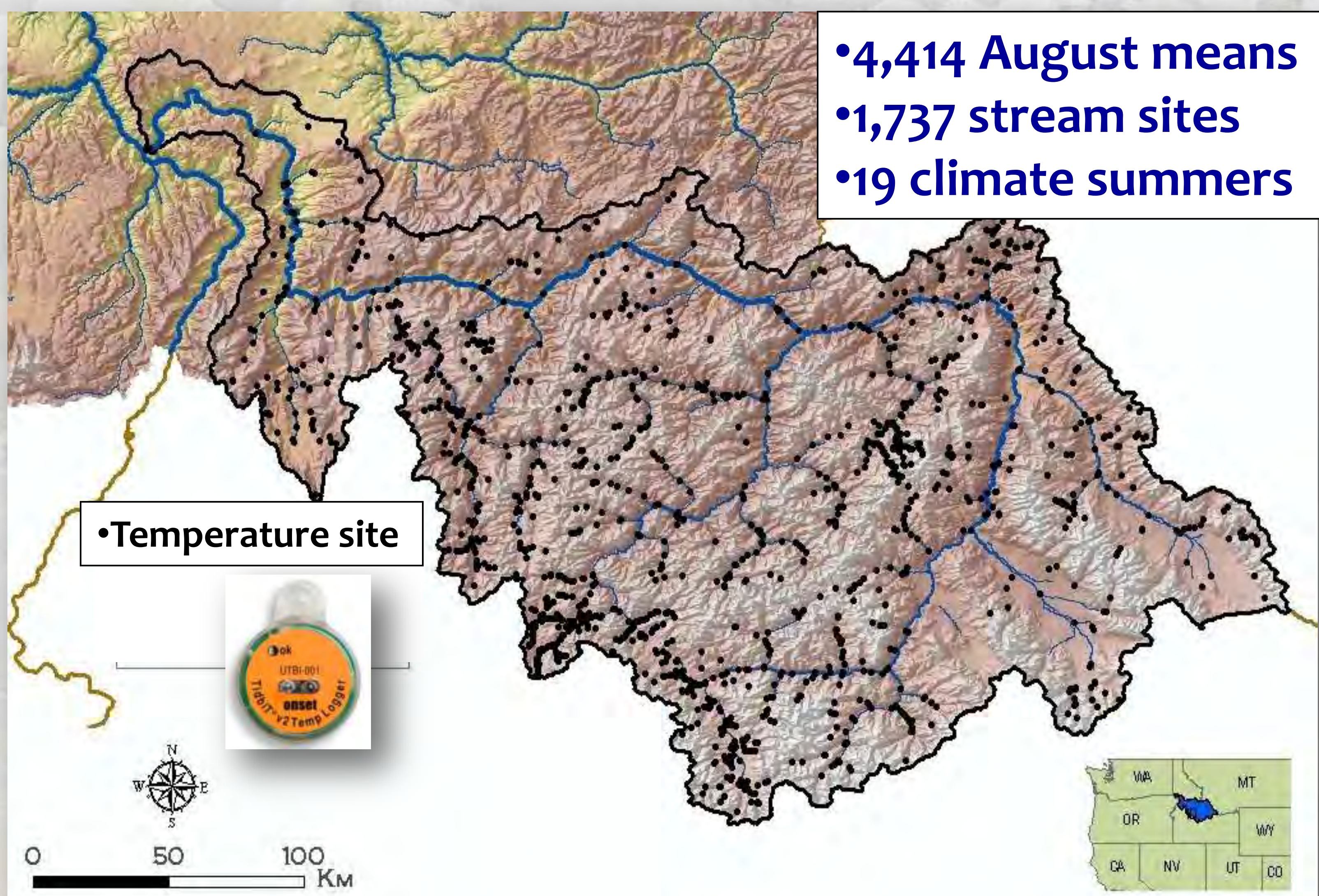
- Flexible & valid covariance structures that accommodate network topology & autocorrelation
- Much improved predictive ability & parameter estimates relative to non-spatial models

Ver Hoef et al. 2006; Peterson & Ver Hoef 2010; Ver Hoef & Peterson 2010

Example: Salmon River Basin

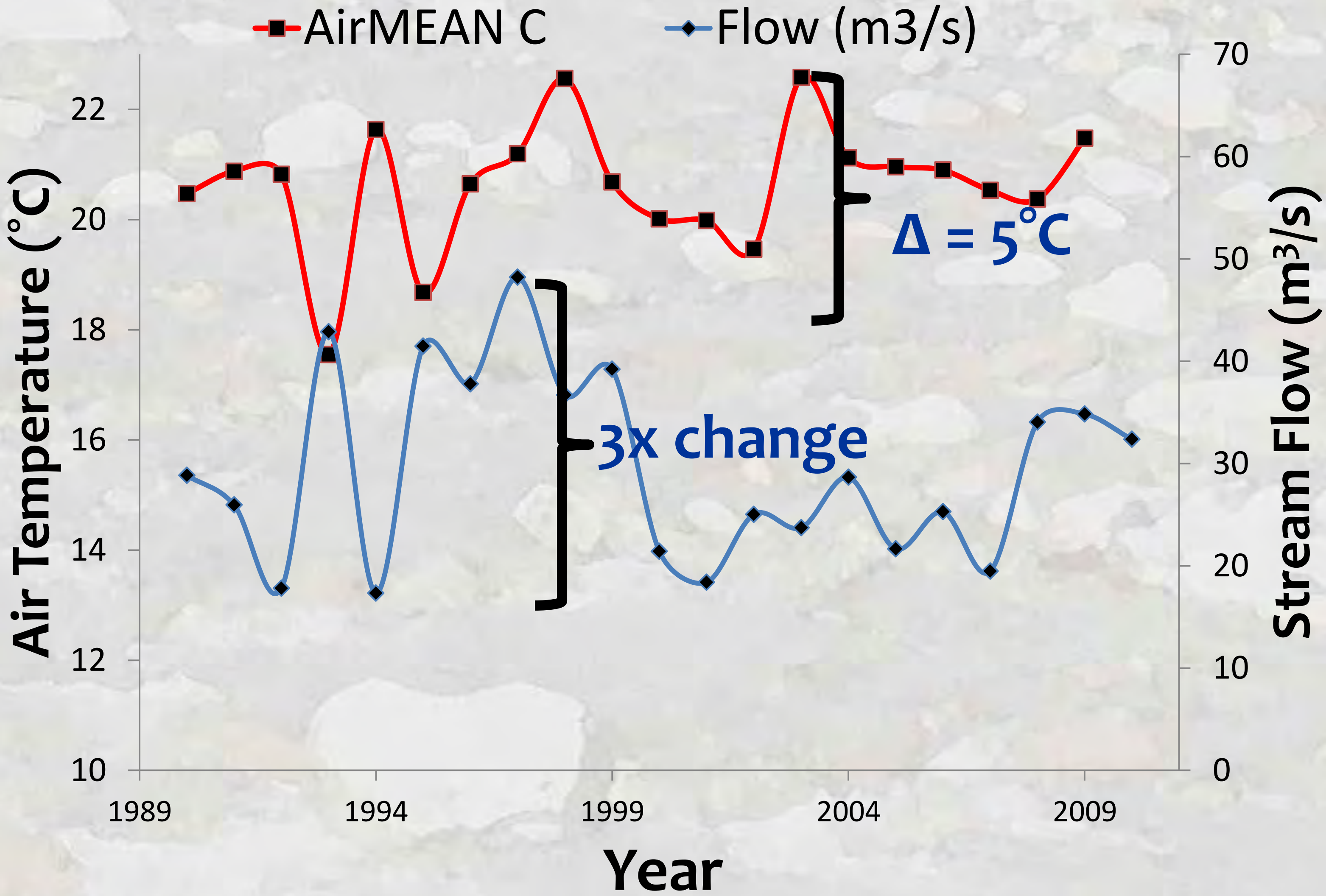
Data extracted from NorWeST

- 4,414 August means
- 1,737 stream sites
- 19 climate summers



Climatic Variability in Historical Record

Extreme years include late 21st-Century "averages"



Salmon River Temperature Model

n = 4,414

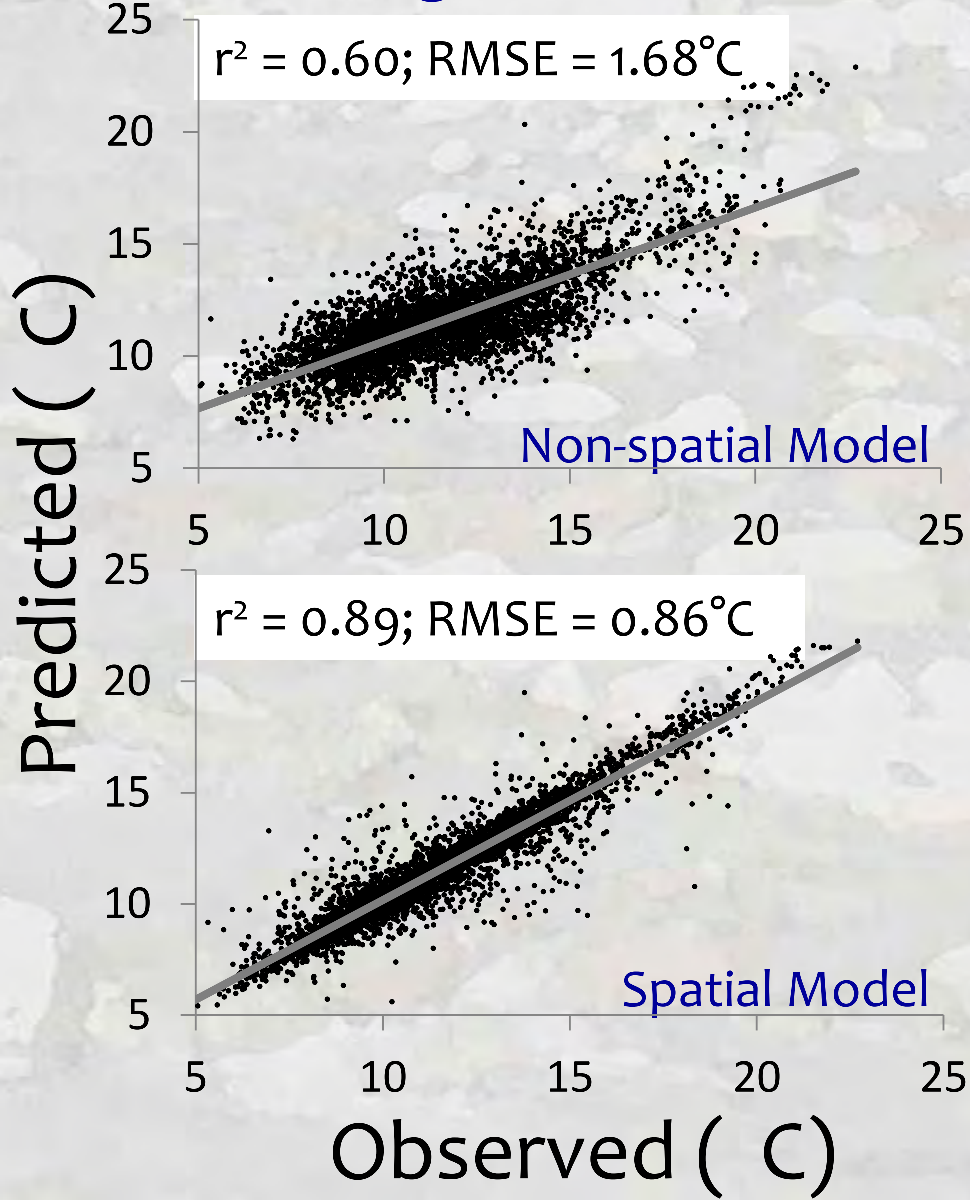
Covariate Predictors

1. Elevation (m)
2. Canopy (%)
3. Stream slope (%)
4. Ave Precipitation (mm)
5. Latitude (km)
6. Lakes upstream (%)
7. Glaciers upstream (%)
8. Baseflow Index
9. Watershed size (km^2)
10. Discharge (m^3/s)*
11. Air Temperature (˚C)#

* = USGS gage data

\# = NCEP RegCM3 reanalysis

Mean August Temperature



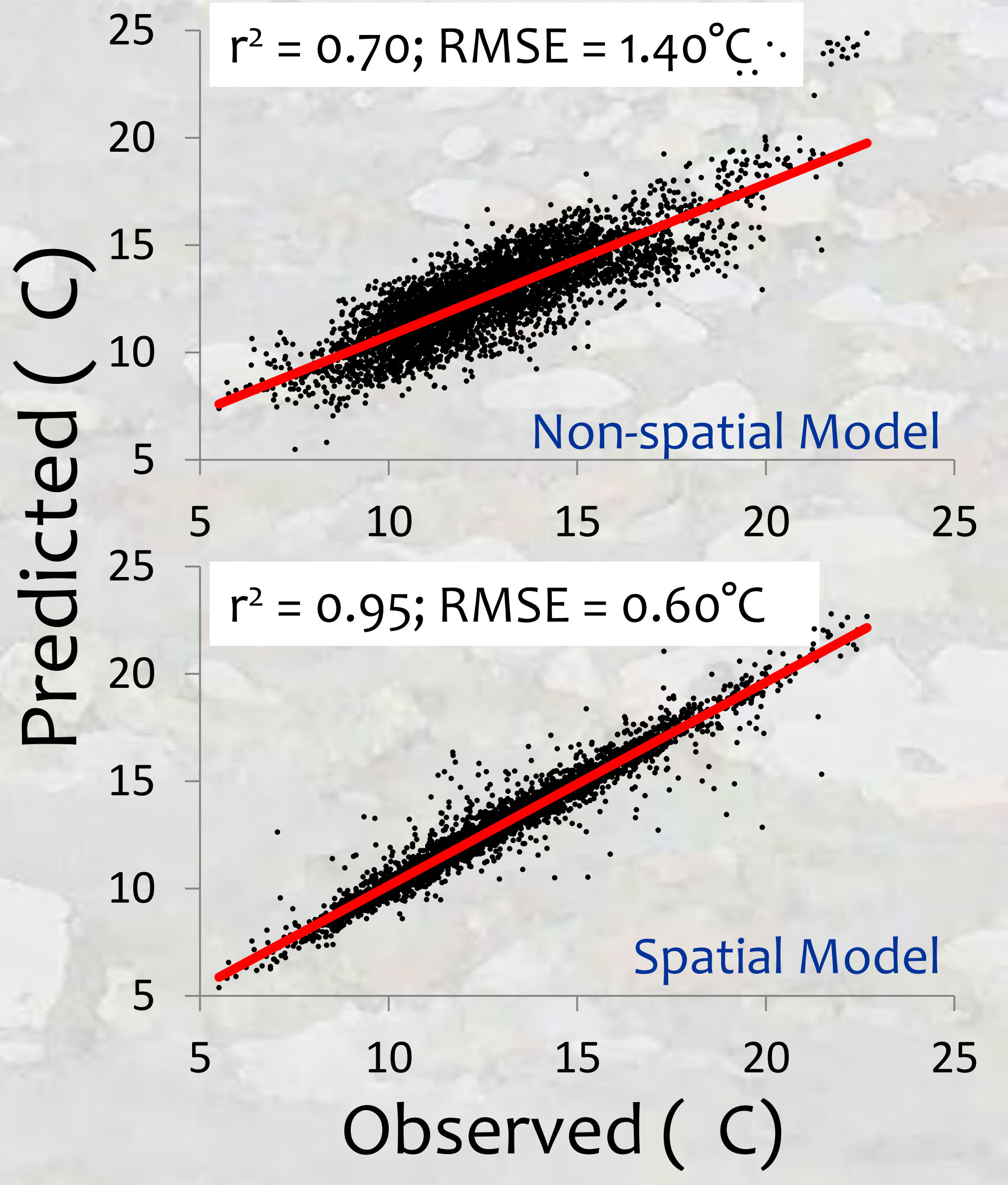
Clearwater River Temp Model

n = 4,487

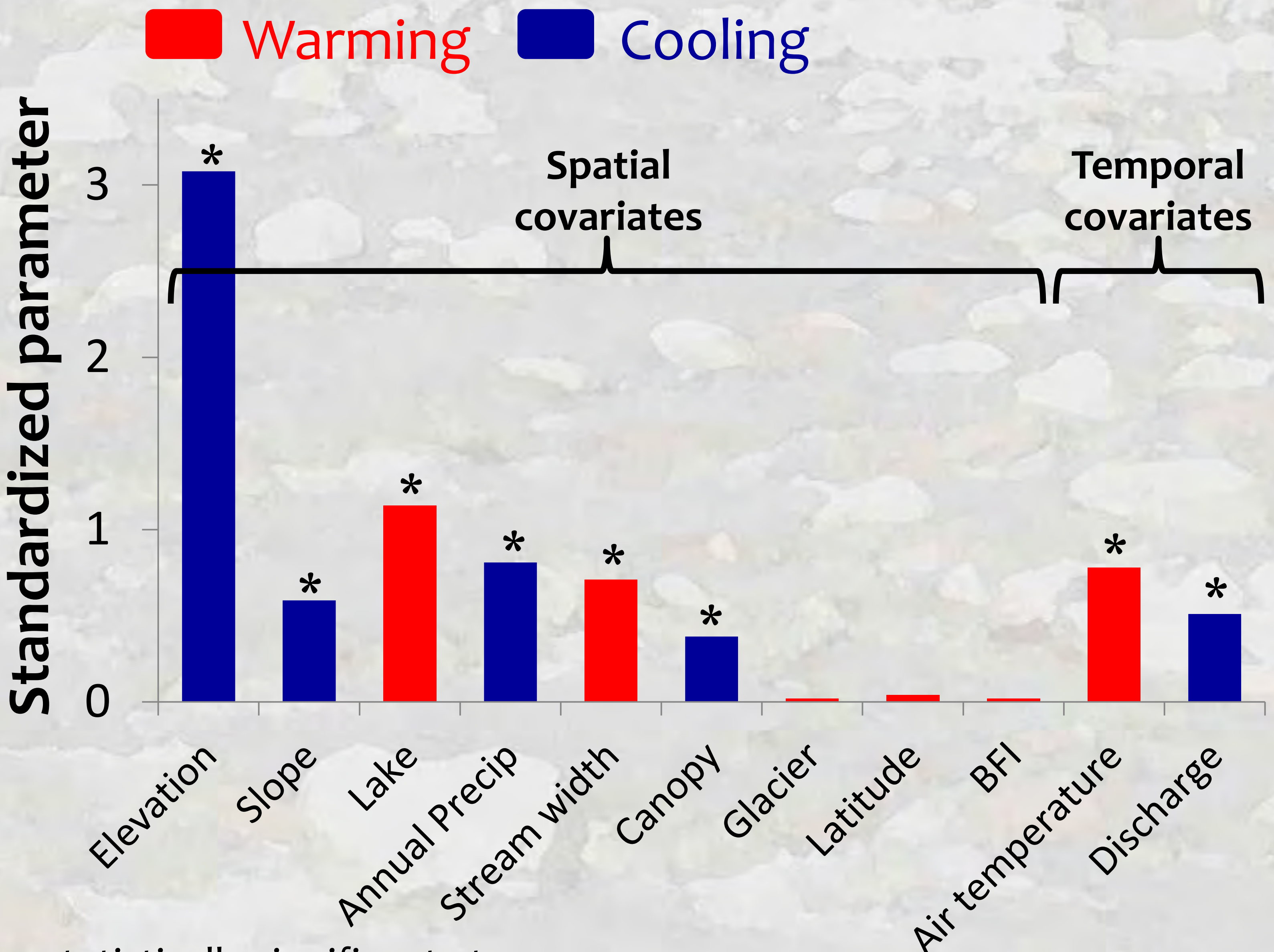
Covariate Predictors

1. Elevation (m)
2. Canopy (%)
3. Stream slope (%)
4. Ave Precipitation (mm)
5. Latitude (km)
6. Lakes upstream (%)
7. Glaciers upstream (%)
8. Baseflow Index
9. Watershed size (km^2)
10. Discharge (m^3/s)
11. Air Temperature (°C)

Mean August Temperature



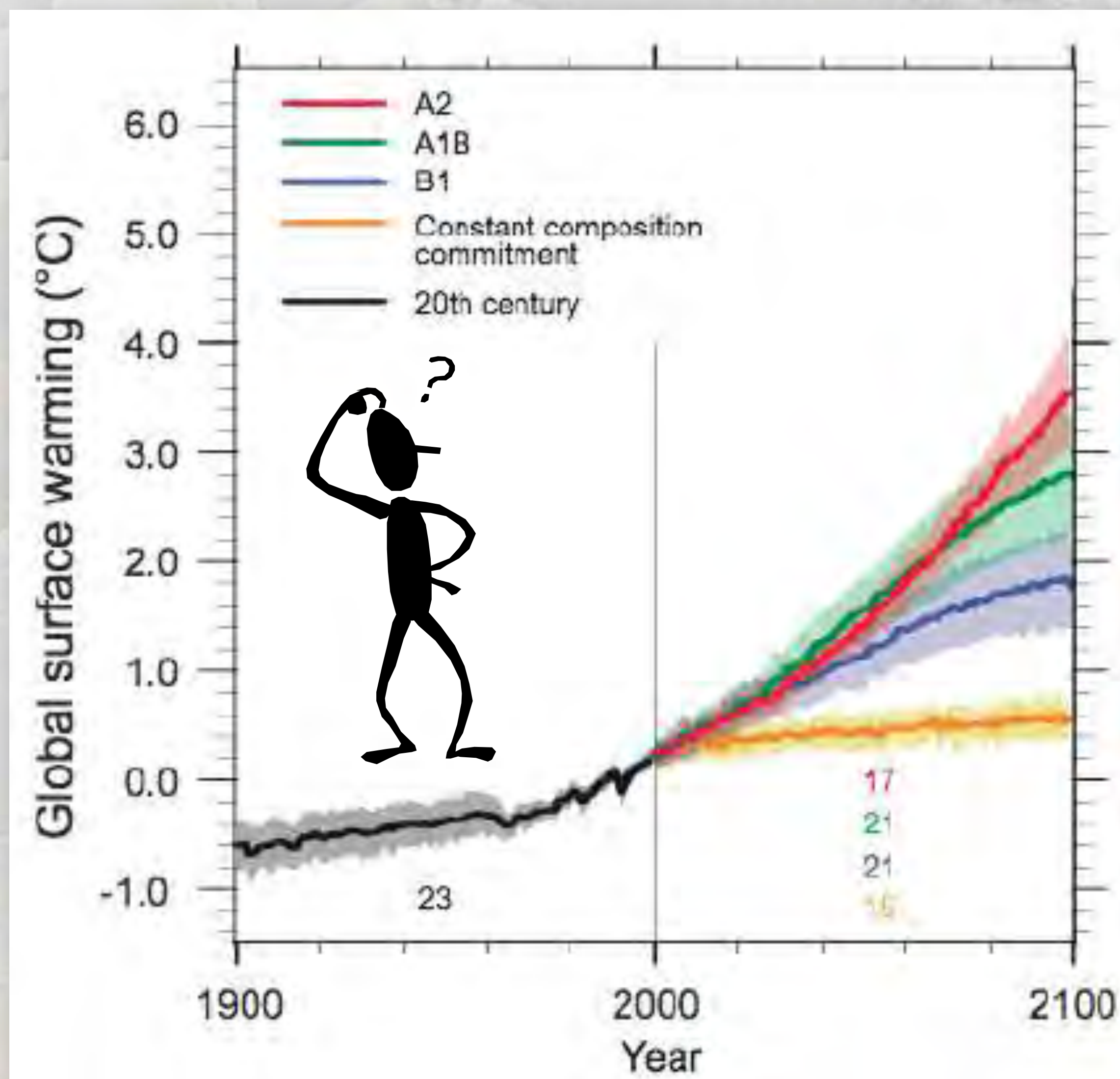
Relative Effects of Predictors



* = statistically significant at $p < 0.01$

Climate Scenario Maps

Many possibilities once model exists…

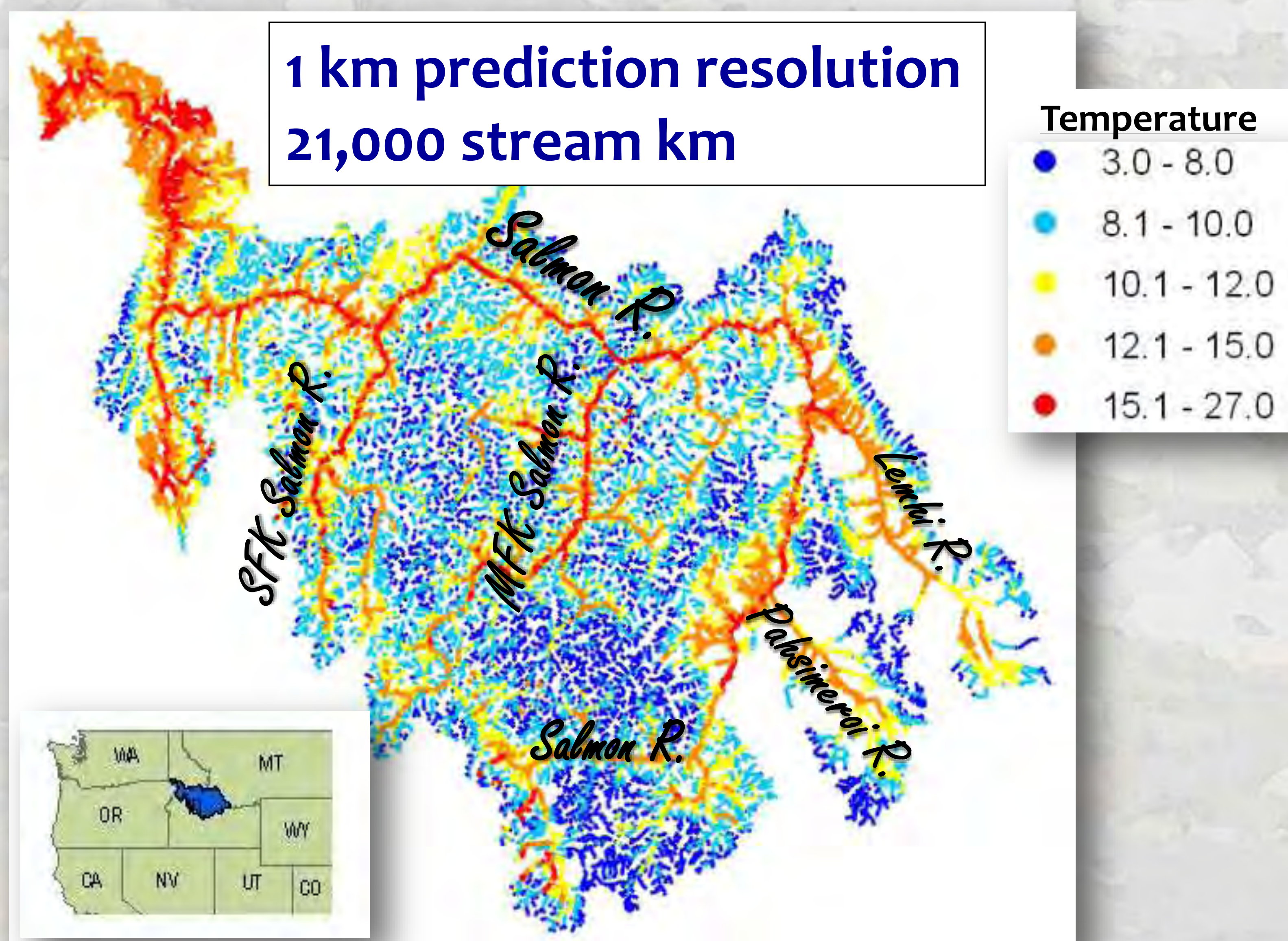


Adjust air & discharge values to represent scenarios

Salmon River Temperature Map

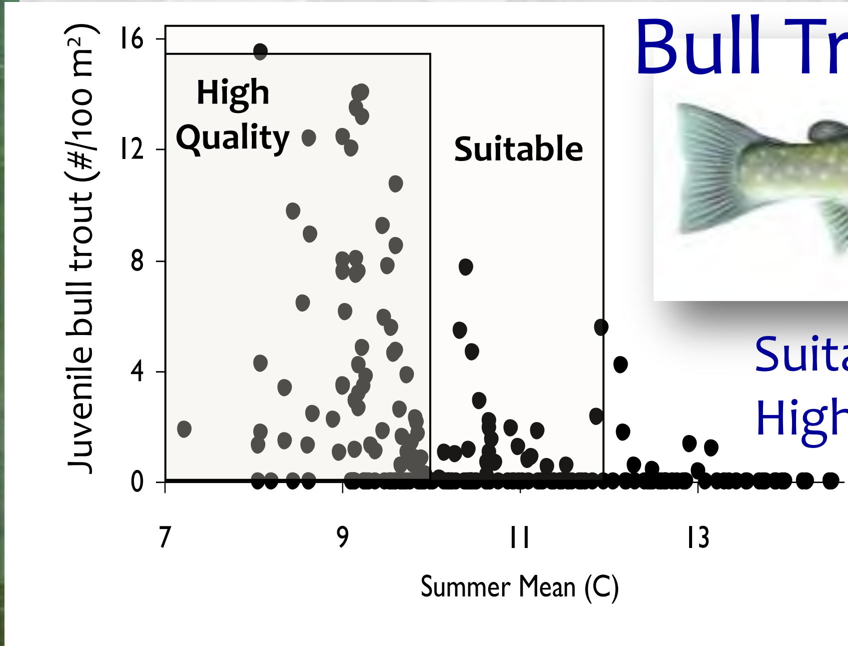
2002-2011 mean August stream temperatures

1 km prediction resolution
21,000 stream km



Effects on Thermal Habitat

Define using thermal criteria

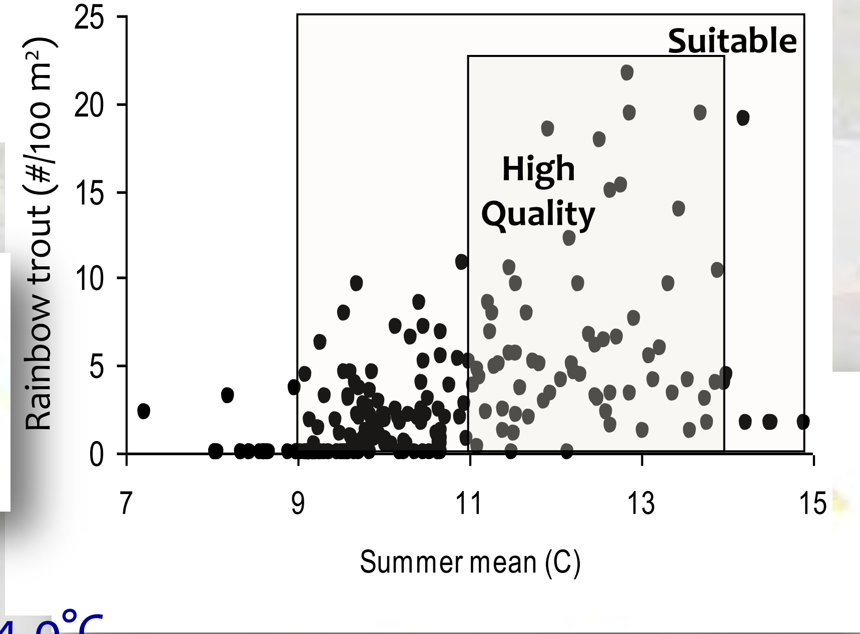


Bull Trout

Suitable habitat < 12.0°C

High-quality habitat < 10.0°C

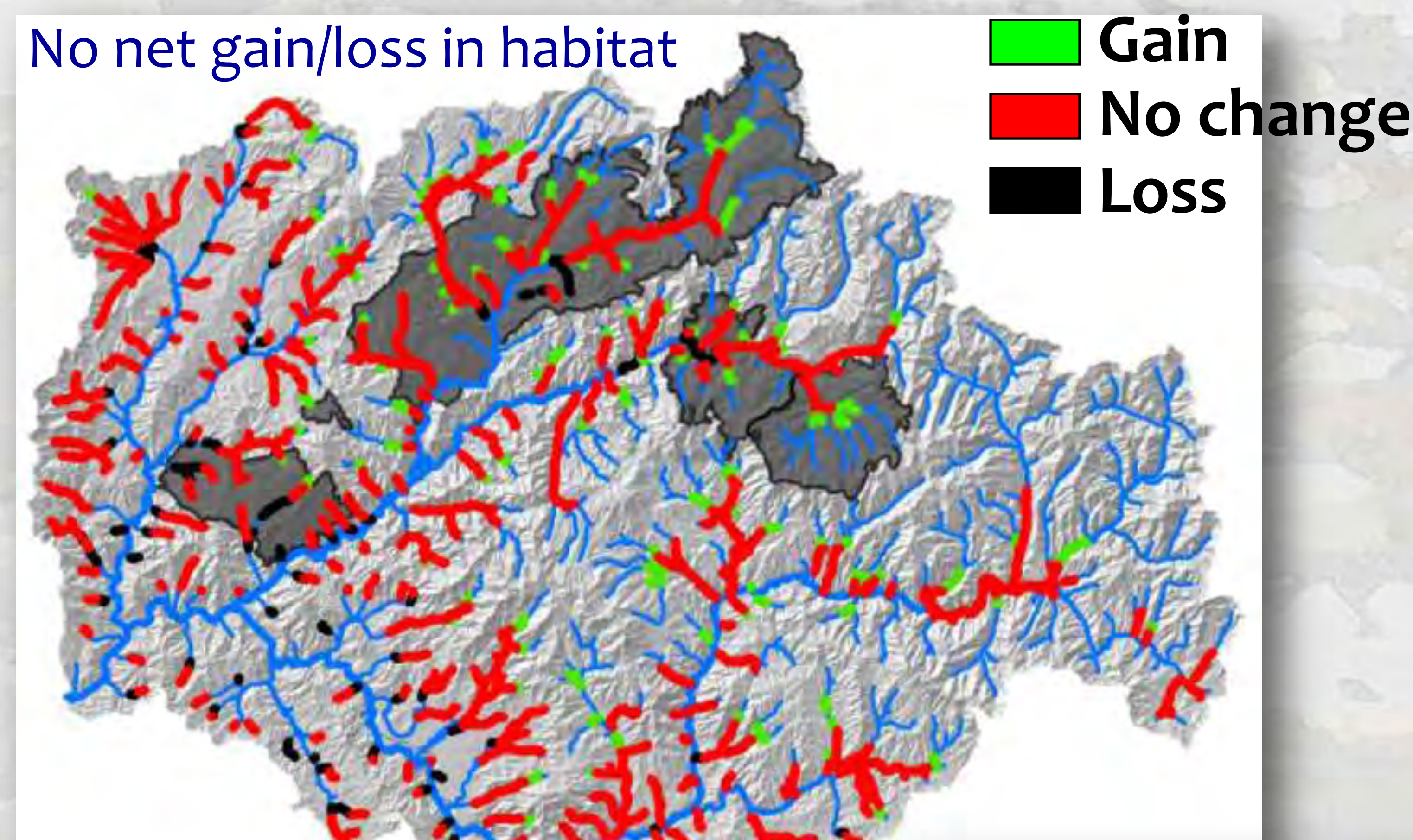
Rainbow Trout



Suitable habitat = > 9.0°C

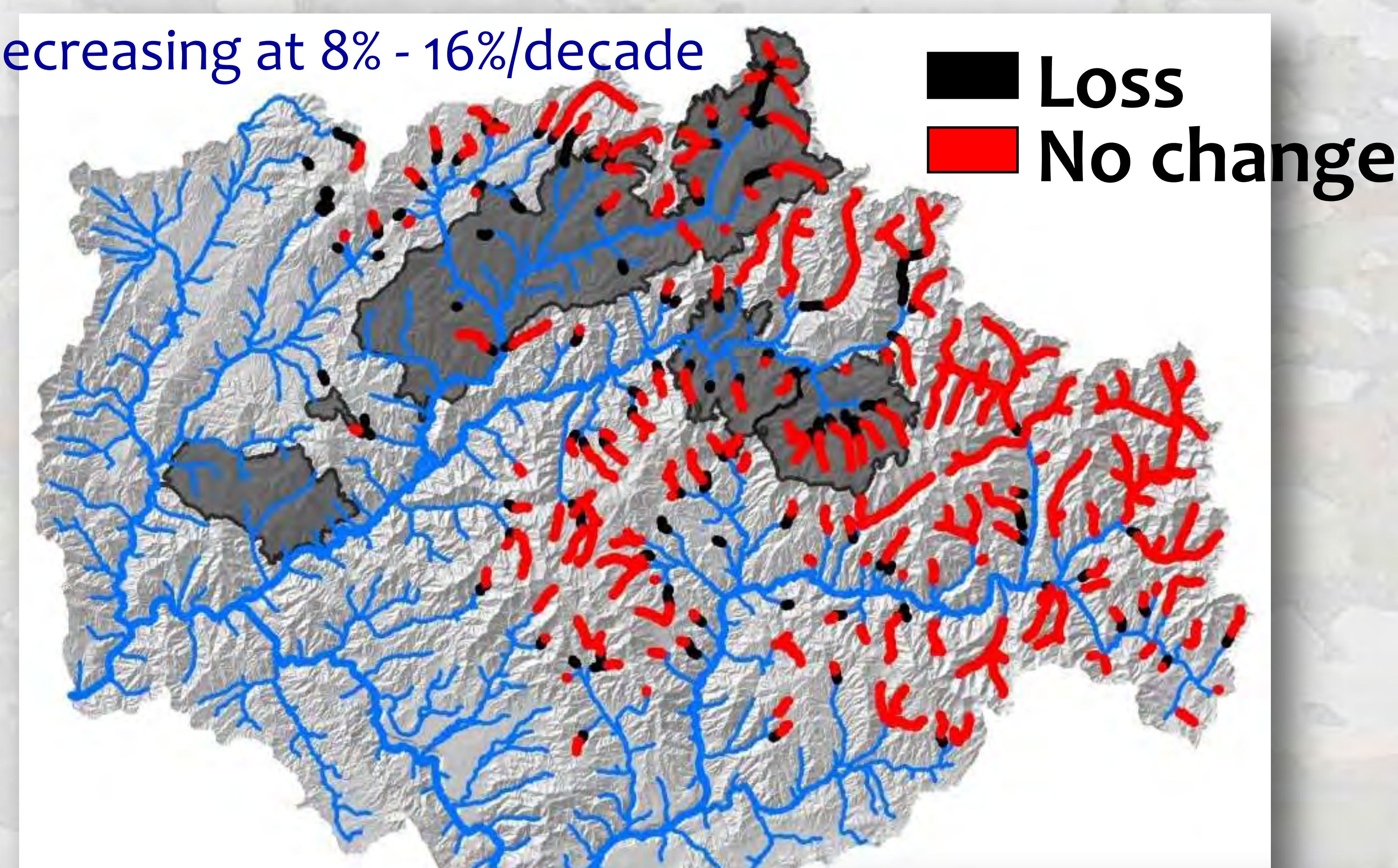
High-quality habitat = 11.0-14.0°C

Historic Climate Change Effects on Rainbow Habitat (1993-2006)



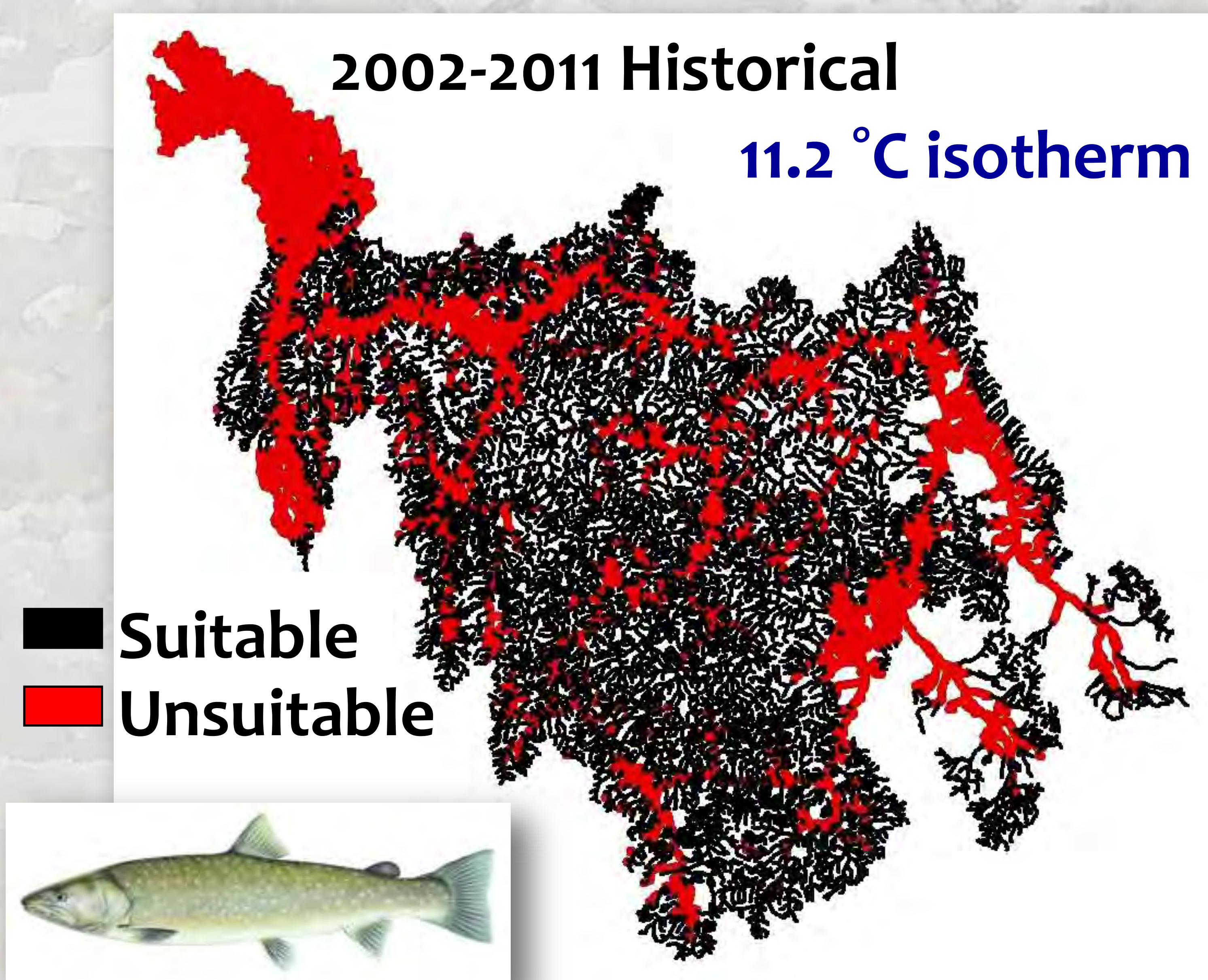
Isaak et al. 2010. *Eco. Apps.* 20:1350-1371

Historic Climate Change Effects on Bull Trout Habitat (1993-2006)

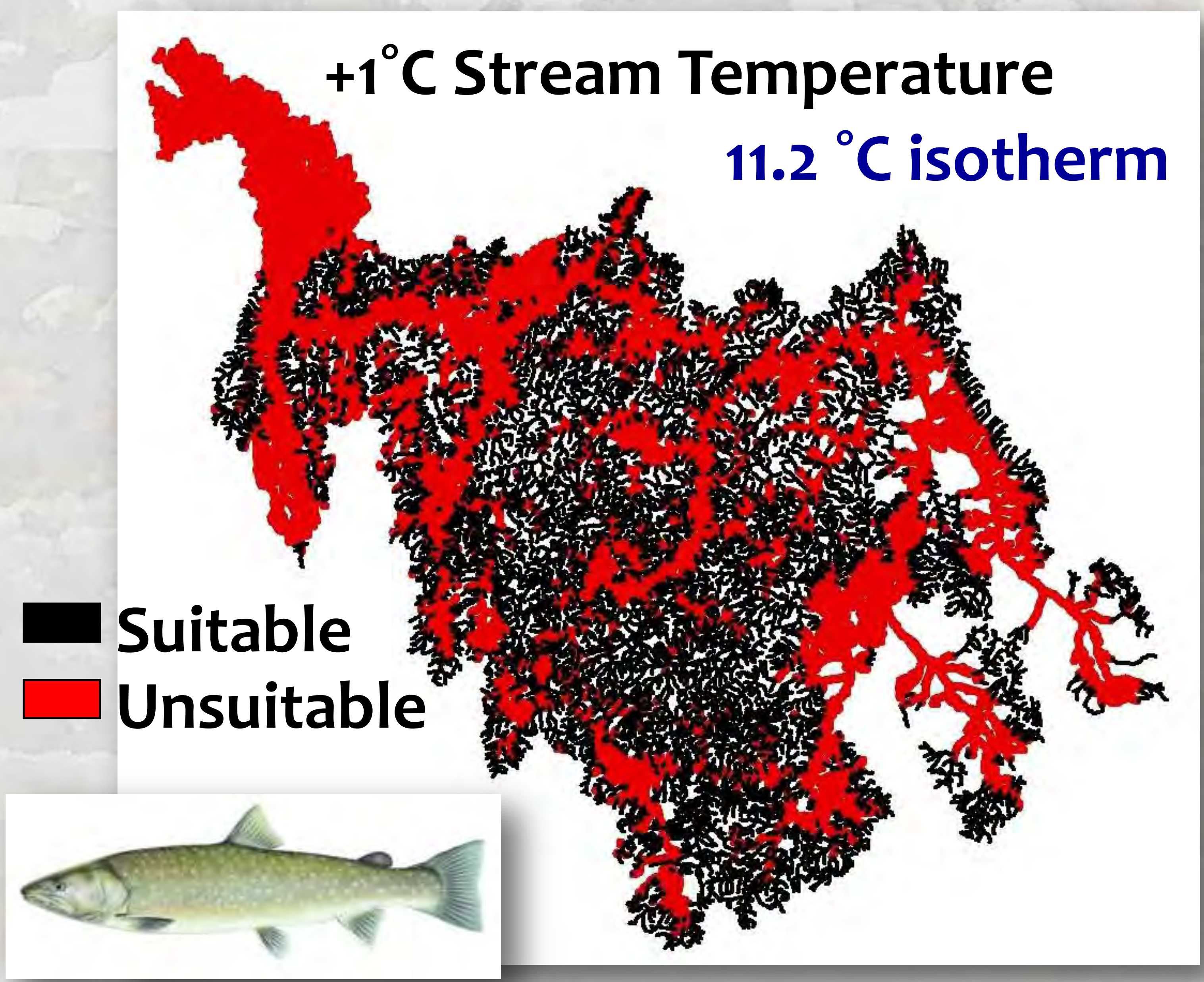


Isaak et al. 2010. *Eco. Apps.* 20:1350-1371

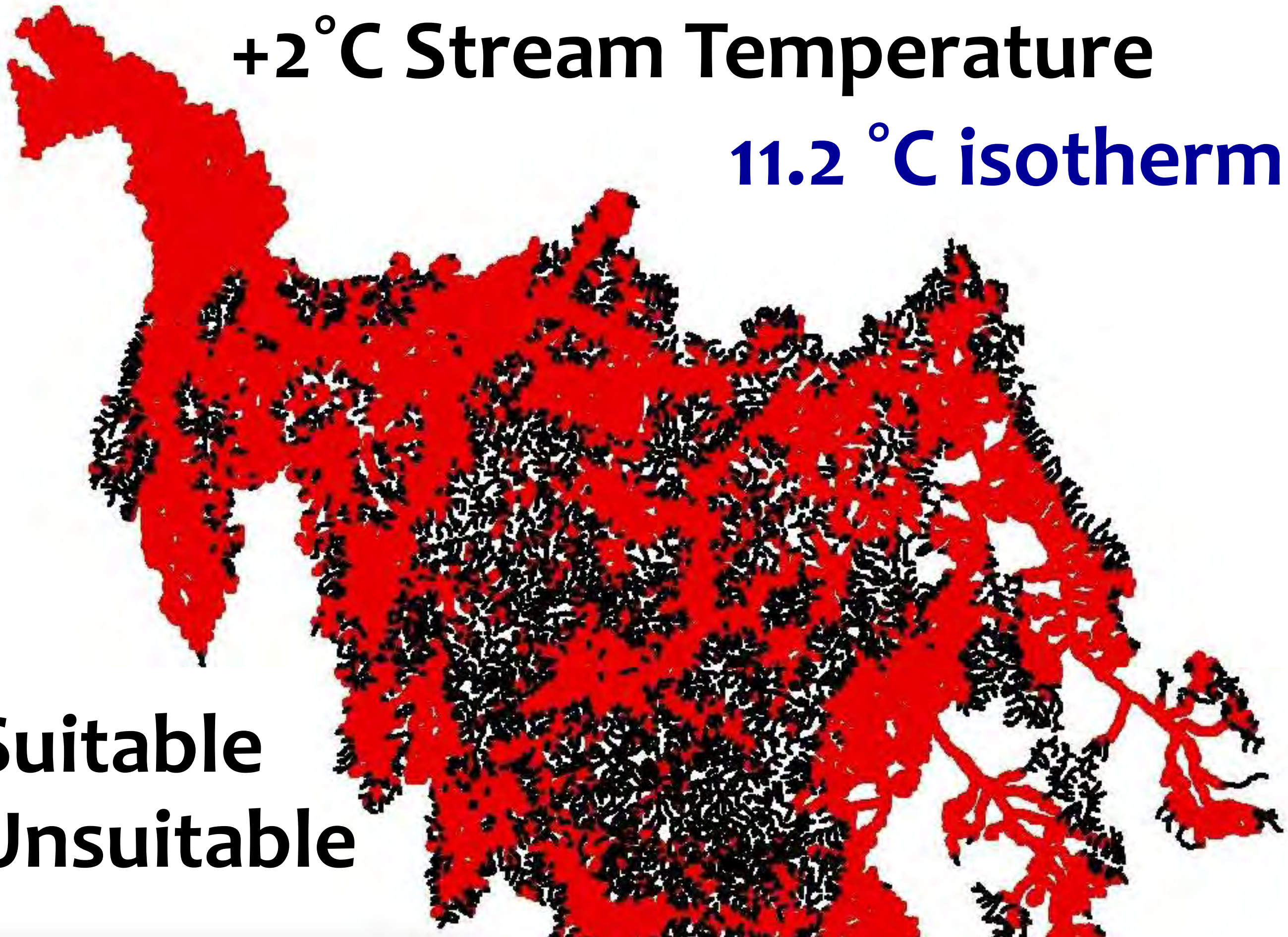
Salmon River Bull Trout Habitats



Salmon River Bull Trout Habitats

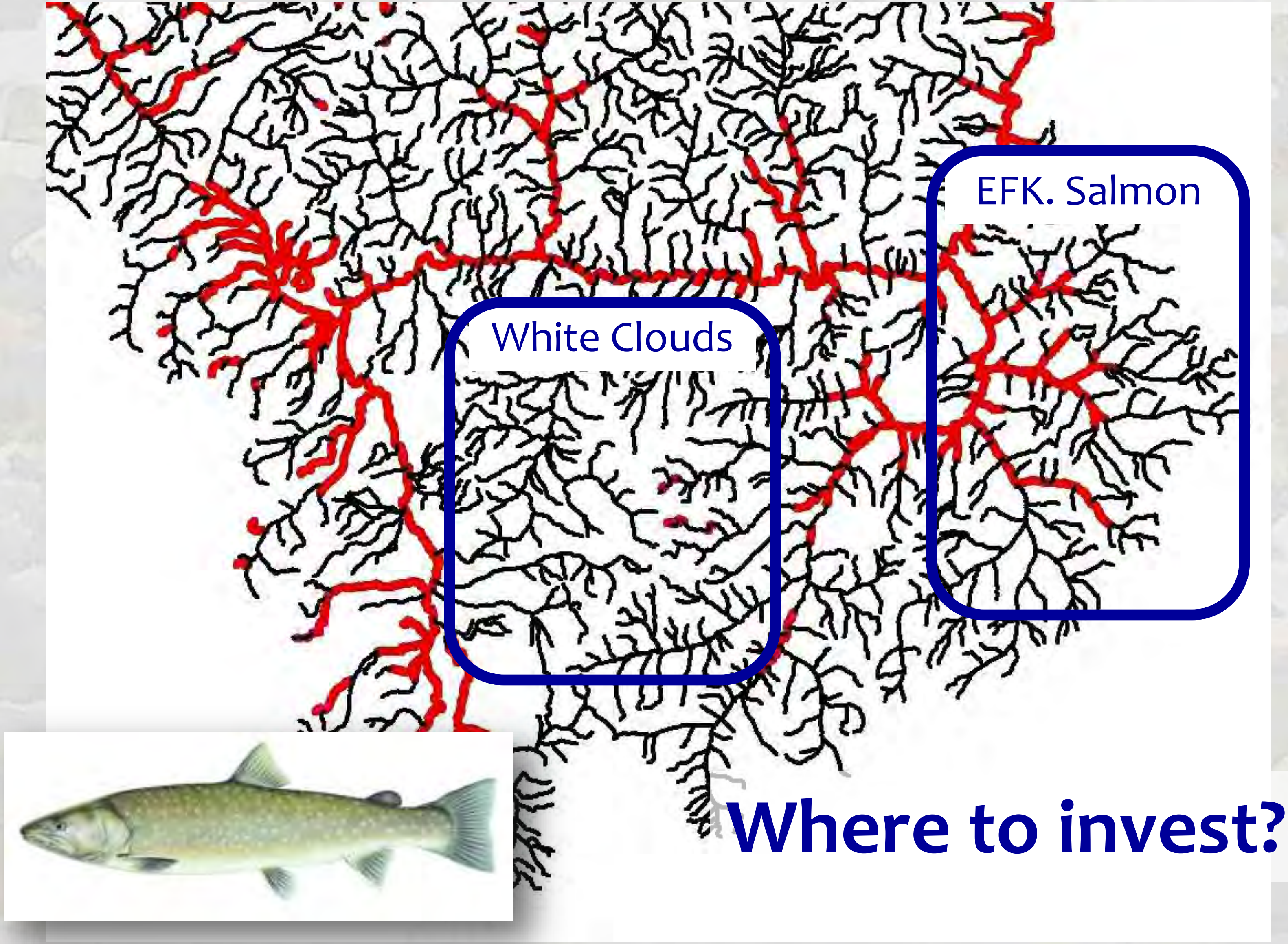


Salmon River Bull Trout Habitats



Spatial Variation in Habitat Loss

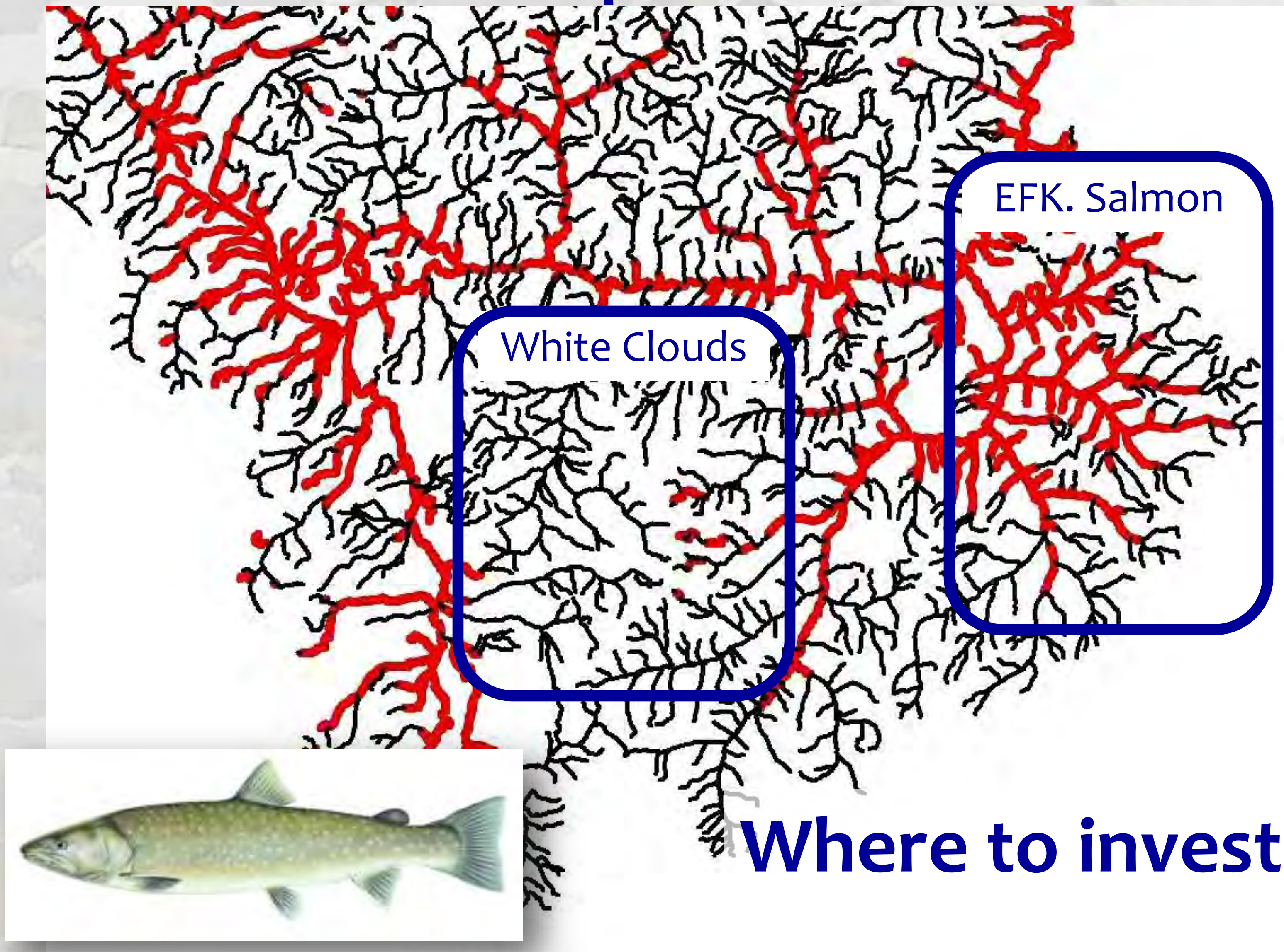
2002-2011 historical scenario



Where to invest?

Spatial Variation in Habitat Loss

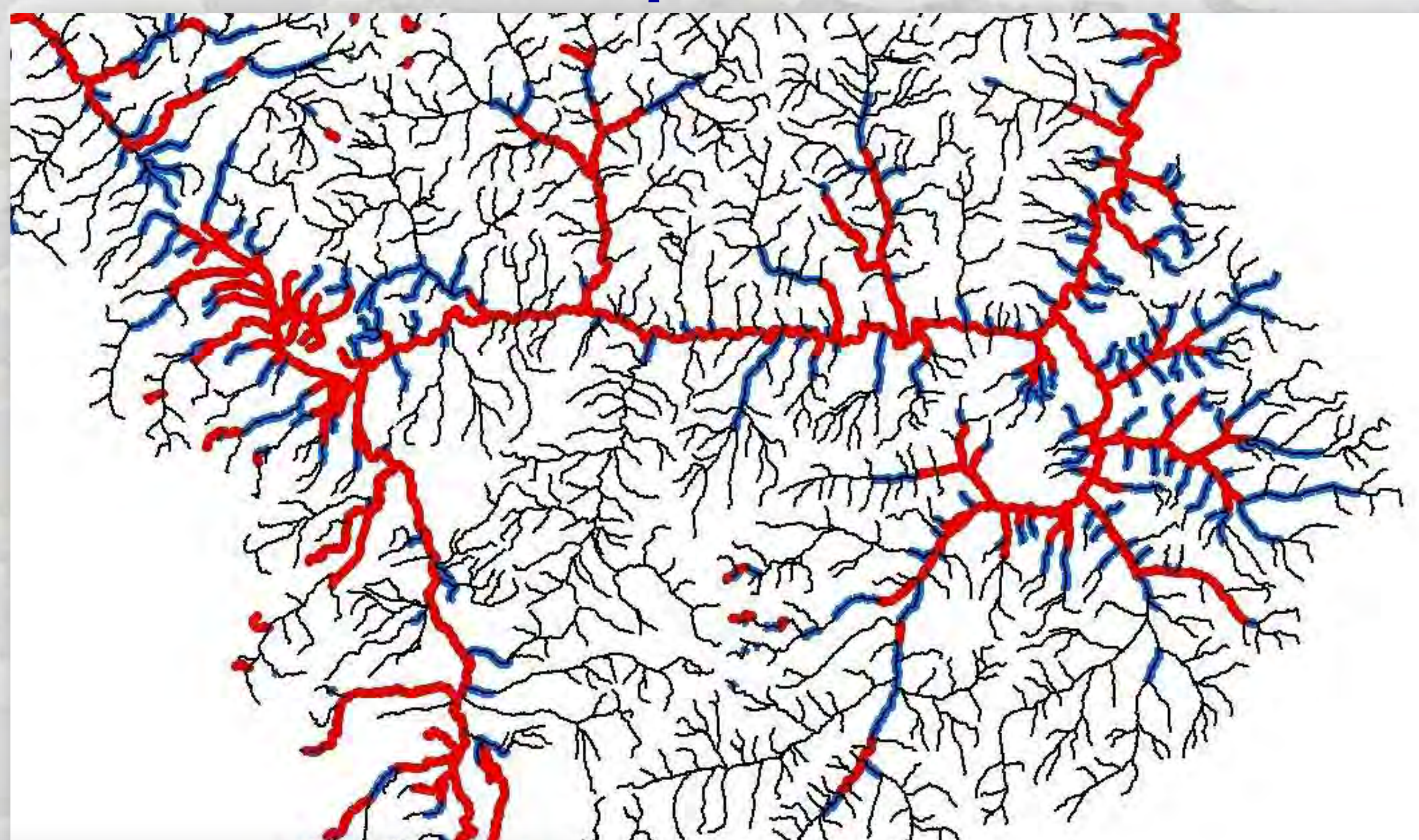
+1°C stream temperature scenario



Where to invest?

Difference Map Shows Vulnerable Habitats

+1°C stream temperature scenario



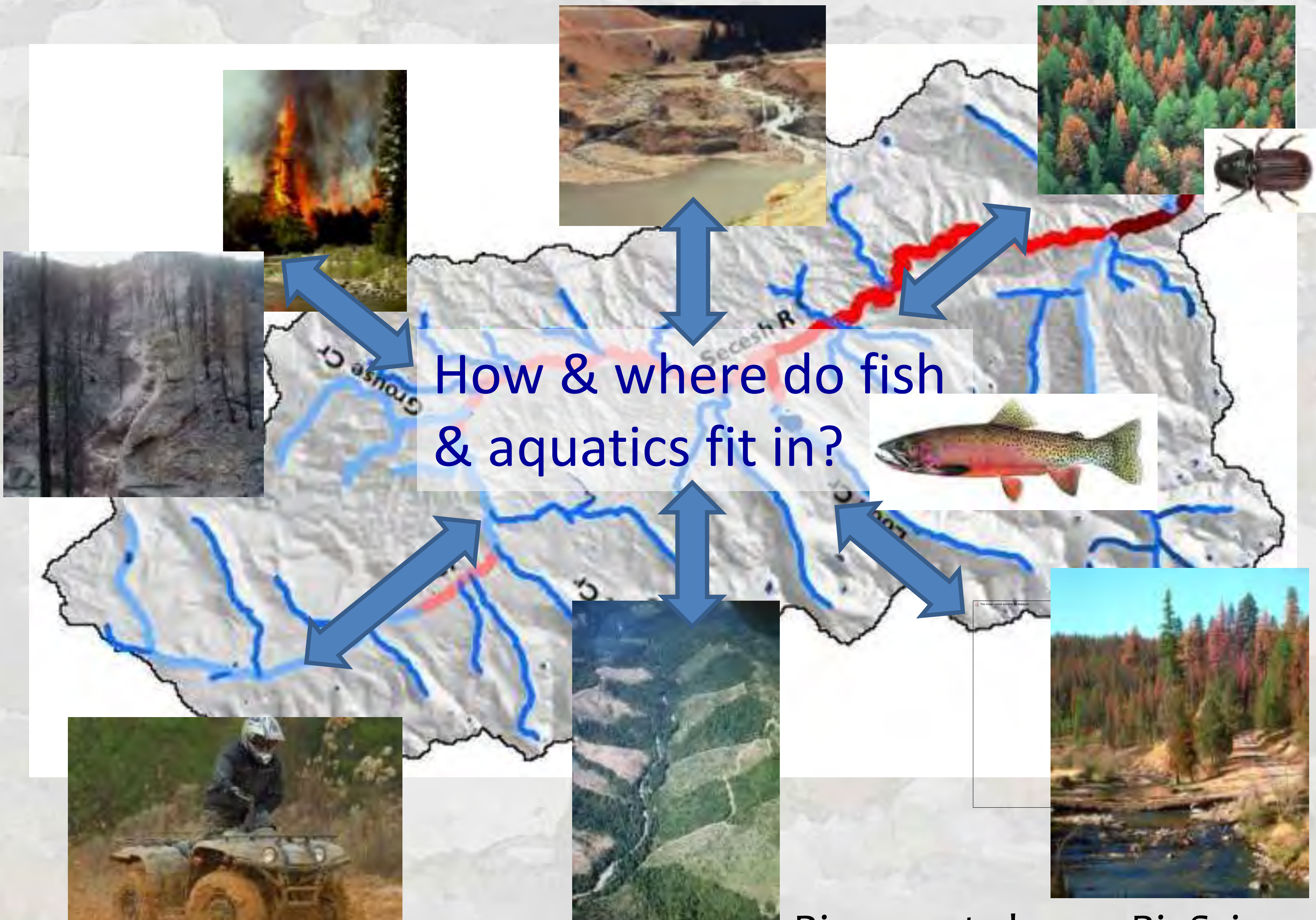
Where to invest?

Where Should Restoration Efforts Occur?

Need to be Tactically & Strategically Smart

- Maintaining/restoring flow
- Maintaining/restoring riparian
- Restoring channel form/function

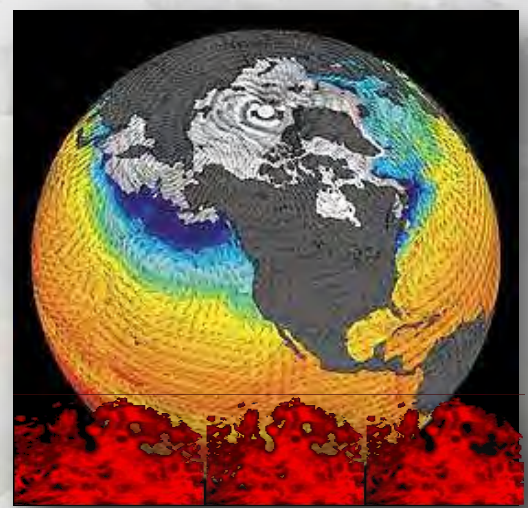
Continuous Resource Maps Will Facilitate Terrestrial-Aquatic Integration



Rieman et al. 2010 BioScience

Big Leap of Faith

GCM

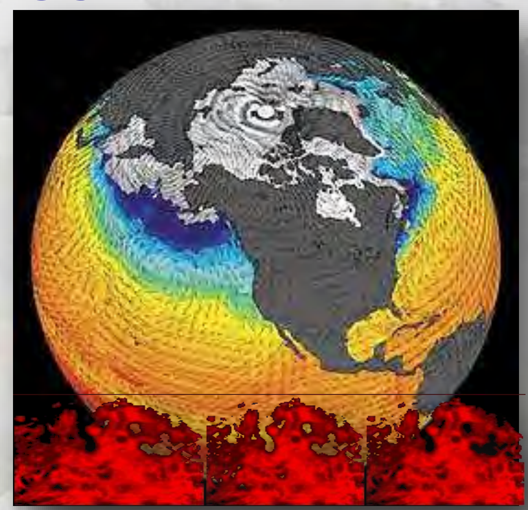


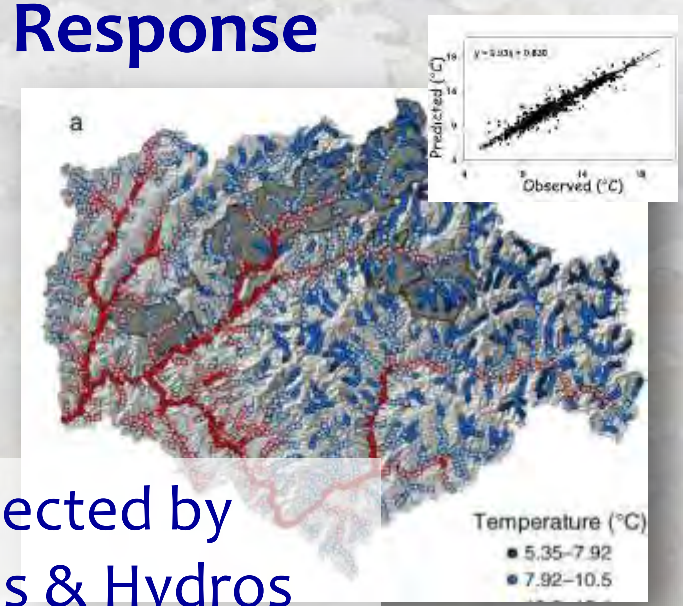
Management
Decisions

Models Developed from Everyone's Data

Coordinated Management Response

GCM





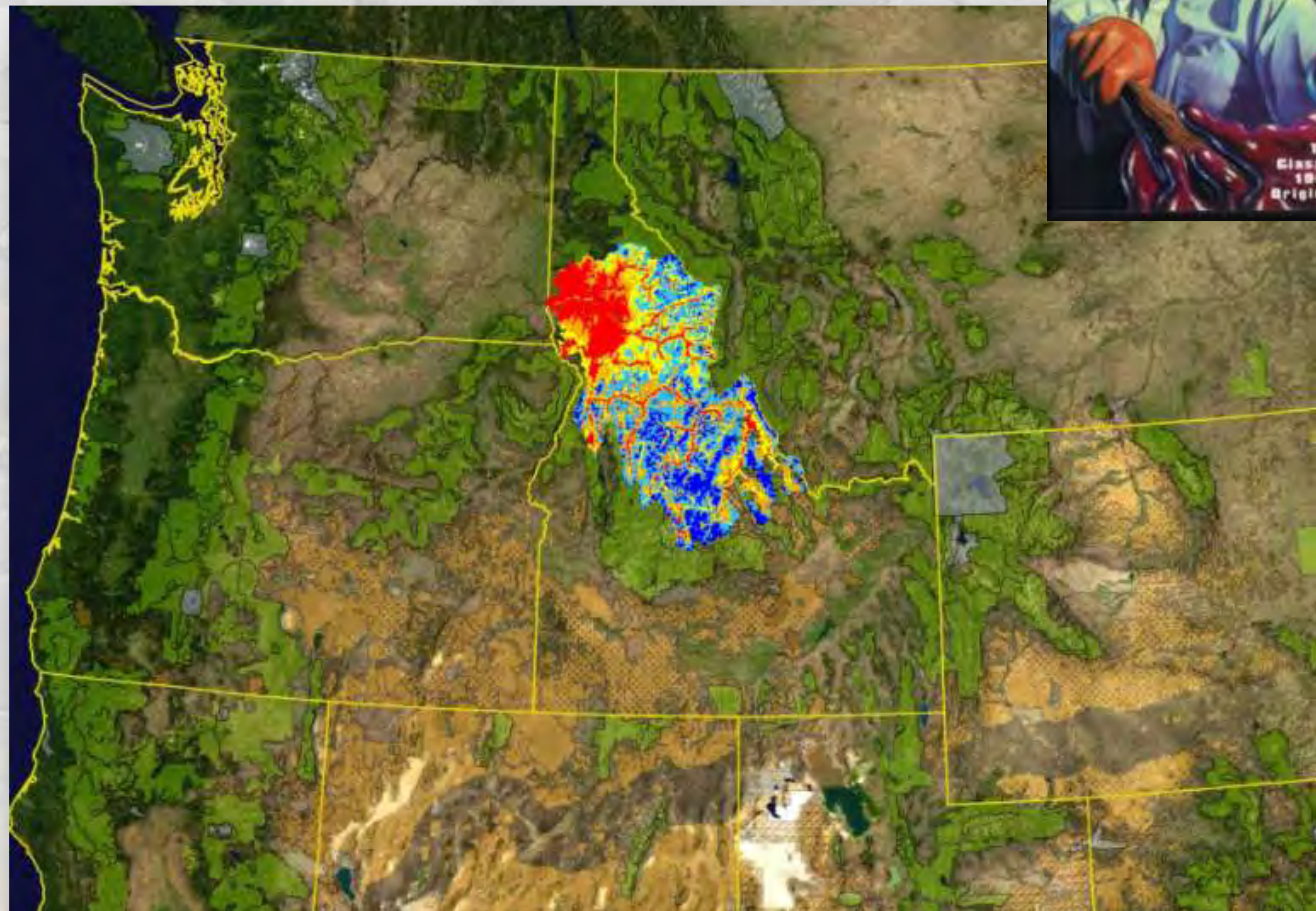
Data Collected by
Local Bios & Hydros

?

Management
Decisions

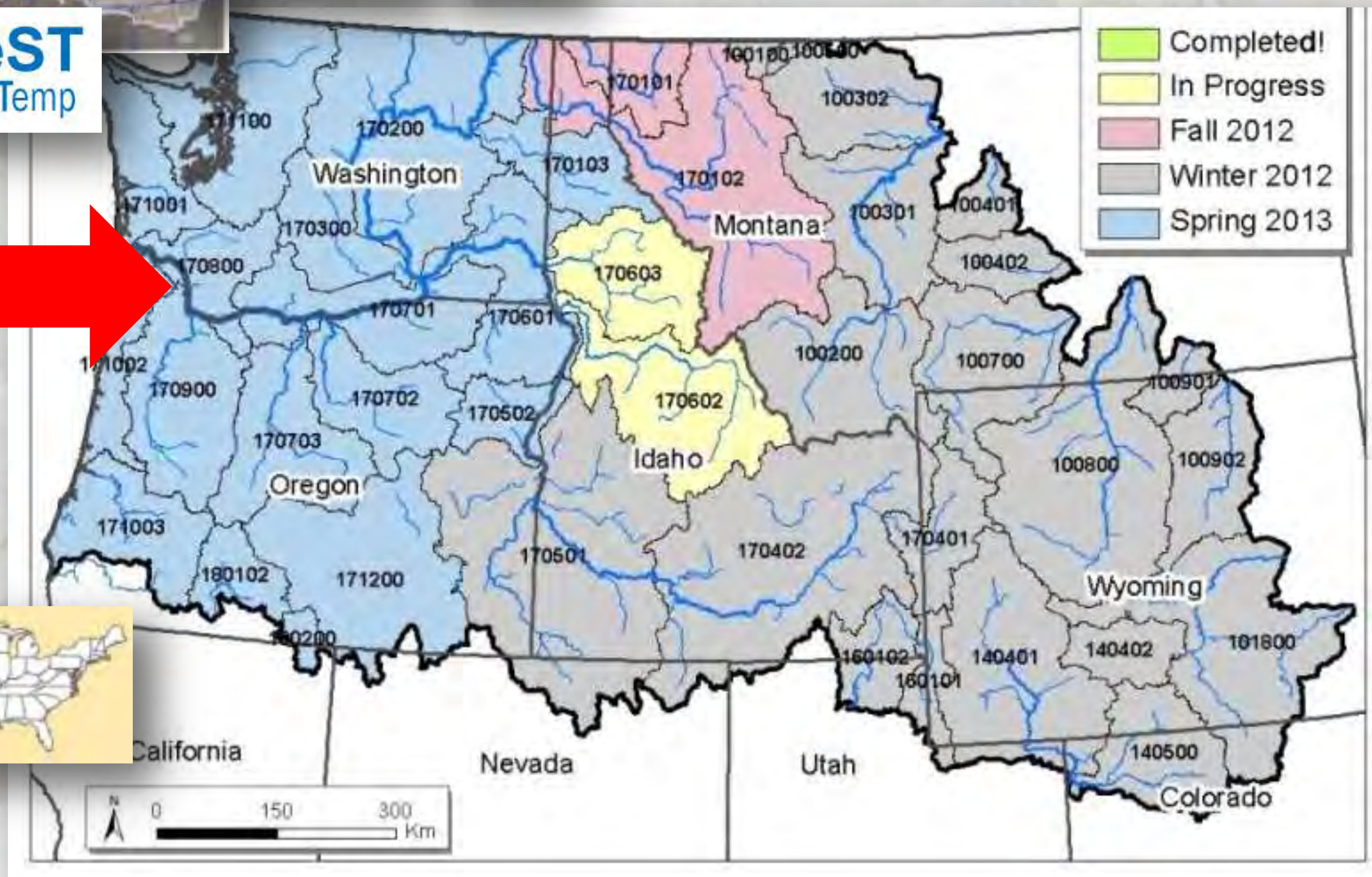
NorWeST Blob Growing…

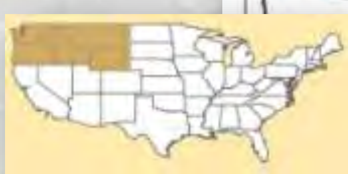
8,888 summers of data swallowed so far…



NorWeST Temperature model timelines (~3rd code HUCs)

NorWeST
Stream Temp

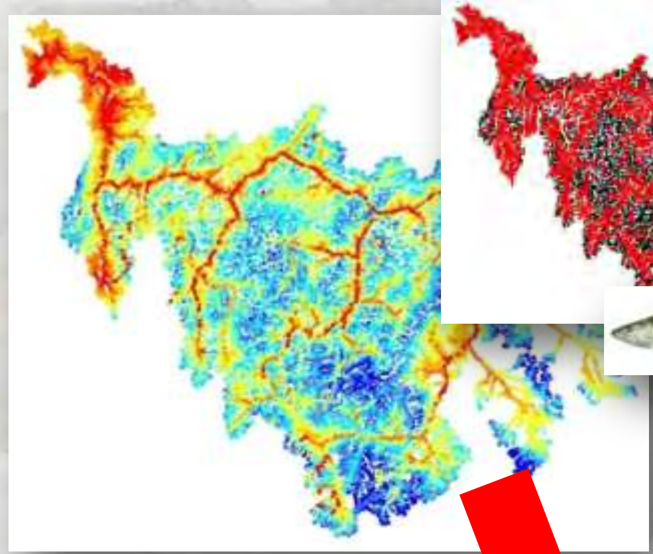


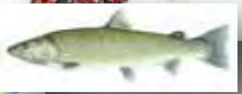


NorWeST Website Coming…

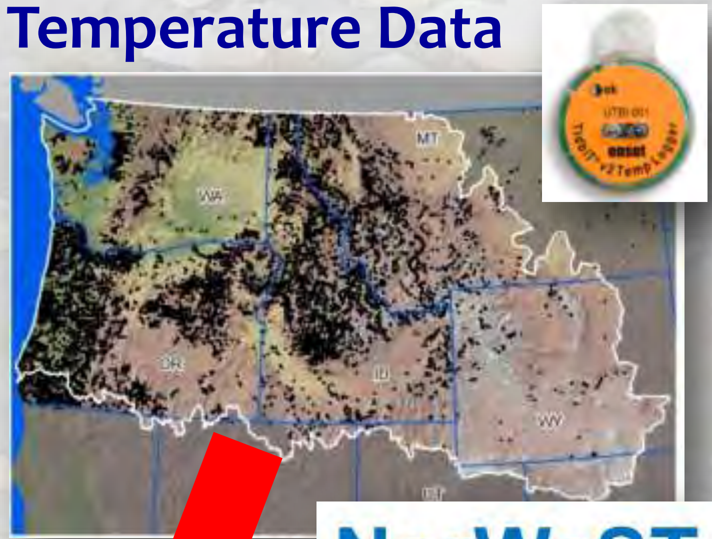
Launch scheduled this winter

GIS maps of climate scenarios

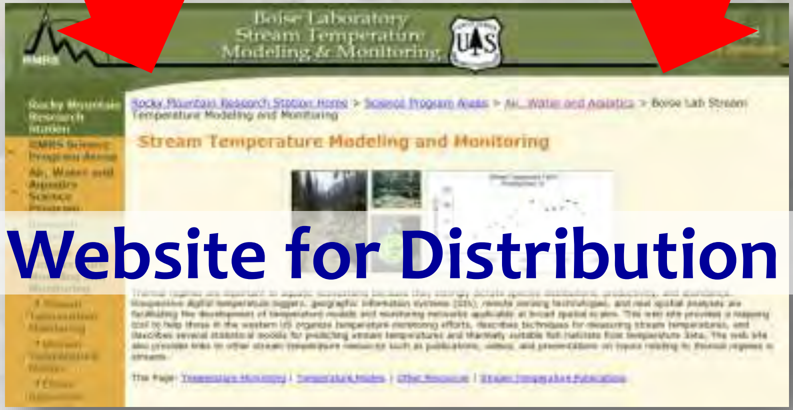




Temperature Data

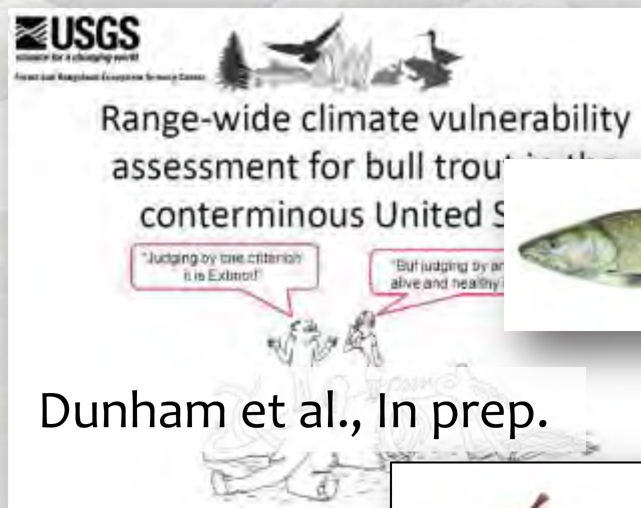


NorWeST Stream Temp

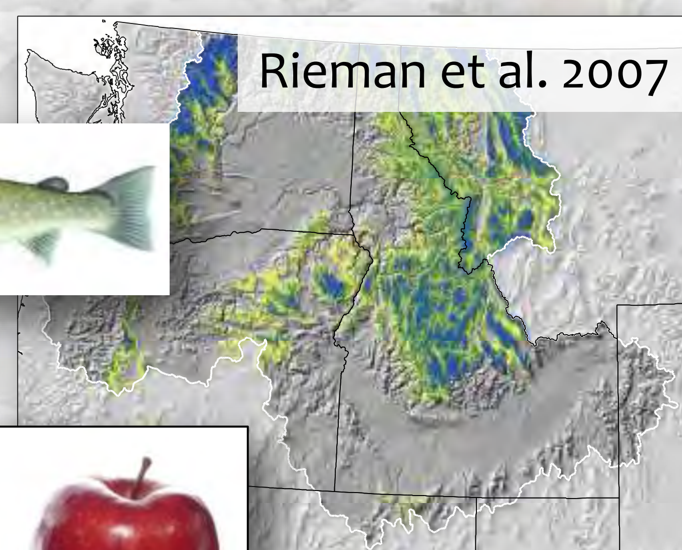


Website for Distribution

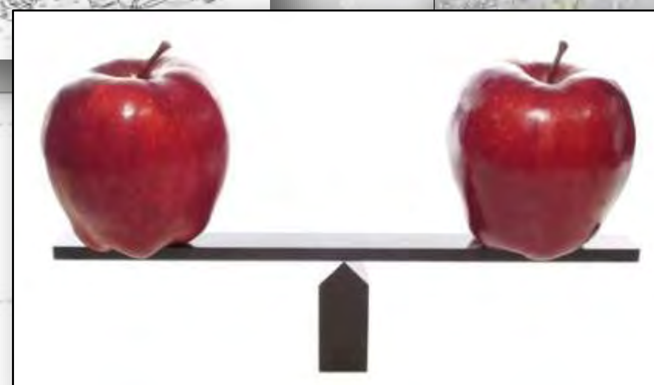
More Precise Bioclimatic Assessments

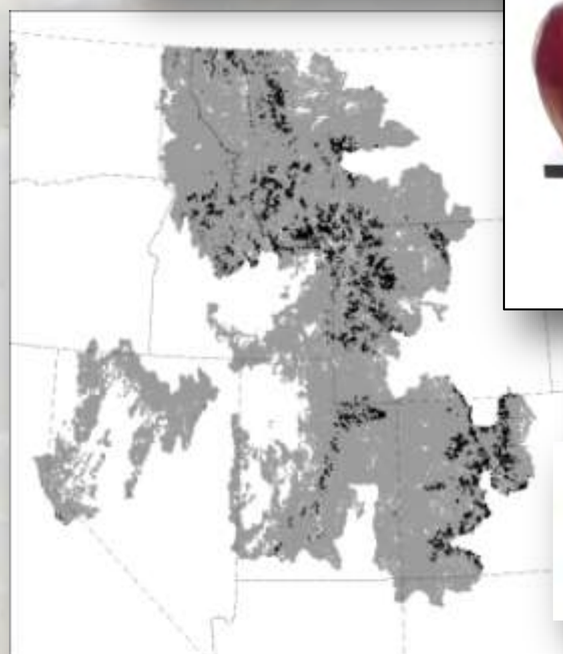


Dunham et al., In prep.

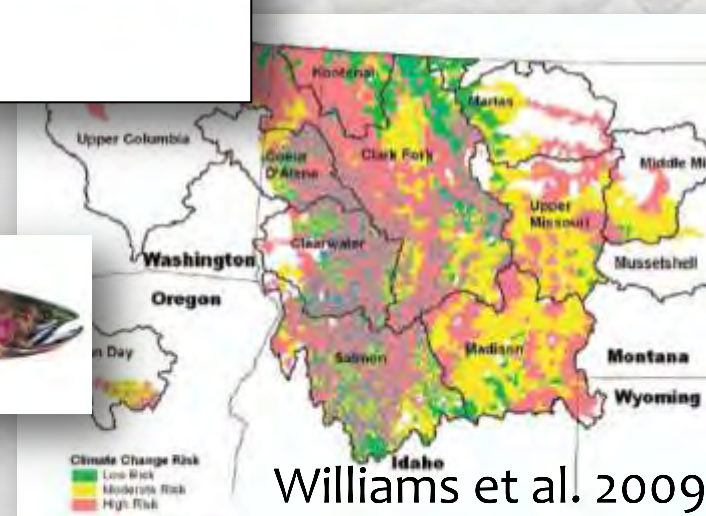


Rieman et al. 2007





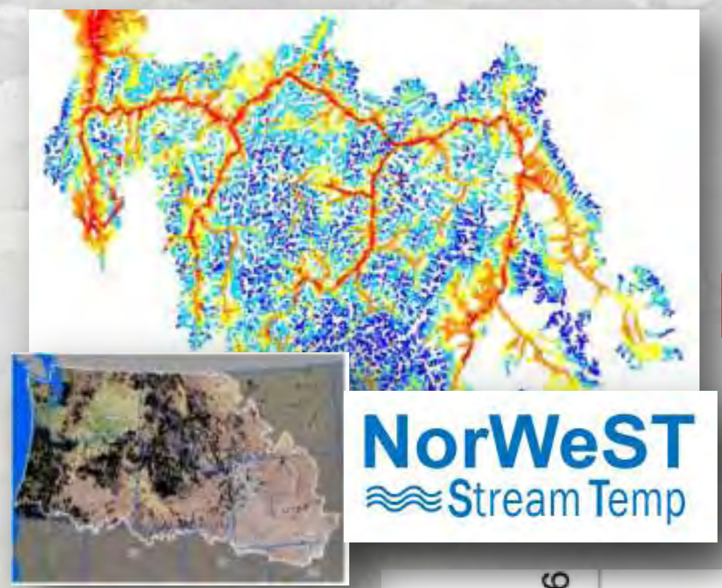
Wenger et al. 2011. *PNAS*.



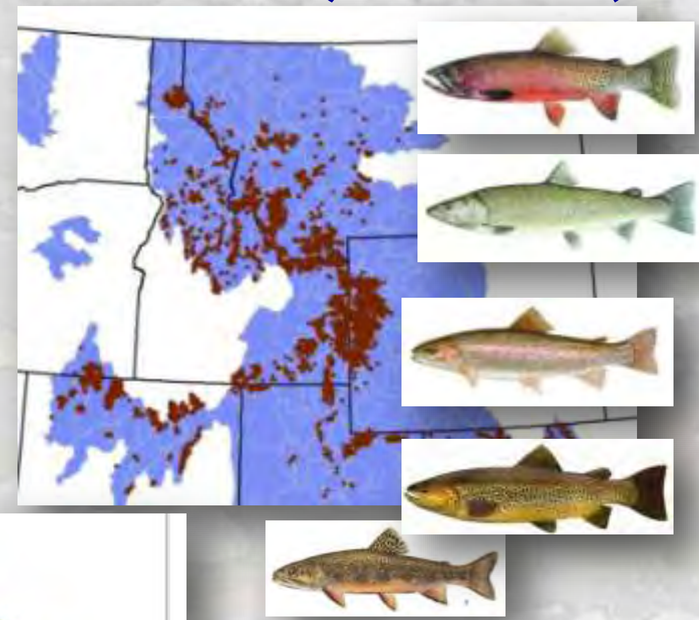
Williams et al. 2009

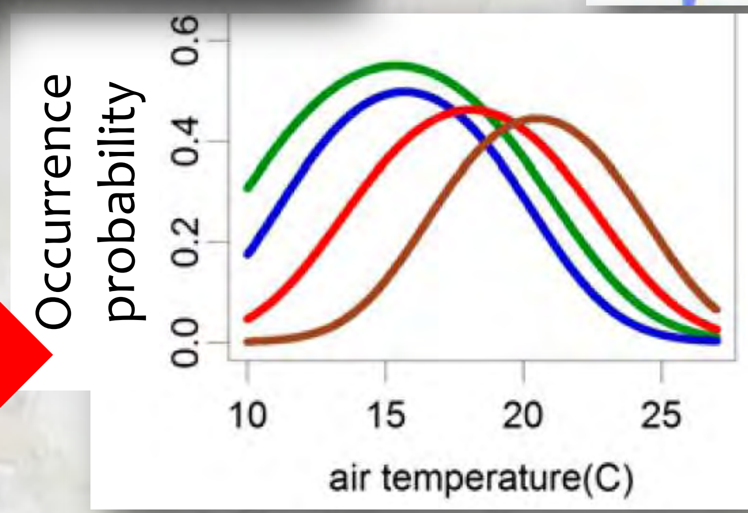
Consistent Thermal Niche Definitions

Stream temperature maps



Regional fish survey databases (n = 10,000)



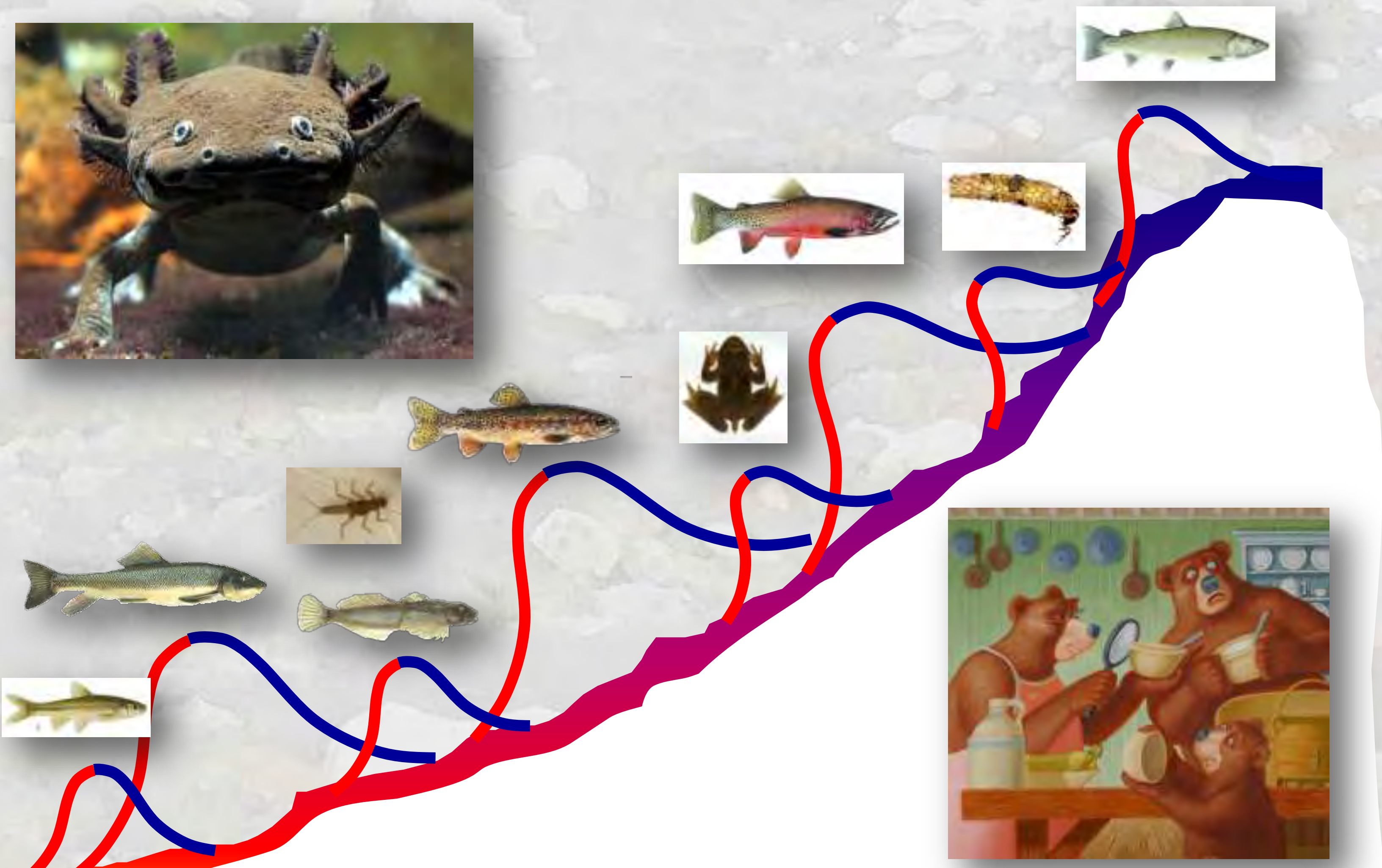


Wenger et al. 2011a. *PNAS* **108**:14175-14180

Wenger et al. 2011b. *CJFAS* **68**:988-1008; Wenger et al., *In Preparation*

Generalizable to All Stream Biotas

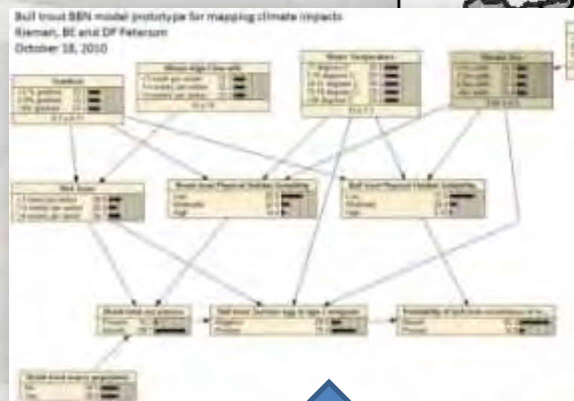
Just need georeferenced biological survey data

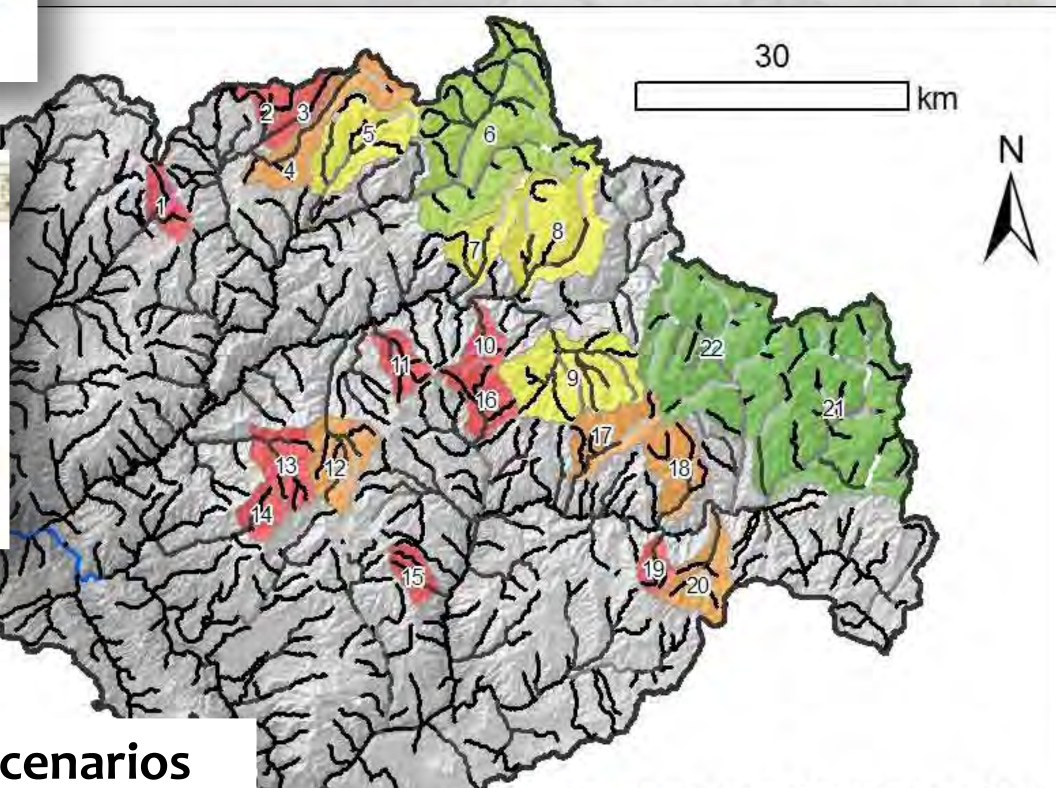


Too warm…Too cold…Just right

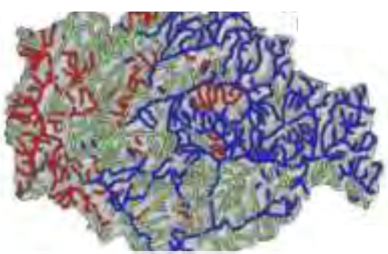
Bull Trout Climate Decision Support Tool

Tool runs on regionally consistent data layers

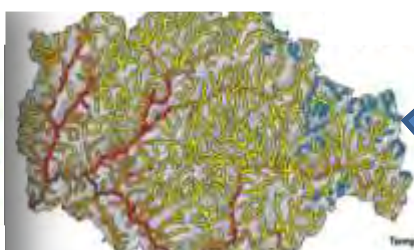




Downscaled Stream Scenarios



Streamflow



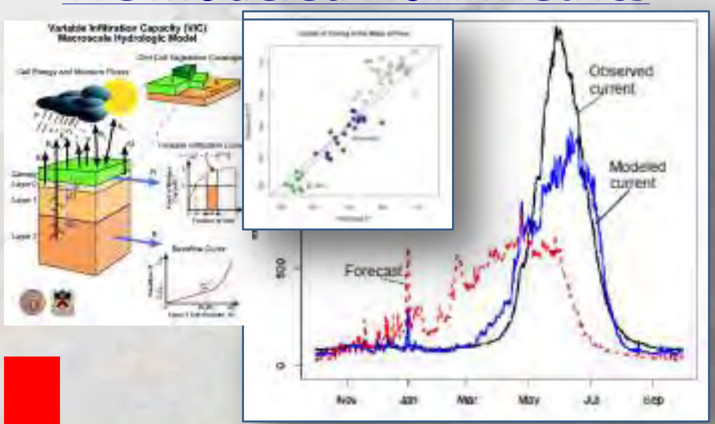
Stream Temperature

Peterson et al. In Press. *Fisheries*

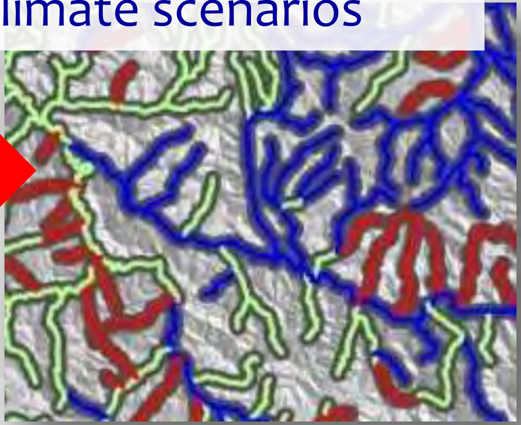
Western U.S. Flow Metrics Webpage

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

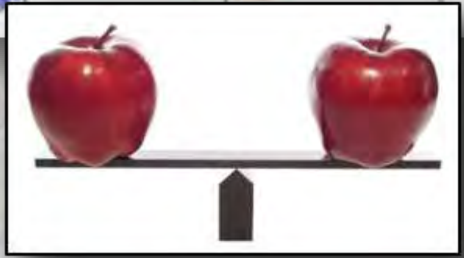
VIC Modeled Flow Metrics



NHD+ stream segments & climate scenarios

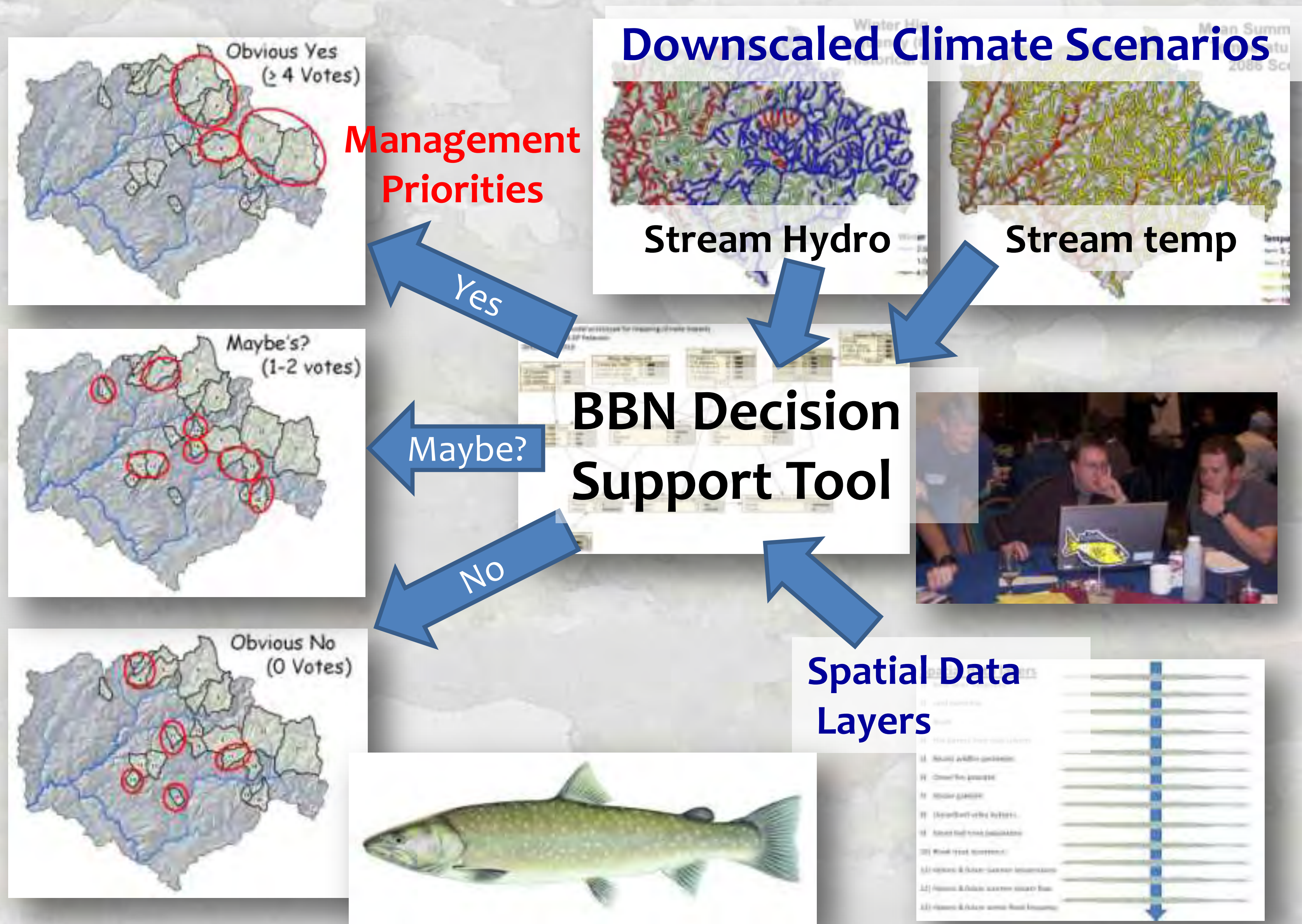


…for the western U.S.



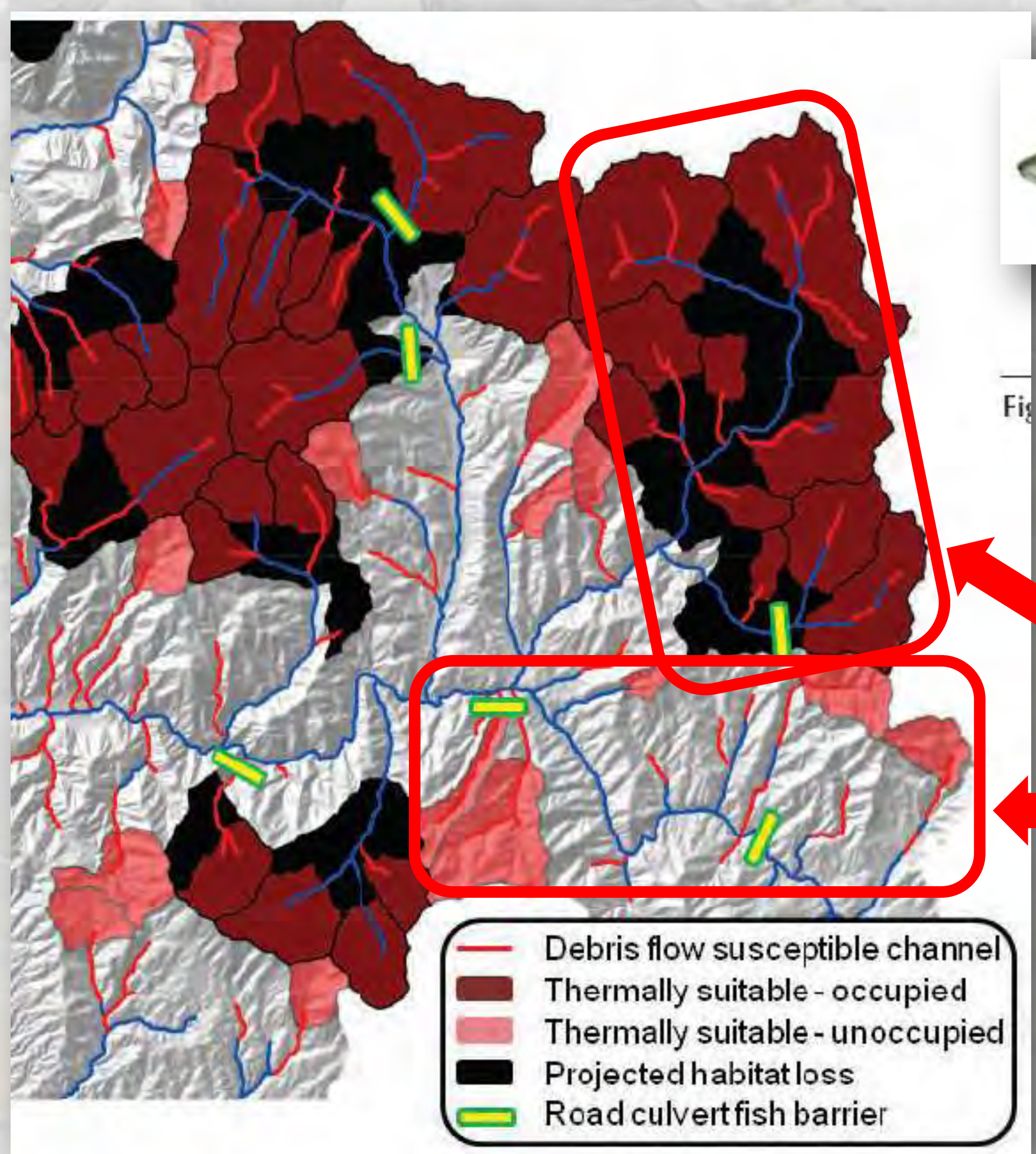
Wenger et al. 2010. *Water Resources Research* 46, W09513

Structured Decision Making



High Resolution Information

Landscape Specific Conditions

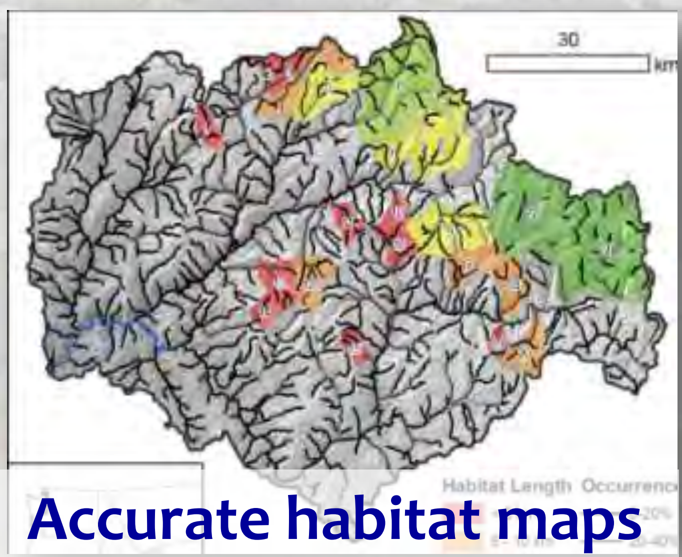


Invest here

Not here

Efficient Biological Monitoring

Distributional status & trend

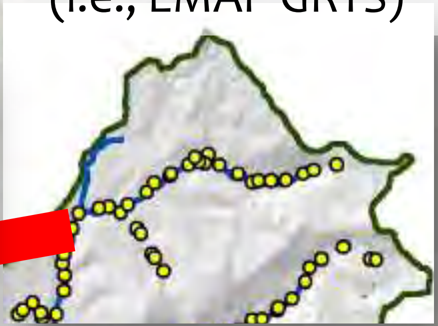


Accurate habitat maps from stream models

=

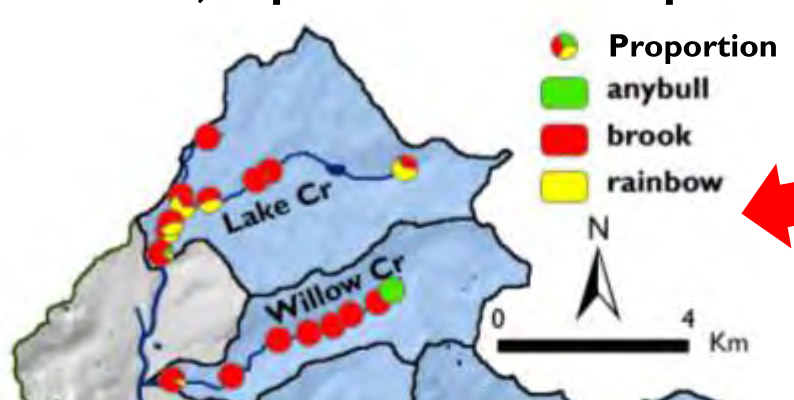
Map

Probabilistic sample (i.e., EMAP GRTS)



Biological survey

Precise, representative sample

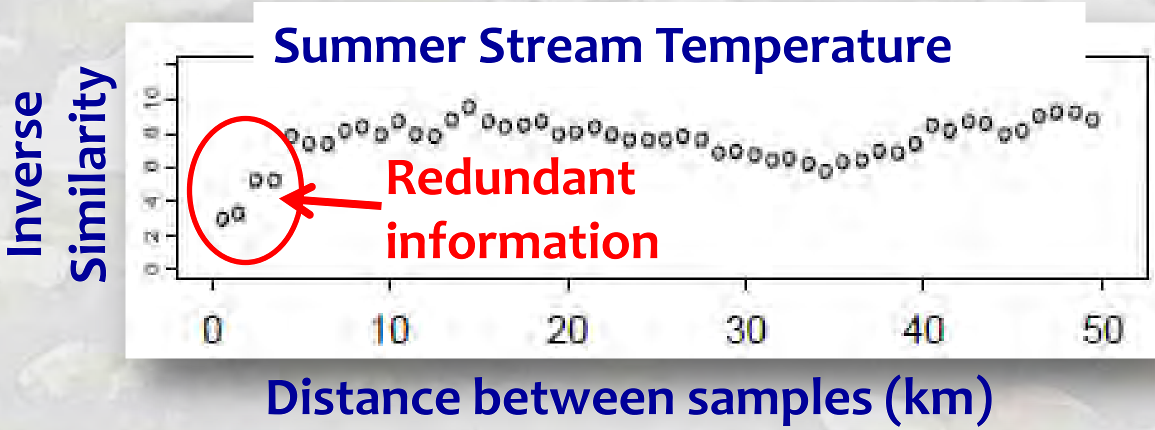


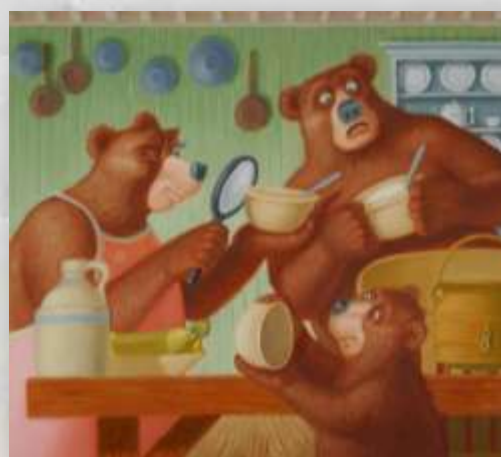
Regionally Consistent Framework

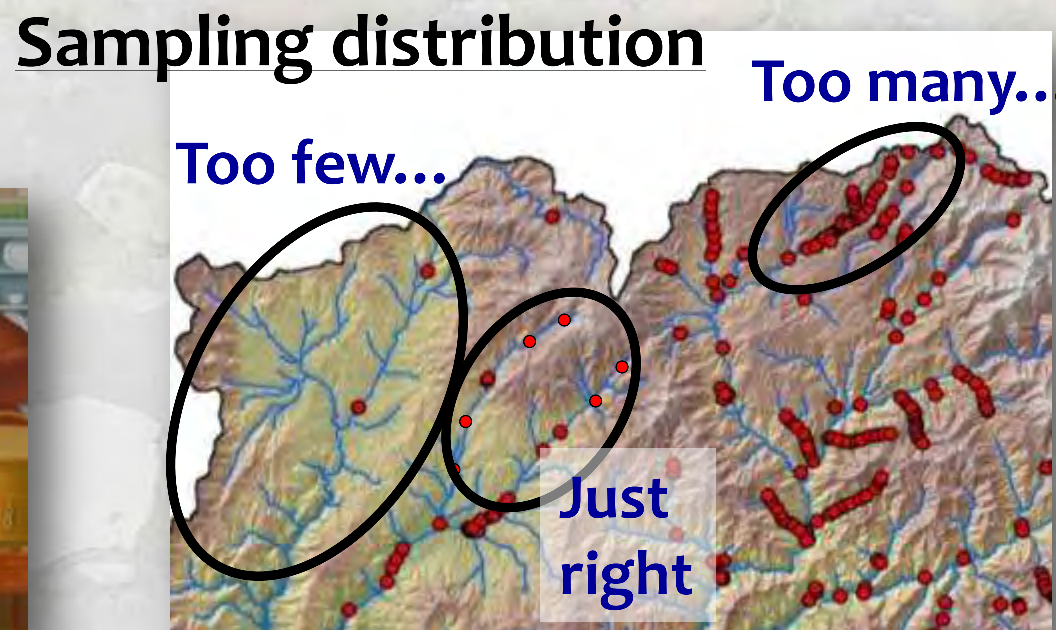
Bull trout status & trend monitoring

Isaak, Rieman & Horan 2009

More Efficient Temperature Monitoring





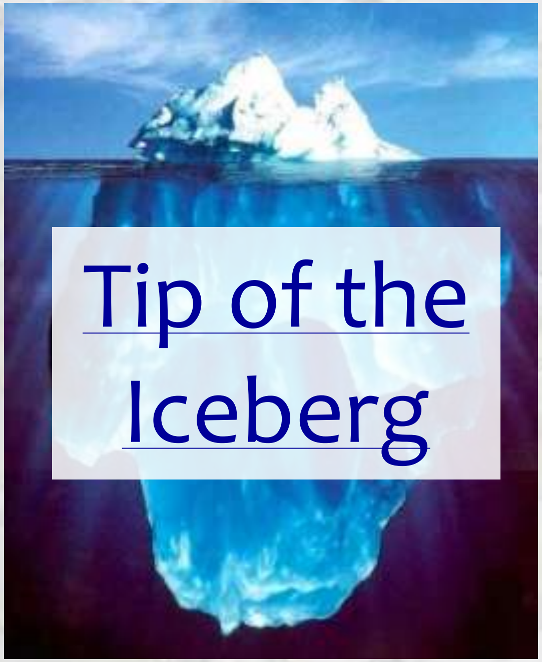


Real-time Access to Stream Spatial Data Anytime, Anywhere

Smartphones as field computers

First "Killer Apps" but more coming…

1st Generation Apps

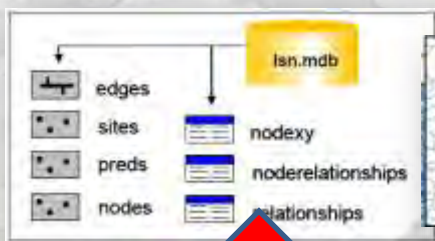


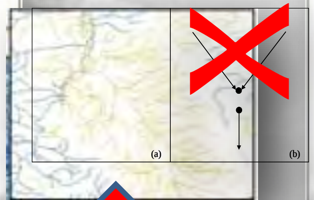
In the Pipeline…

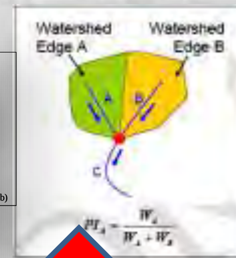
- "Block-kriging" of stream-scale population estimates
- Optimized monitoring designs for biological & water quality parameters
- Improved fish distribution maps & models
- Precise thermal niche definitions for trout
- Improved climate vulnerability assessments

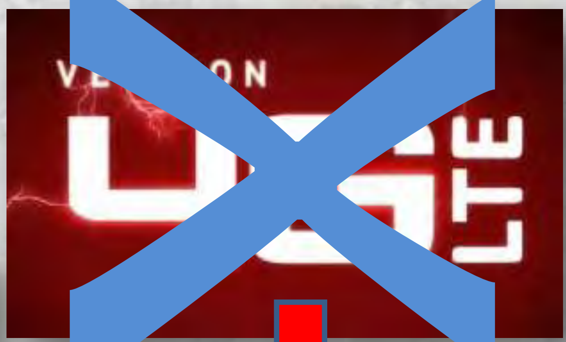
An InterNet for Stream Data

GIS infrastructure now exists…

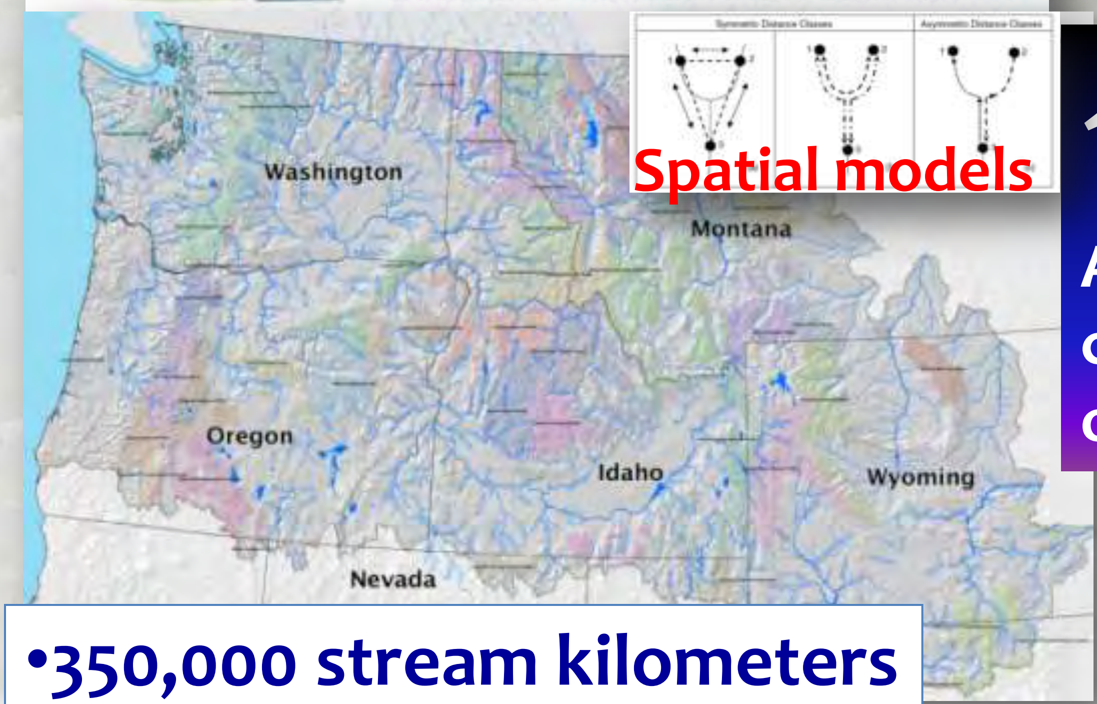








Great Northern
LANDSCAPE CONSERVATION COOPERATIVE



Spatial models

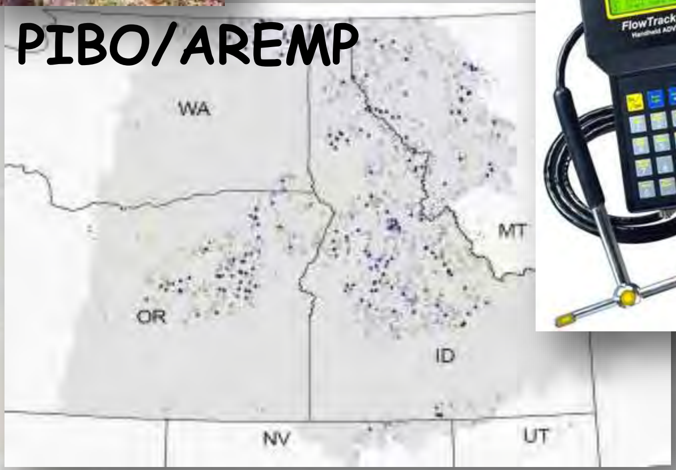
1G LCC

Accurate & consistent scaling of information

•350,000 stream kilometers

Boise Spatial Streams Group

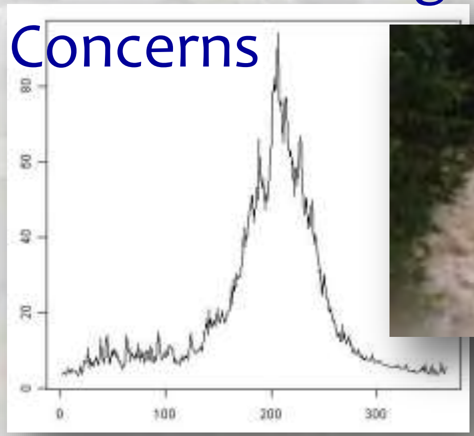
Big Data Powers Big Models… but Local Monitoring is Where it All Starts



Easy Method for Full Year Monitoring

Underwater Epoxy Protocol

Annual Flooding Concerns



Underwater epoxy

$130 = 5 years of data

Data retrieved from underwater

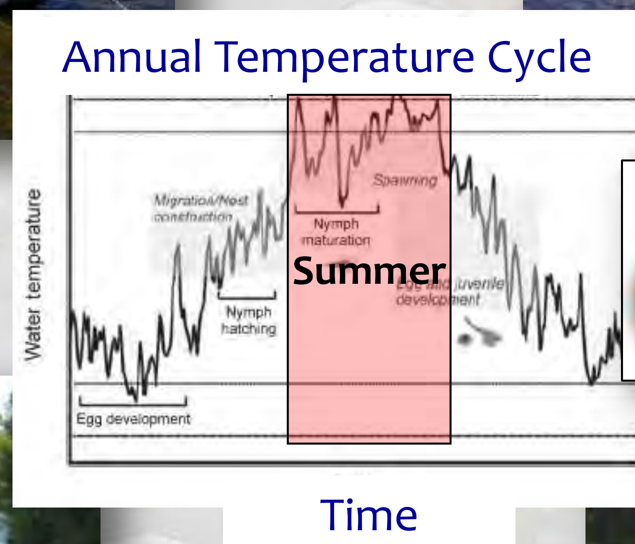
Sensors or PVC housings glued to large boulders

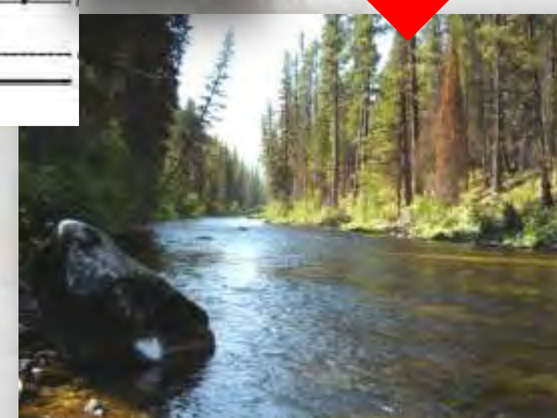
Isaak & Horan 2011. *NAJFM* **31**:134-137

Big Boulders & Small Sensors

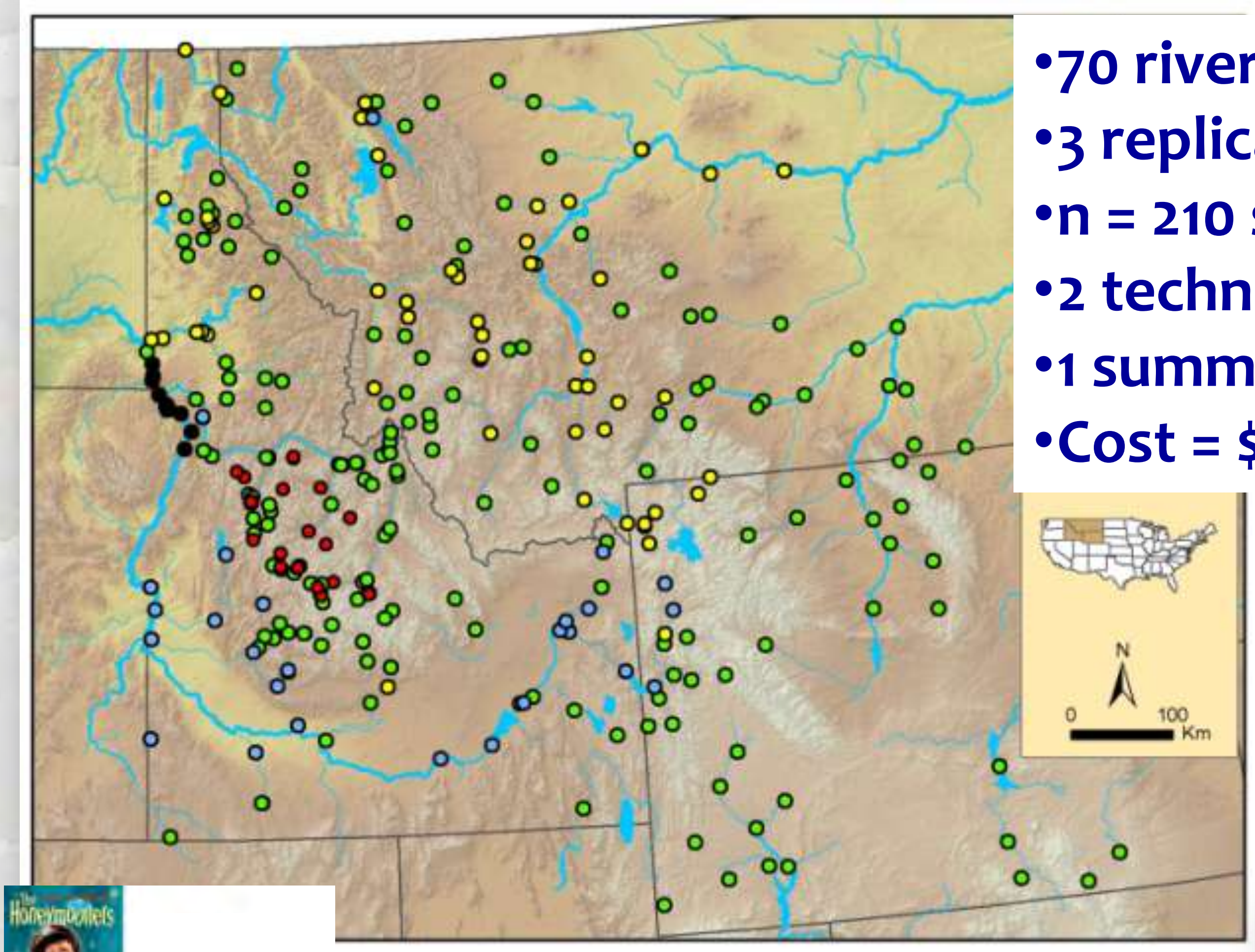
Bridge pilings, roadbed riprap…

Significant Monitoring Gap: Full Year Temperatures from Unregulated Rivers



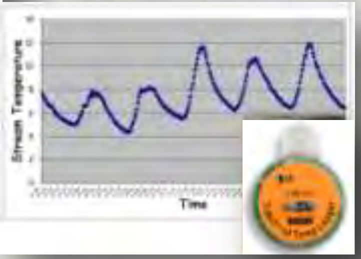


NoRRTN: Northern Rockies River Temperature Network



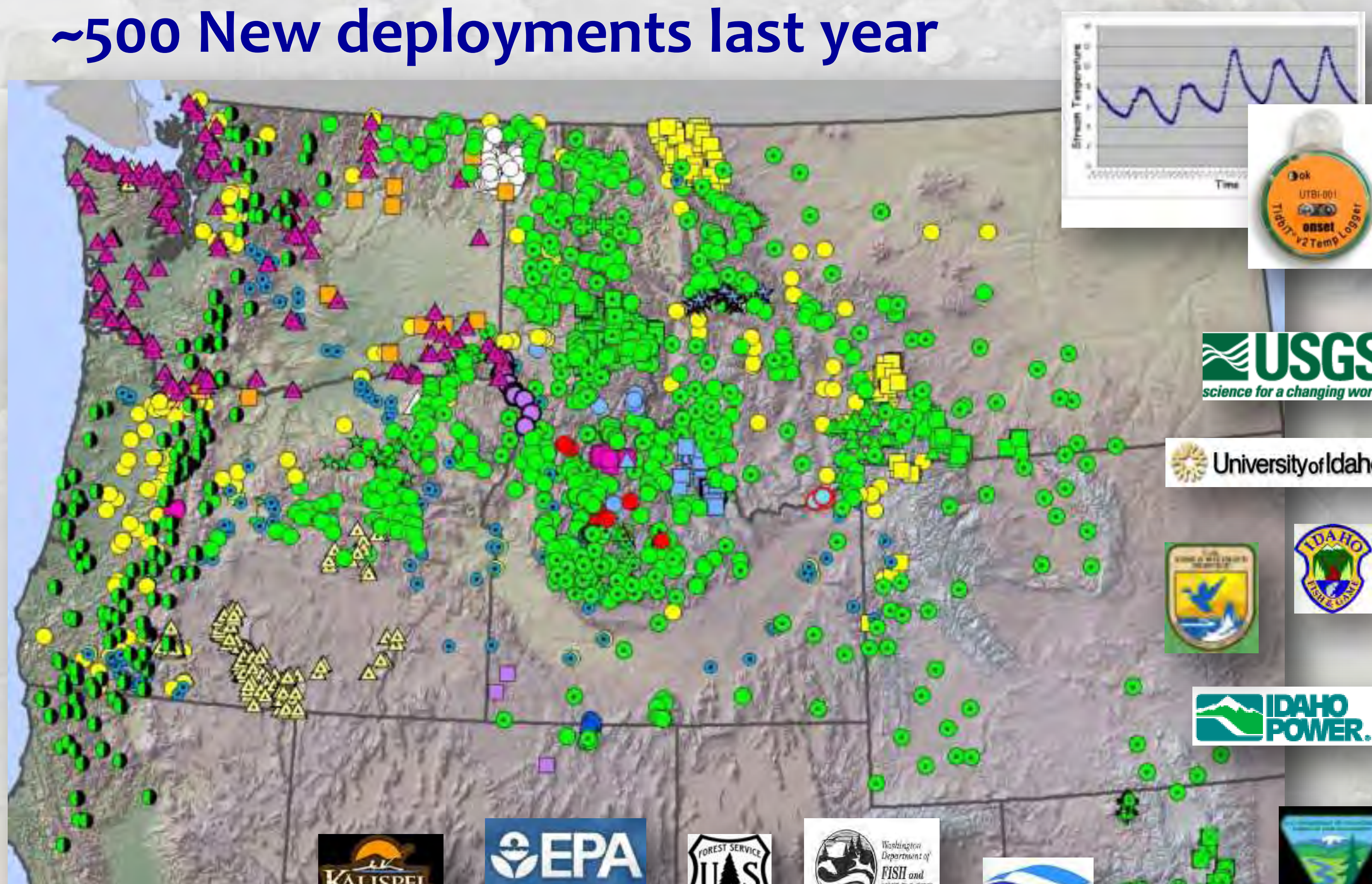
- •70 rivers;
- •3 replicates/river;
- •n = 210 sites;
- •2 technicians;
- •1 summer of work;
- •Cost = $50,000;

Also Norton



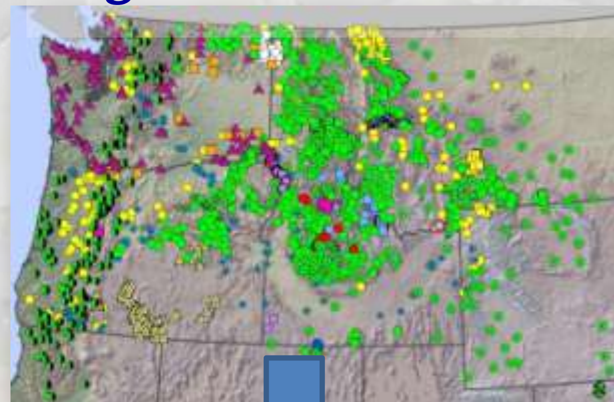
Full Year Stream Temperature Monitoring Becoming Popular…

2,761 Current full-year monitoring sites
~500 New deployments last year



A GoogleMap Tool for Dynamic Queries of Temperature Monitoring Sites

Regional Sensor Network

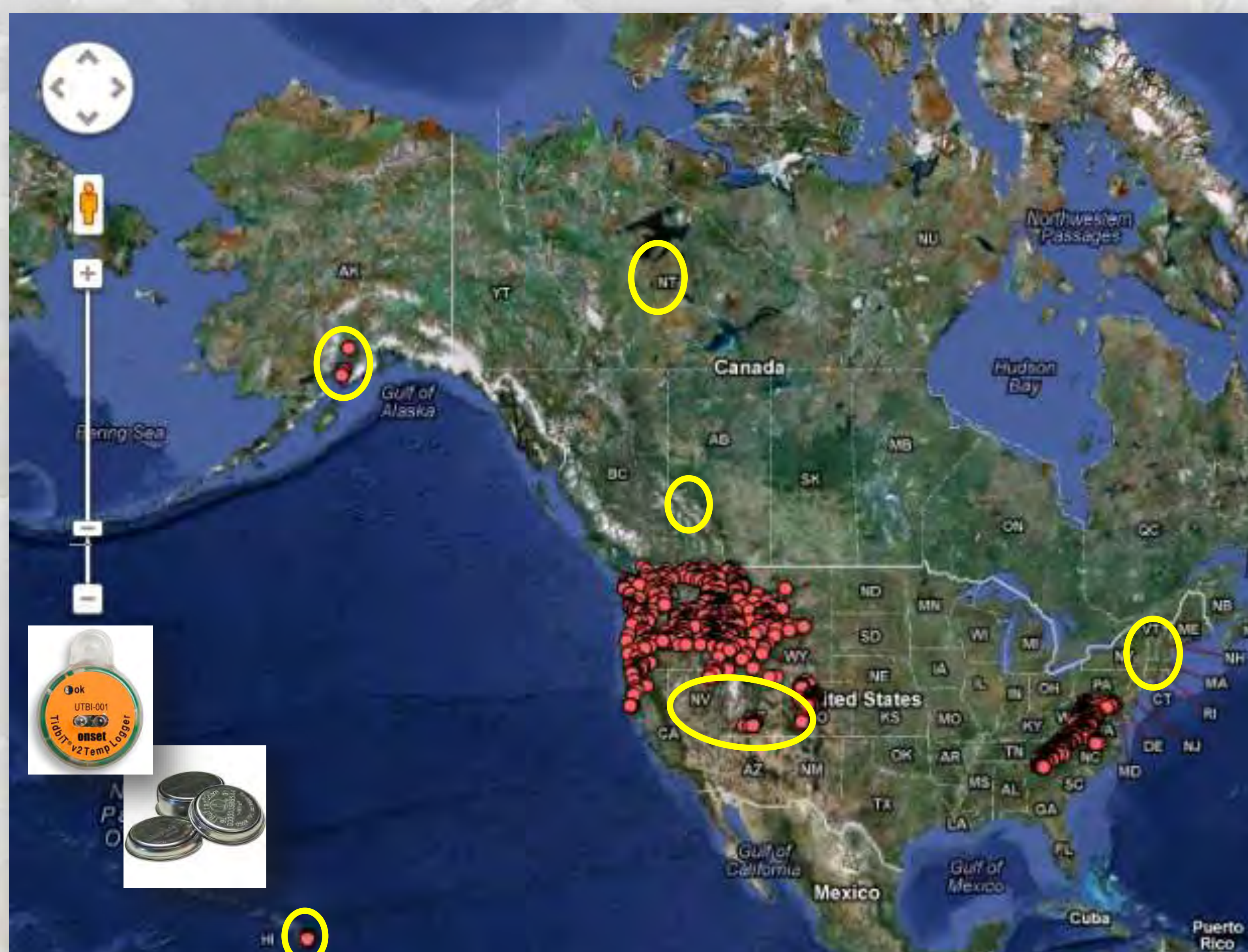


Site Information

- Stream name
- Data steward contact information
- Agency
- Site Initiation Date

Query Individual Sites

Continental Monitoring Network Emerging



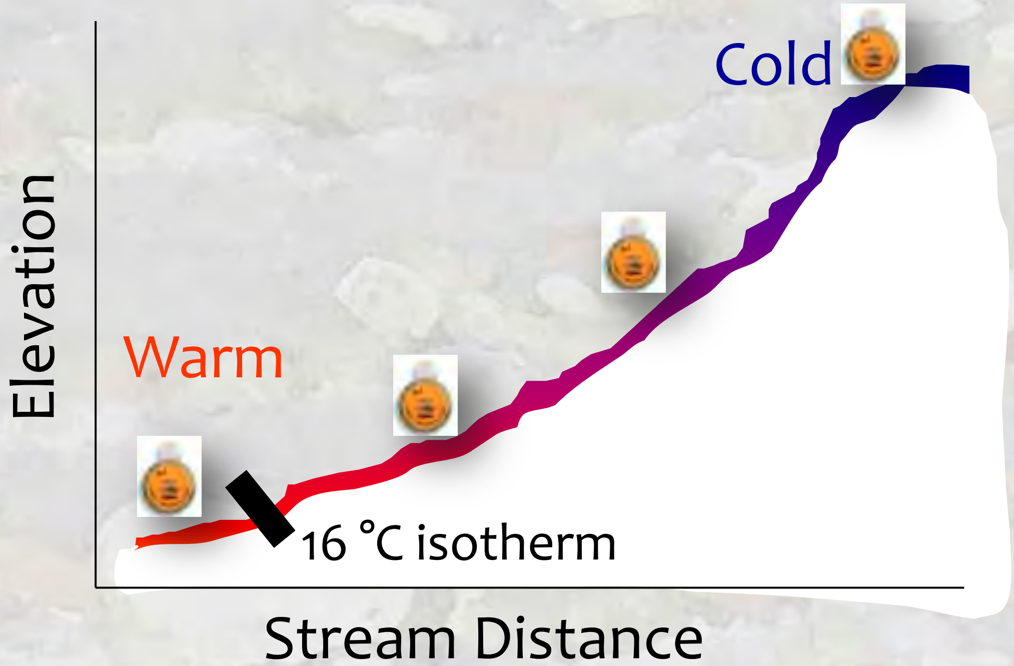
Monitoring Sites in CRCT Range

Mike Golden
Matt Grove
Kelly Larkin-McKim
Rick Henderson
Andrew Briebart
Gwynne Chandler

Stream-Specific Climate Change Scenarios

Calculation of Stream Isotherm Shifts

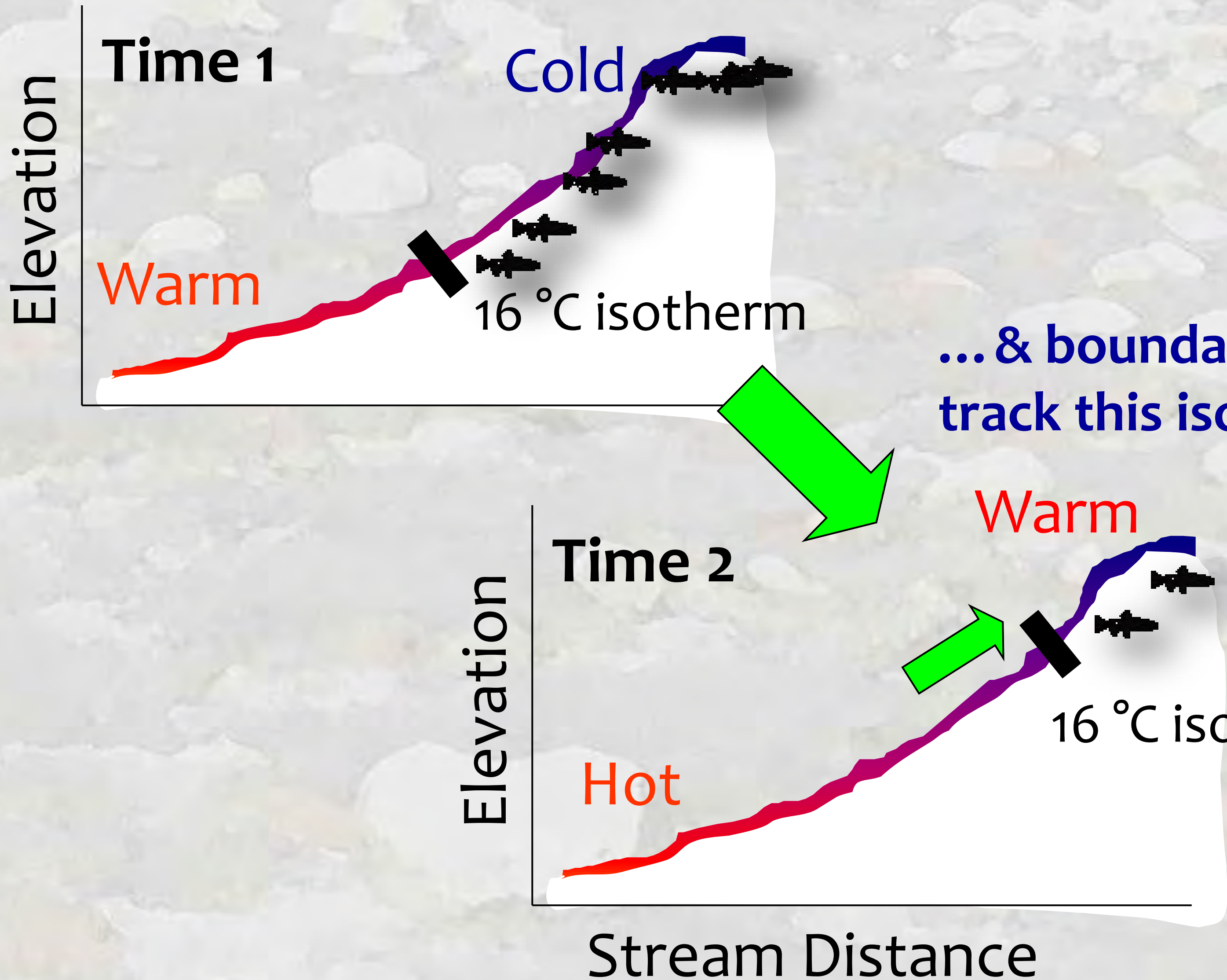
1) Stream temperature lapse rate (°C / 100 m)
2) Long-term stream warming rate (°C / decade)
3) Stream slope (degrees)
4) Stream sinuosity



Isaak & Rieman. 2012. *Global Change Biology* **18**, doi: 10.1111/gcb.12073

Key BioClimate Model Assumption:

Critical isotherm delimits species boundary…

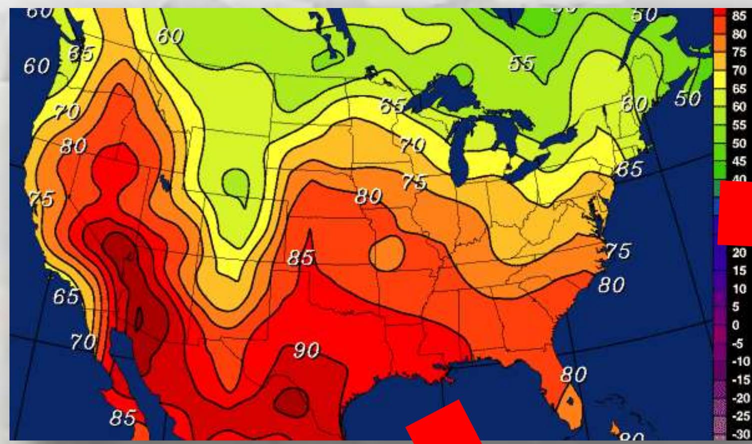


…& boundaries will track this isotherm

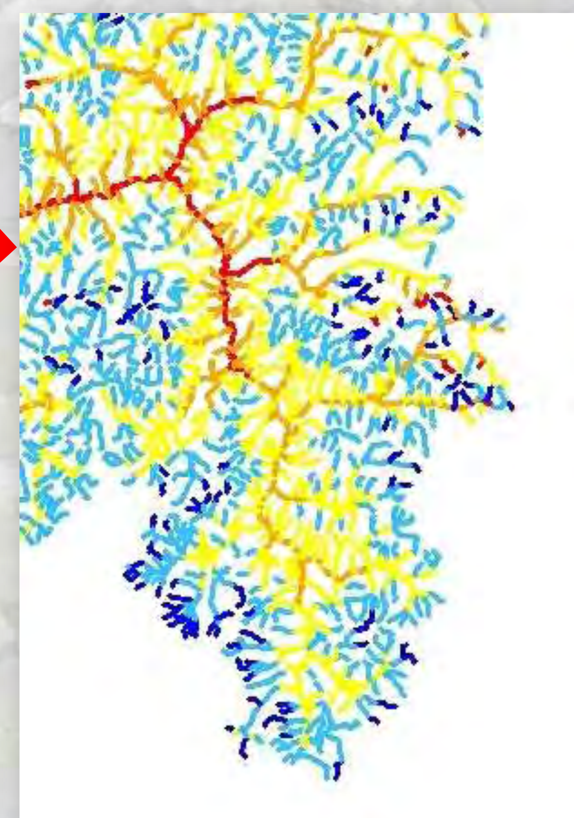
What is an Isotherm?

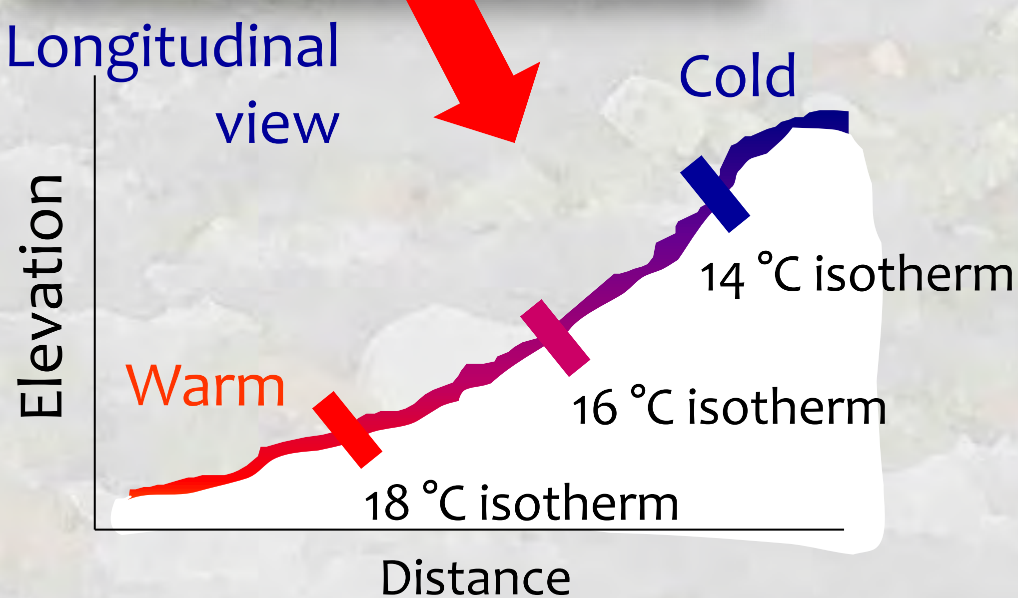
How does it apply to streams?

Isotherm = Line connecting locations with equal temperatures



Stream plan view



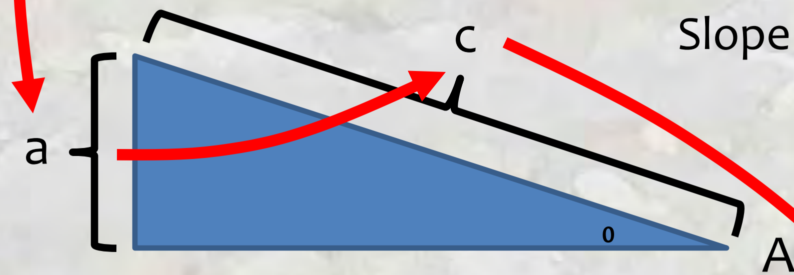


A Use for High School Trigonometry!

Step 1. Calculate vertical displacement for a given stream lapse rate and long-term warming rate.

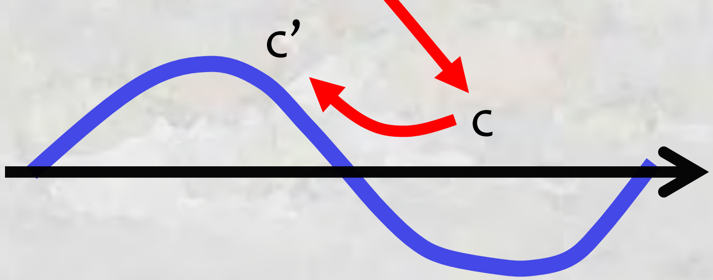
$$\text{Displacement (a)} = \frac{\text{Warming rate}}{\text{Lapse rate}} = \frac{0.2^oC/\text{decade}}{0.4^oC/100m} = +50m/\text{decade}$$

Step 2. Translate displacement to distance along stream of a given slope.



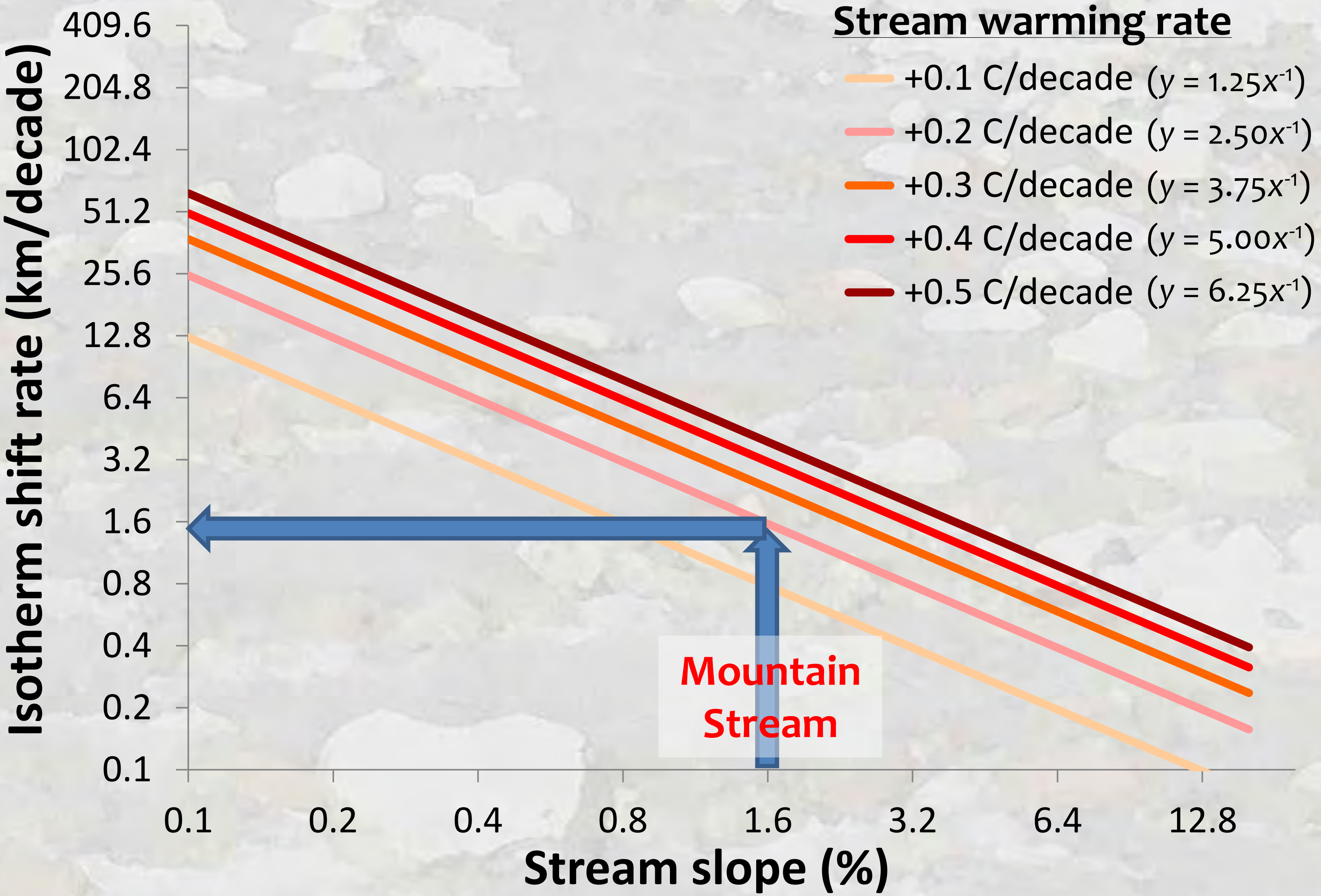
$$\text{Slope distance (c)} = \frac{a}{\sin A^0}$$

Step 3. Multiply slope distance by stream sinuosity ratio in meandering streams.



Isotherm Shift Rate Curves

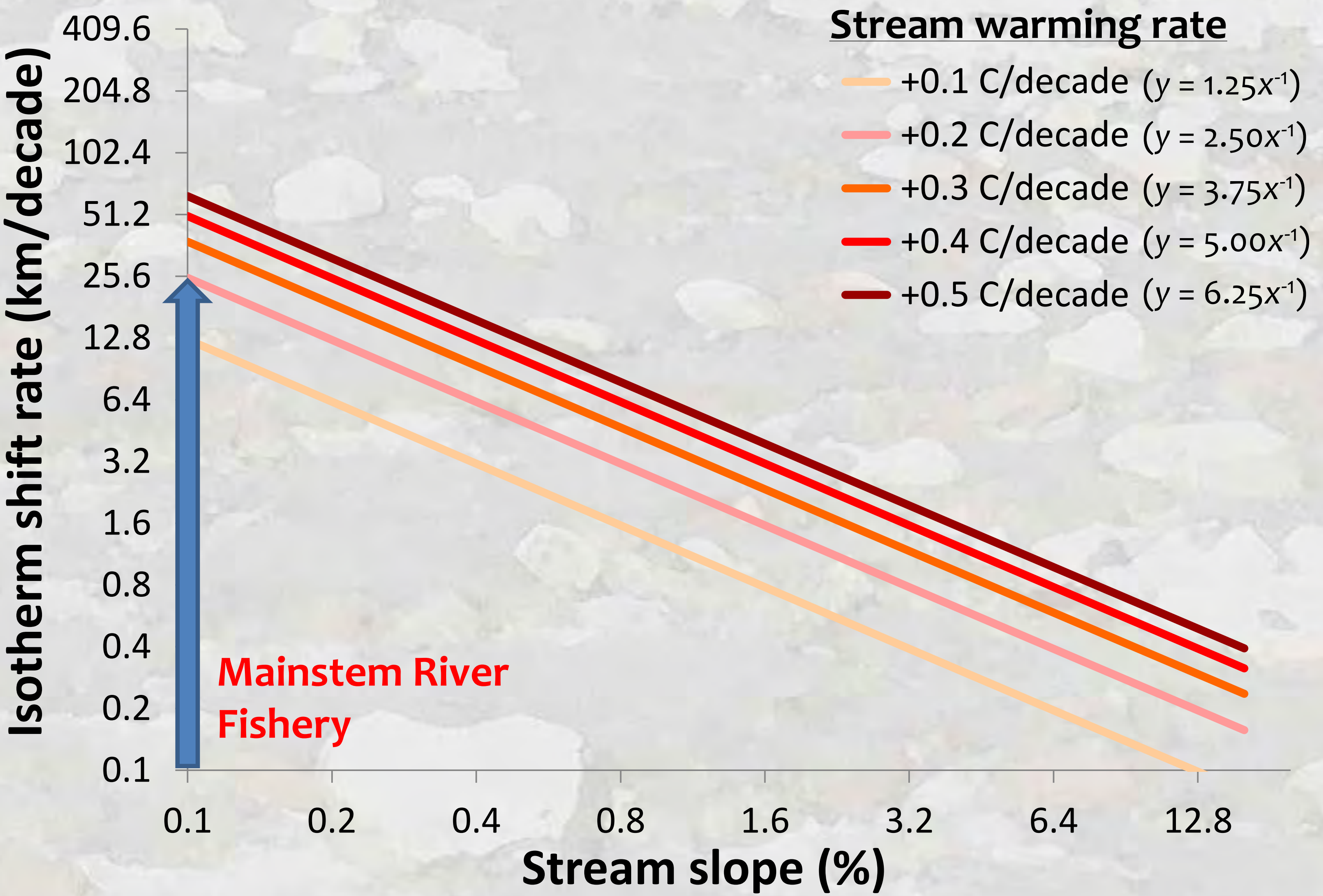
Stream lapse rate = 0.8 °C / 100 m



Isaak & Rieman. 2012. *Global Change Biology* **18**, doi: 10.1111/gcb.12073

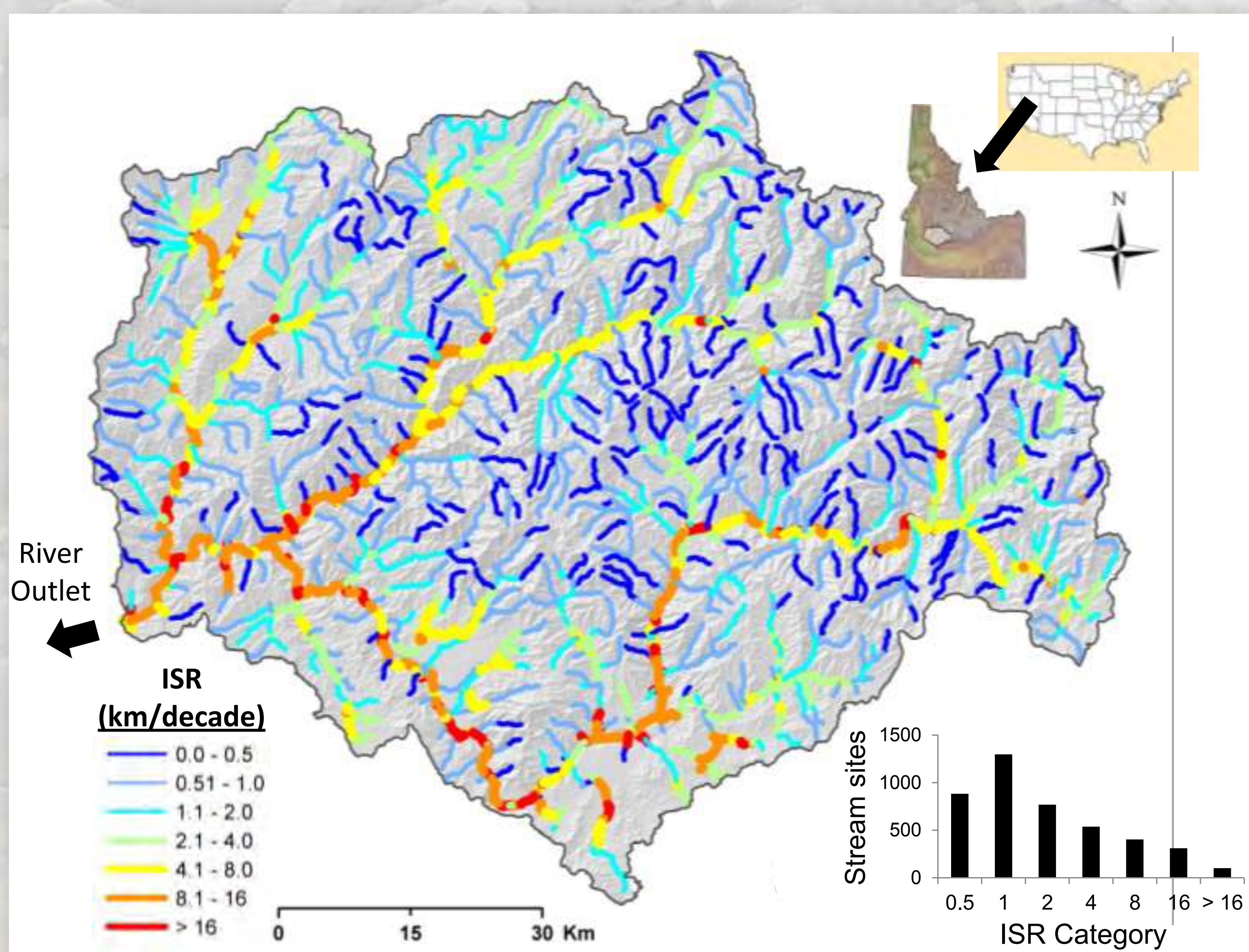
Isotherm Shift Rate Curves

Stream lapse rate = 0.8 °C / 100 m



Isaak & Rieman. 2012. *Global Change Biology* **18**, doi: 10.1111/gcb.12073

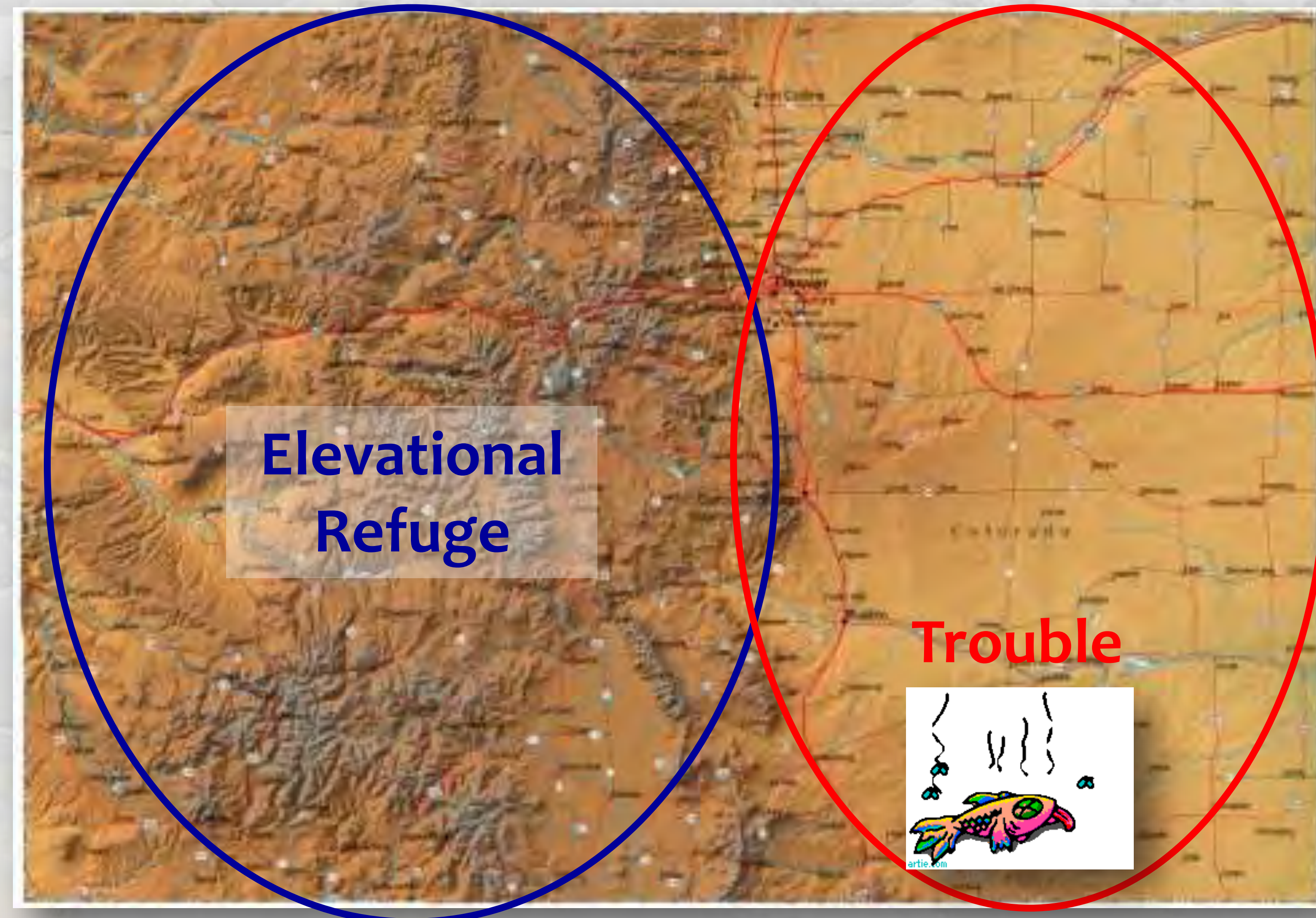
River Network Climate Velocity Map



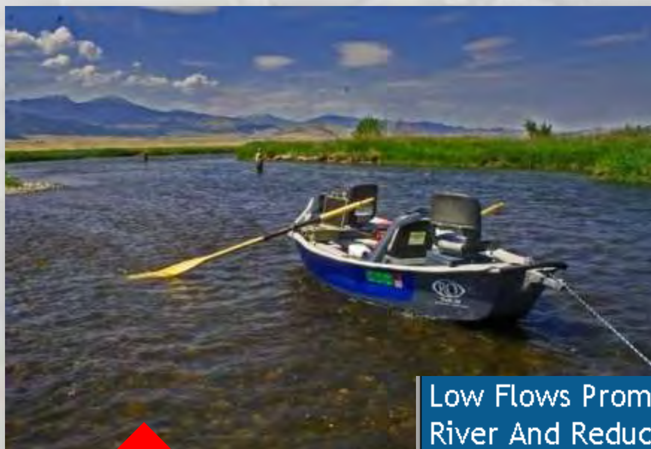
sensu Loarie et al. 2009. *Nature* **462**:1052-1055.

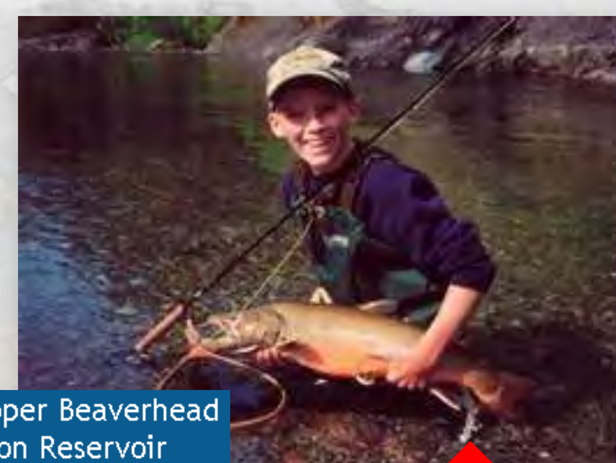
If It's Steep, It Will Slow the Creep…

Topography will be our Frien-emy



Mainstem Fisheries Will See First & Most Pronounced Thermal Impacts

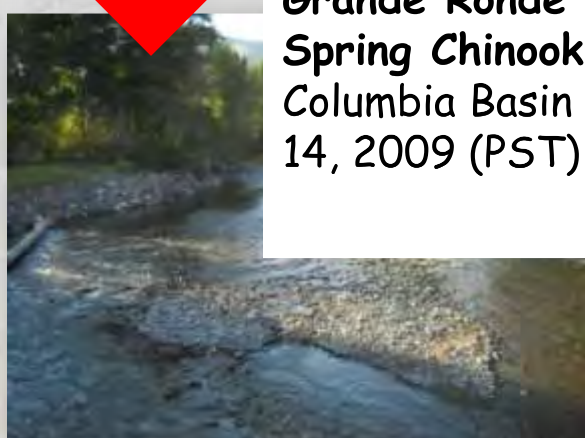


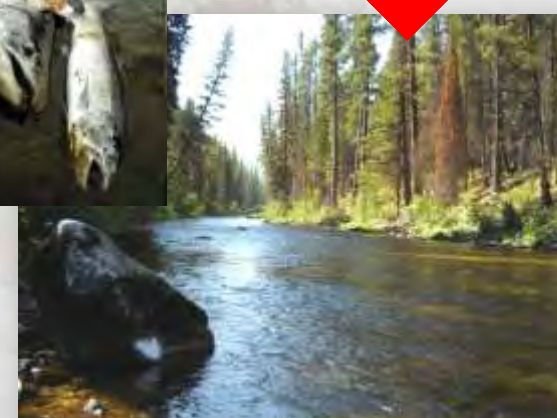


Low Flows Prompt Fishing Closure On Upper Beaverhead River And Reduced Limits On Clark Canyon Reservoir

Wednesday, September 29, 2004
Fishing

High Water Temperature In Grande Ronde Kills 239 Adult Spring Chinook
Columbia Basin Bulletin, August 14, 2009 (PST)

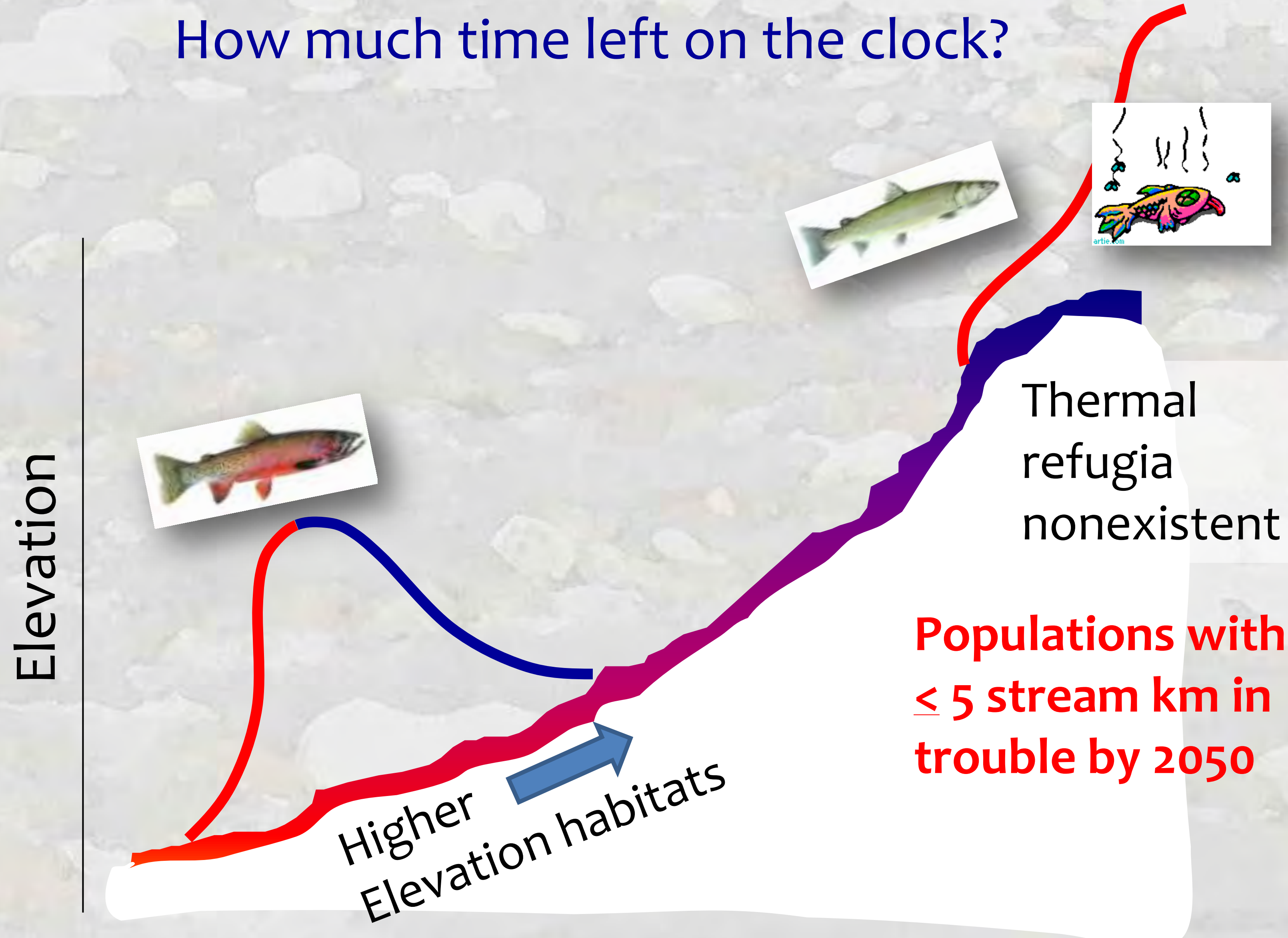




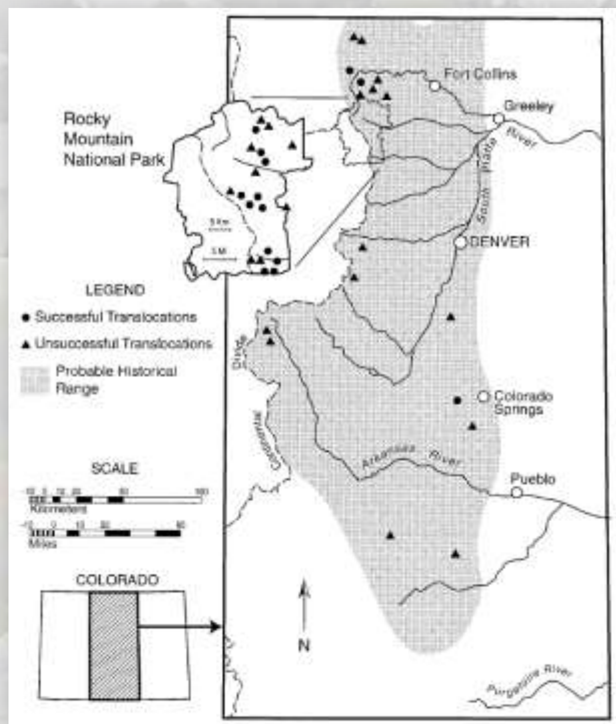
Headwater Populations

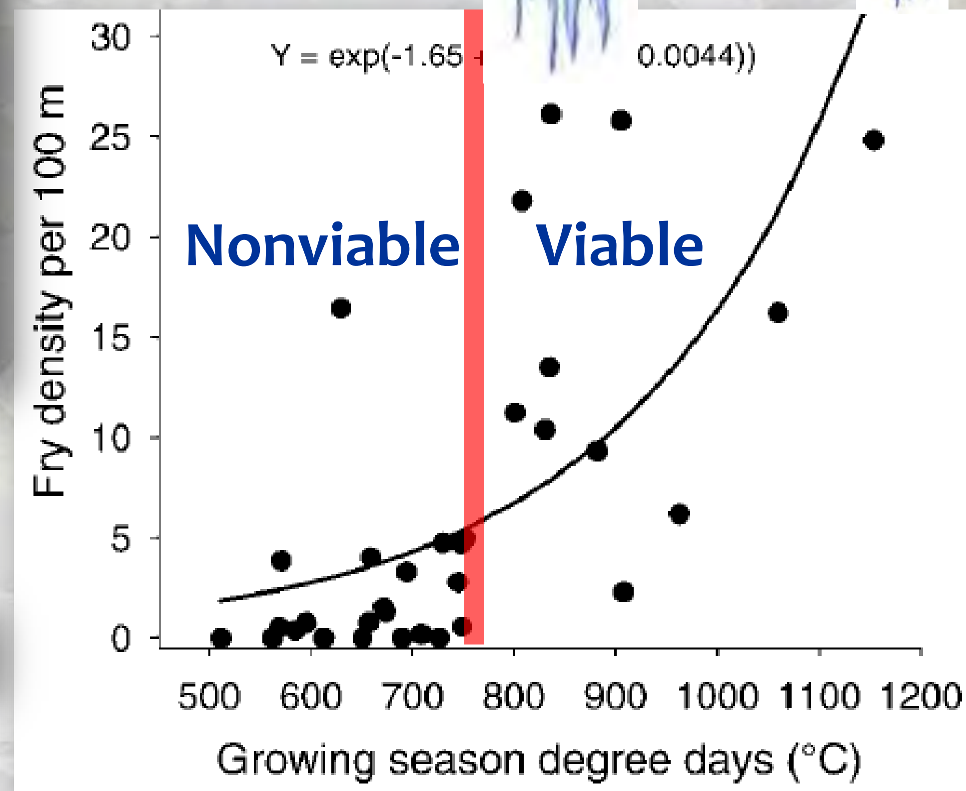
Is it a problem?

How much time left on the clock?



CRCT Habitats Often Too Cold…

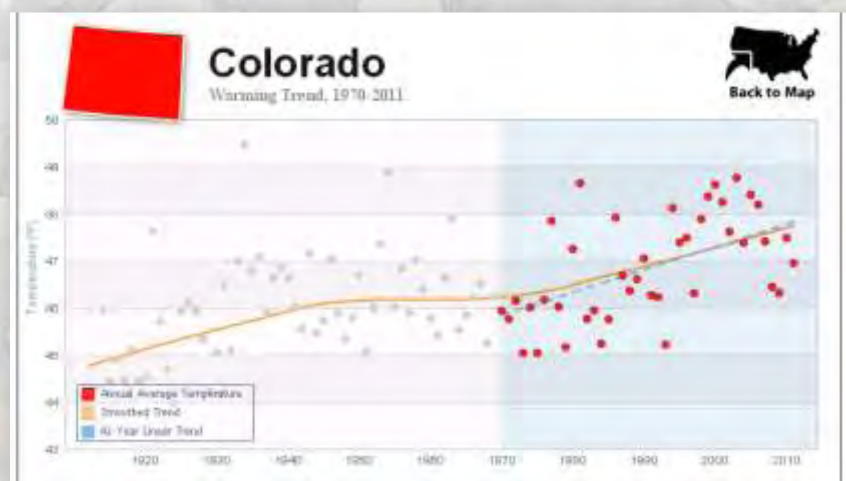


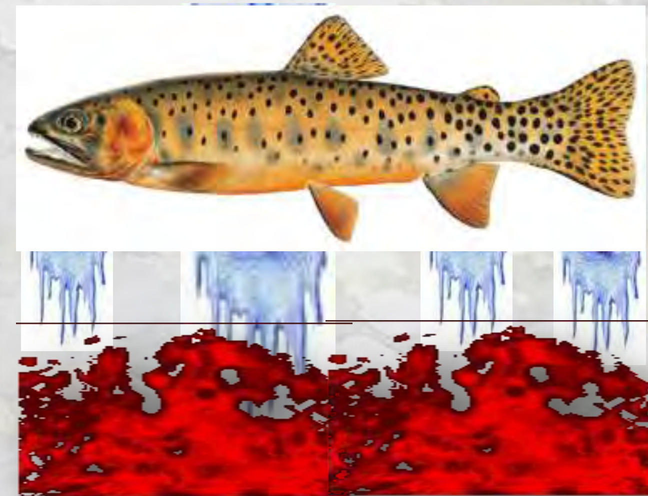


Harig et al. 2000; Harig & Fausch 2002; Coleman & Fausch 2007

… But Now Are Slowly Thawing…

+0.26 °C/decade from 1970-2011





Air warming 0.26 °C/ decade ~

a) stream warming 0.15 °C/decade ~

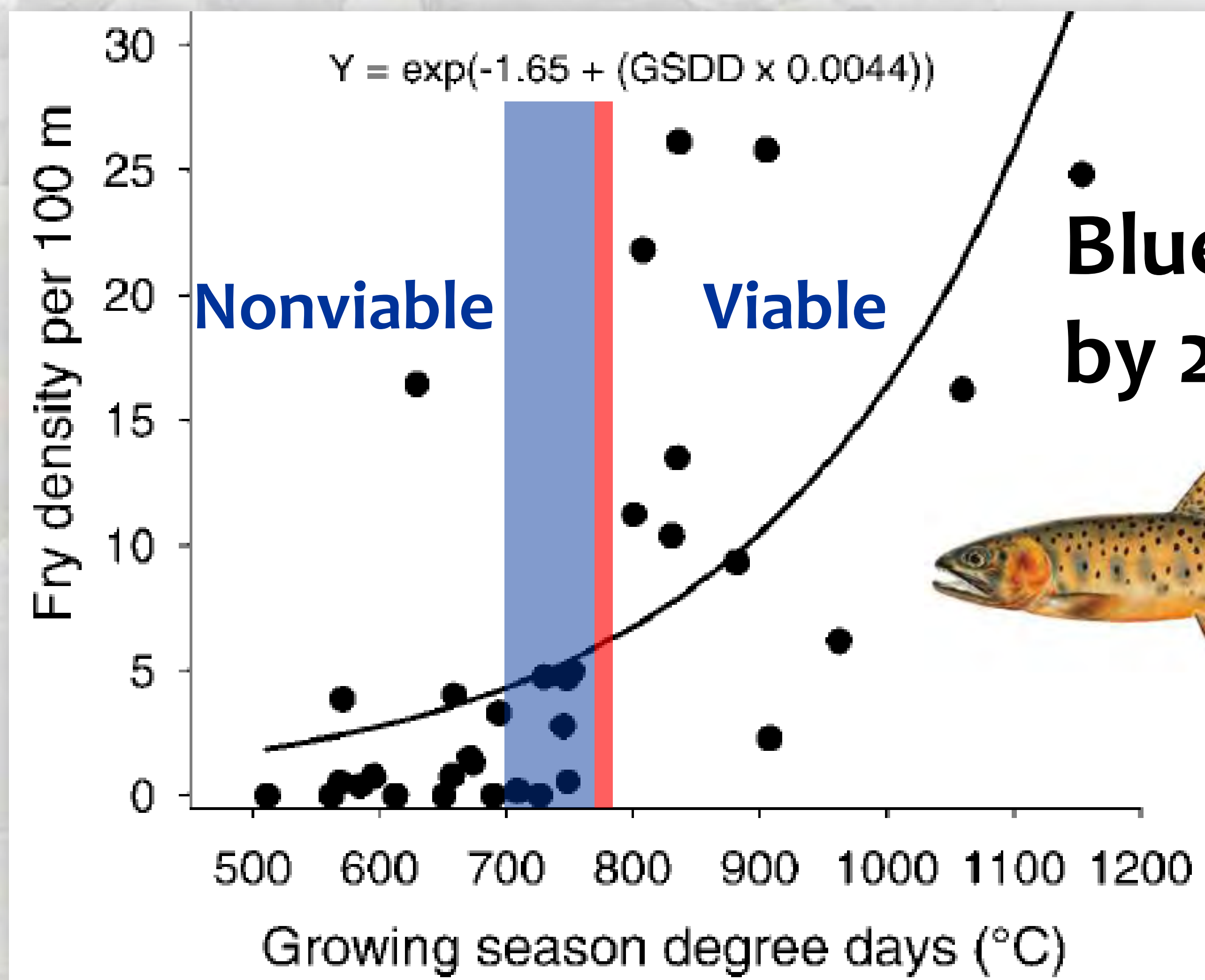
0.5 - 1 km/decade isotherm shift in 1% - 5% slopes

b) stream warming 0.15 °C/decade ~

+20 degree days/decade ~

+80 degree days by 2050.

…& New Habitats Will Come Online



Blue = new by 2050?…

Harig et al. 2000; Harig & Fausch 2002; Coleman & Fausch 2007

Sensor Technology for Stream Discharge

Traditional technique =
labor intensive & expensive

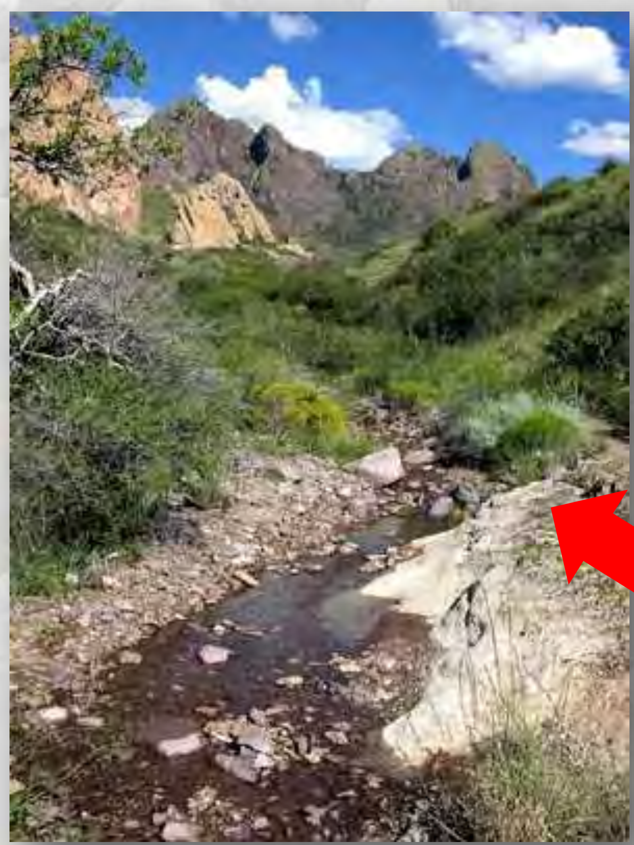
Portable Doppler Velocimeter

Pressure Transducers

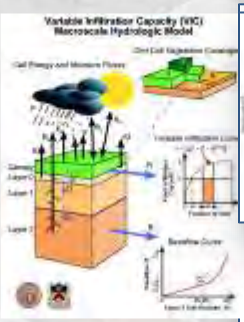
New discharge sensors =
new possibilities

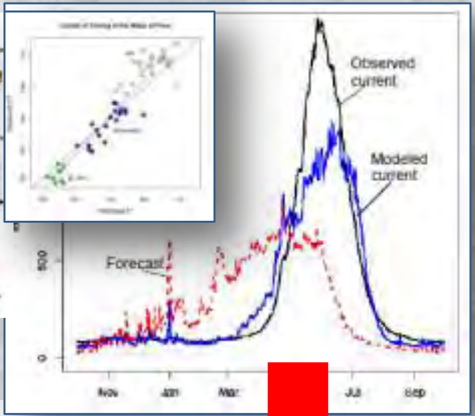
Hydrologic Models for Tiny Streams?

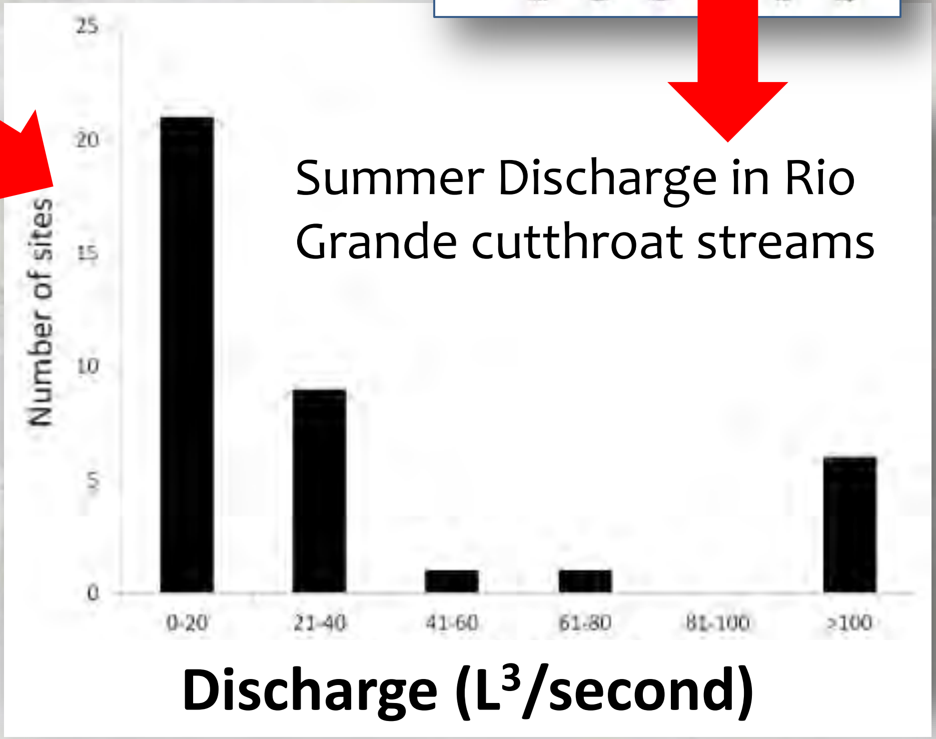
Why model it if it can be directly measured?



VIC Flow Model







Andrew Todd, unpublished

Year 1 Measurement = Habitat Size

Upper Green River CRCT Populations

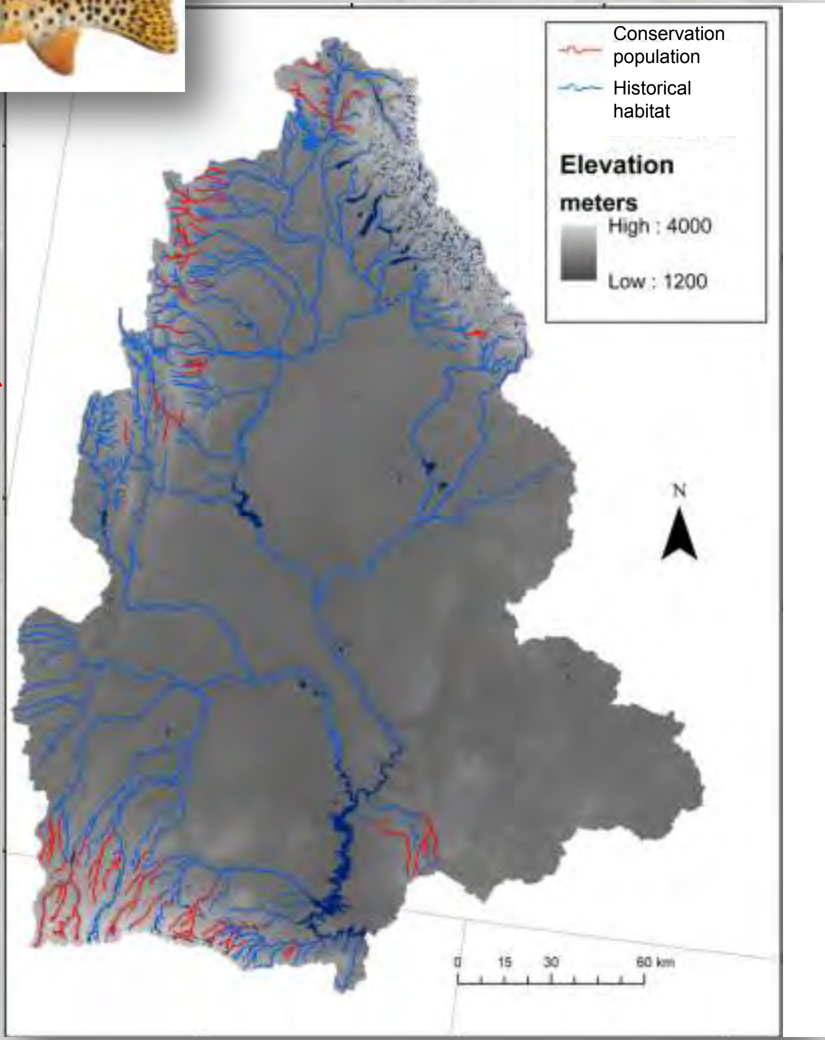
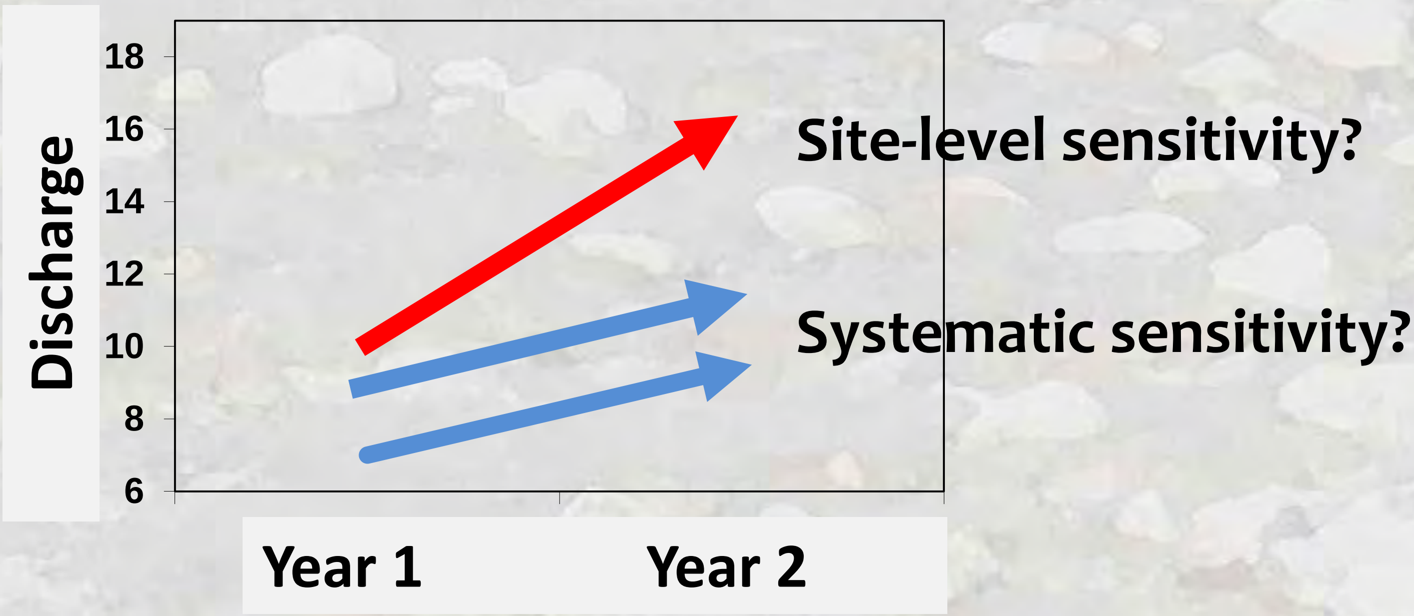
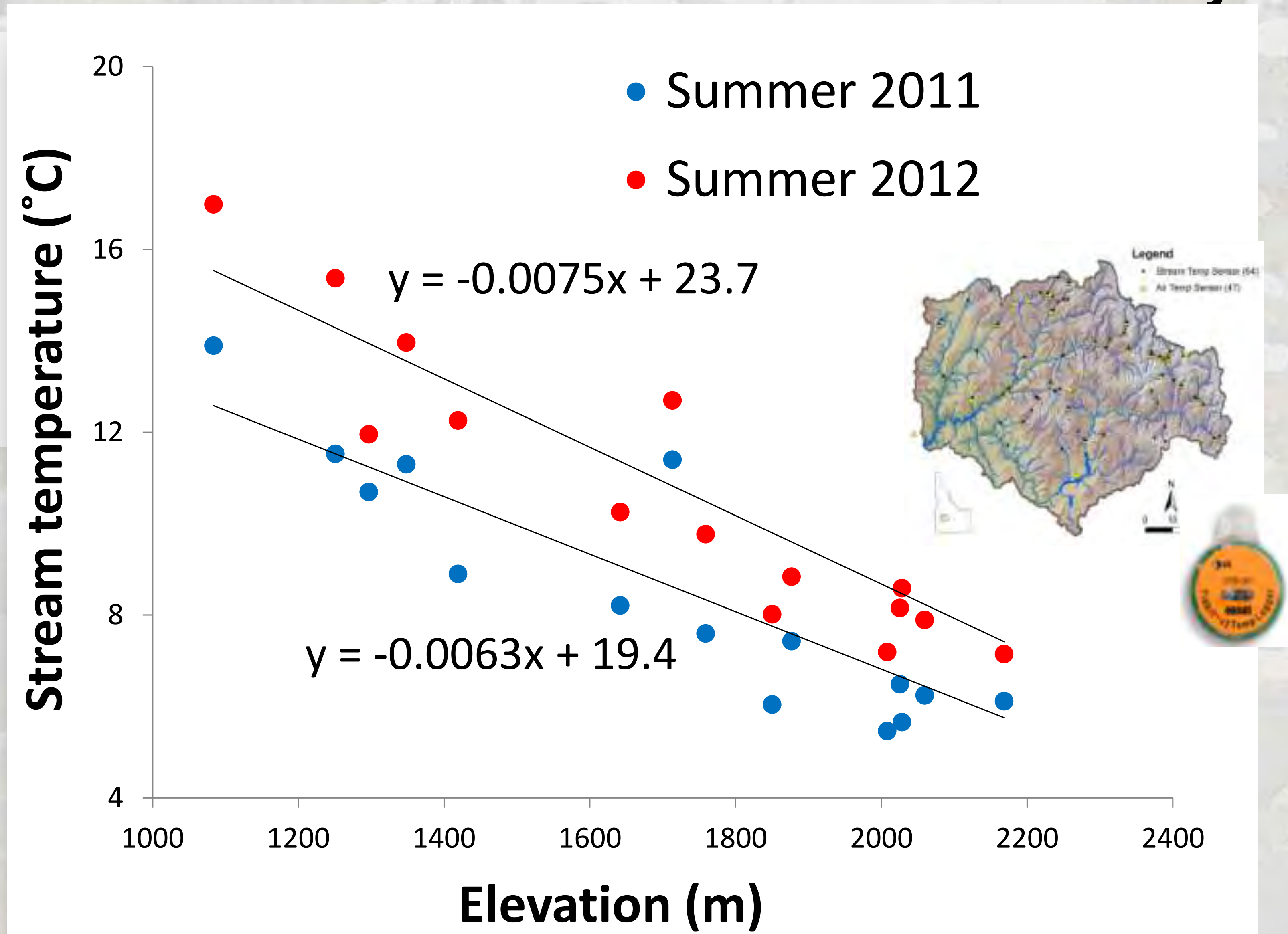


Figure from James Roberts

Year 2 Measurement minus Year 1 Measurement = Climate Sensitivity



Year 2 Measurement minus Year 1 Measurement = Climate Sensitivity

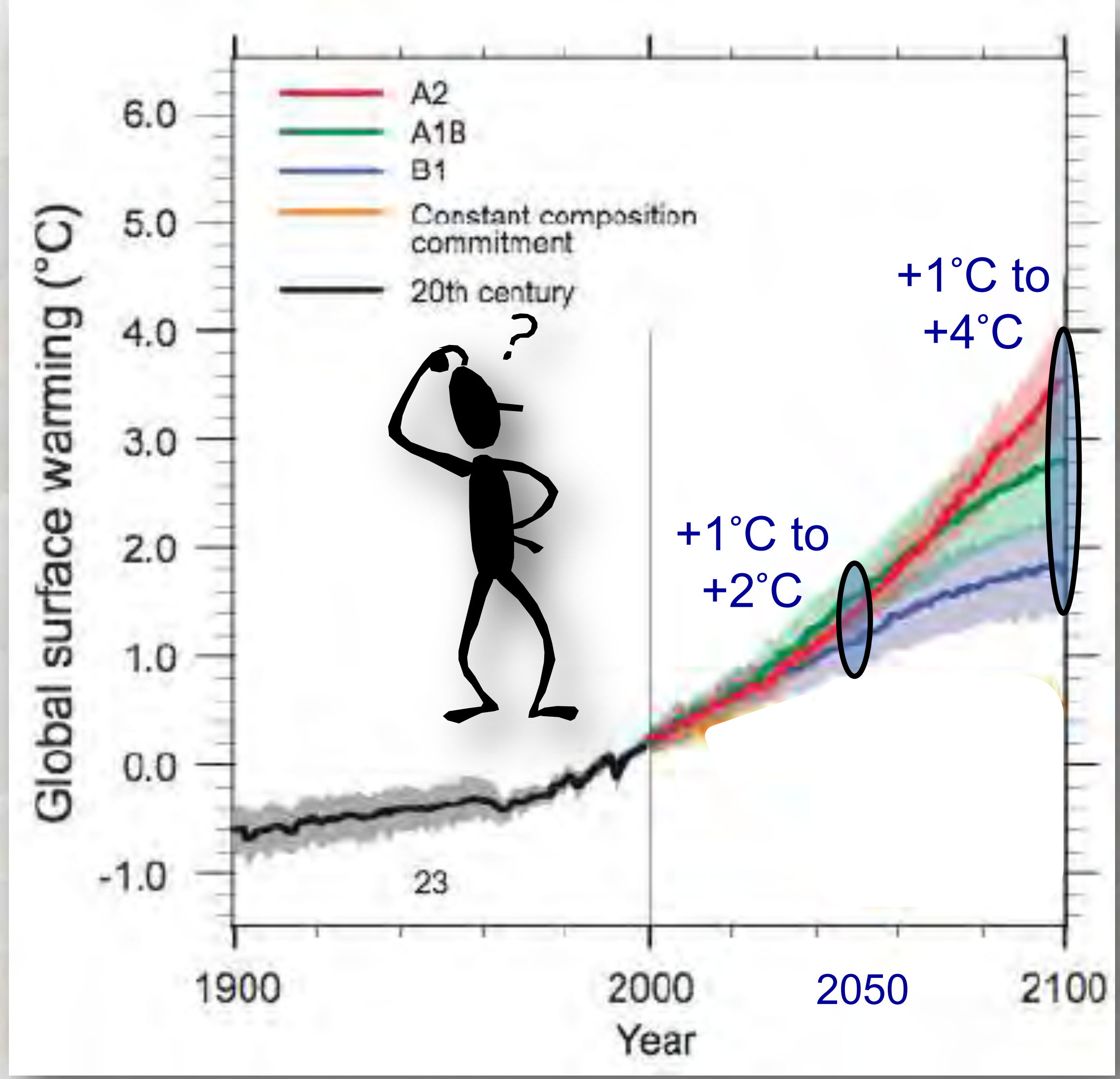


Much Can Be Done to Inform This Question

Where should scarce resources be spent?

Significant Unknowns:

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



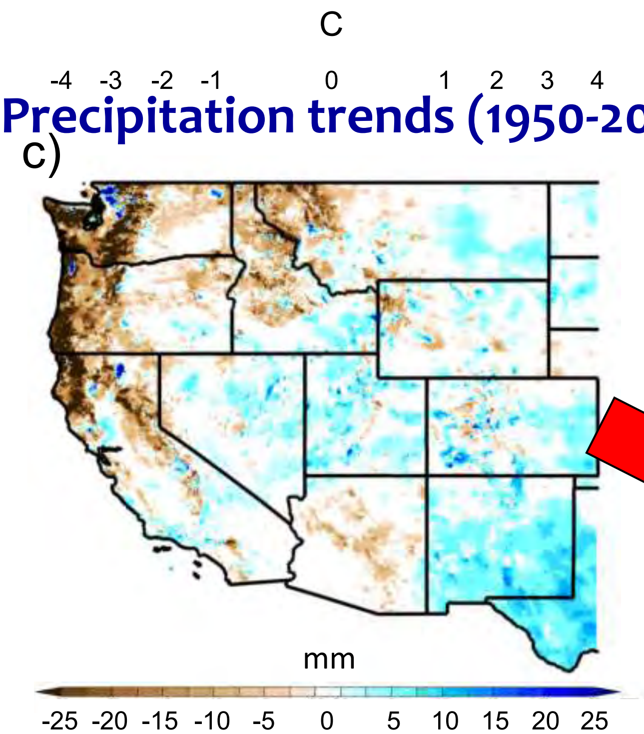
A2?
A1B?
B1?

IPCC 2007

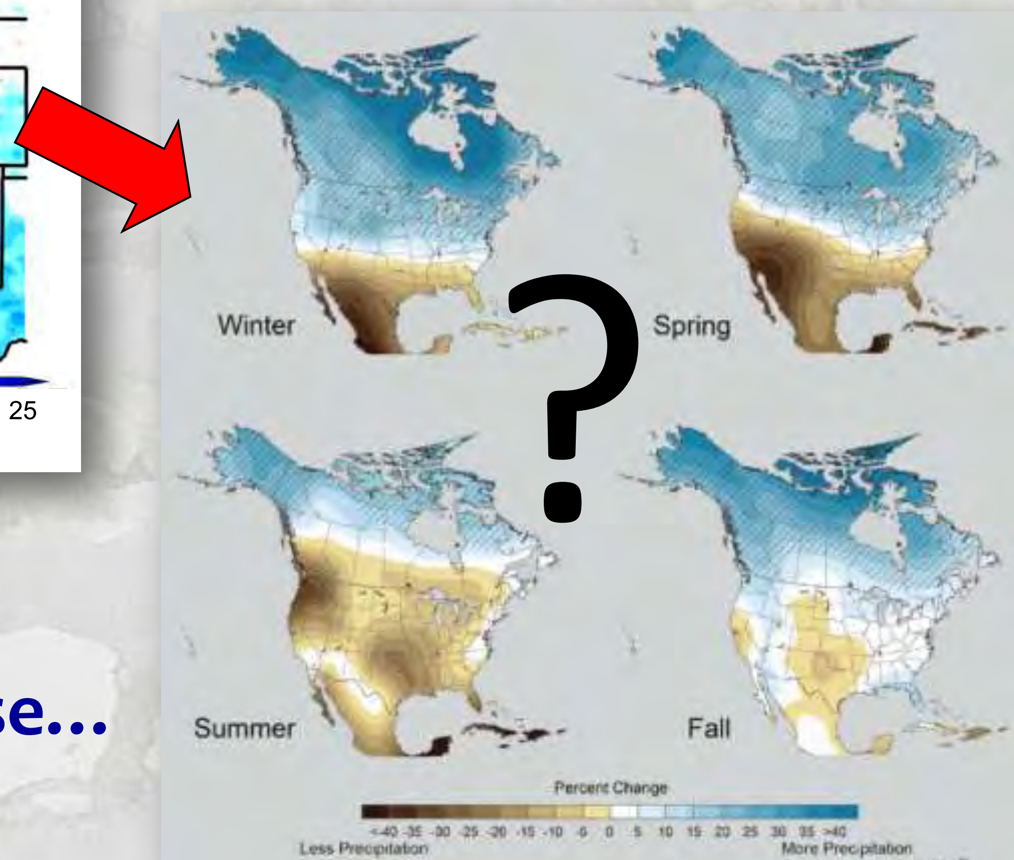
owns:

et Wetter or Dryer?

Precipitation trends (1950-2009)



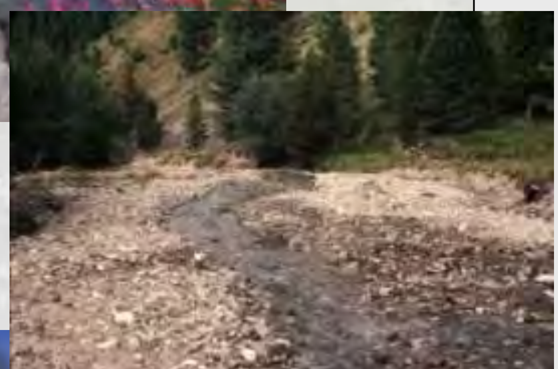
Future trends (2080-2099)?

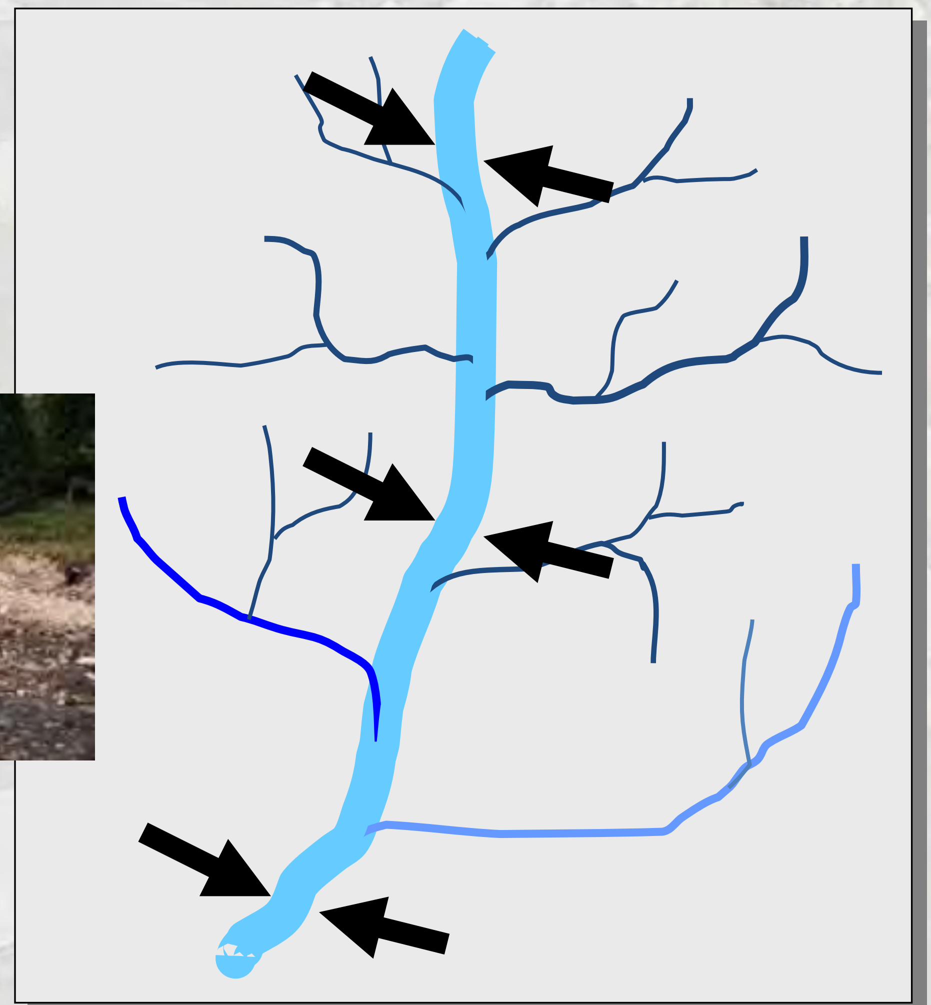


Past may not be a prelude in this case…

U.S. Climate Change Science Program. 2009

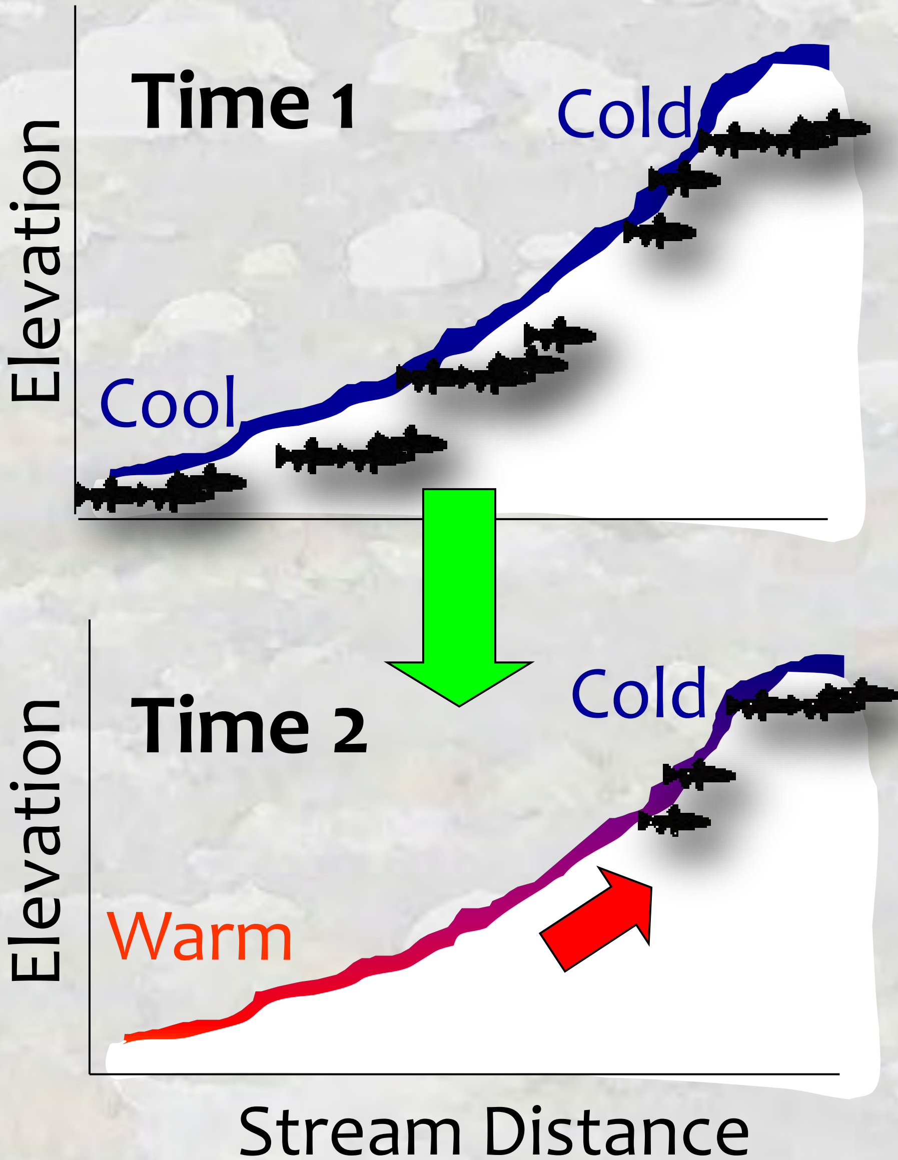
Precipitation Declines = Habitat Reductions / Loss?

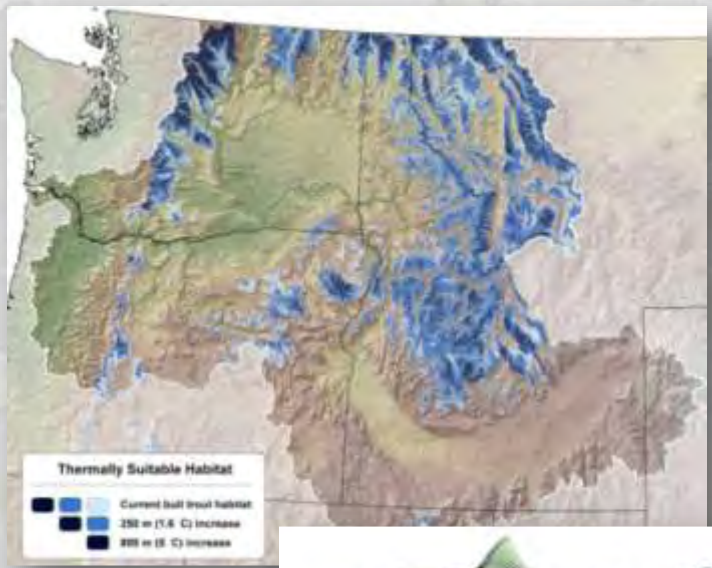




Significant Unknowns:

How Fast Are Fish Distributions Shifting?





Average distribution shift across taxa =

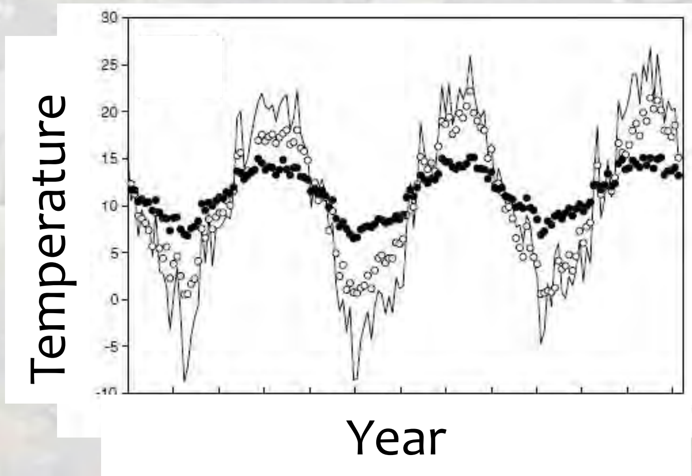
6.1 km/decade poleward OR

6.1 m/decade higher

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

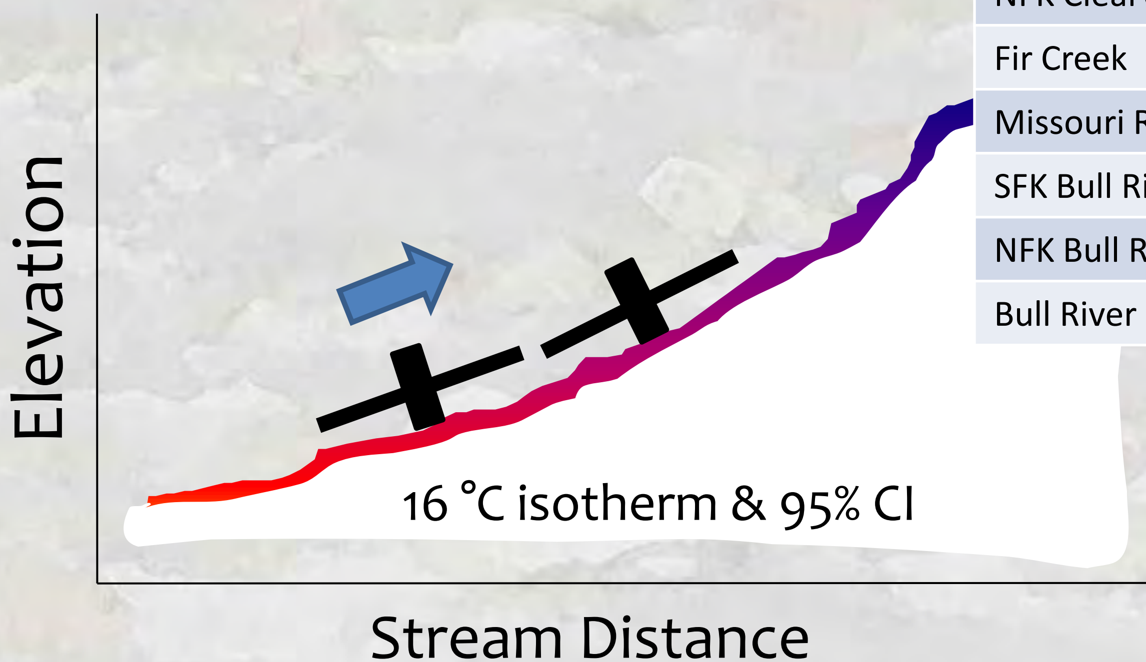
Power Analysis for Trend Detection

How long does monitoring have to occur?



Streams differ in thermal variation which masks warming trend

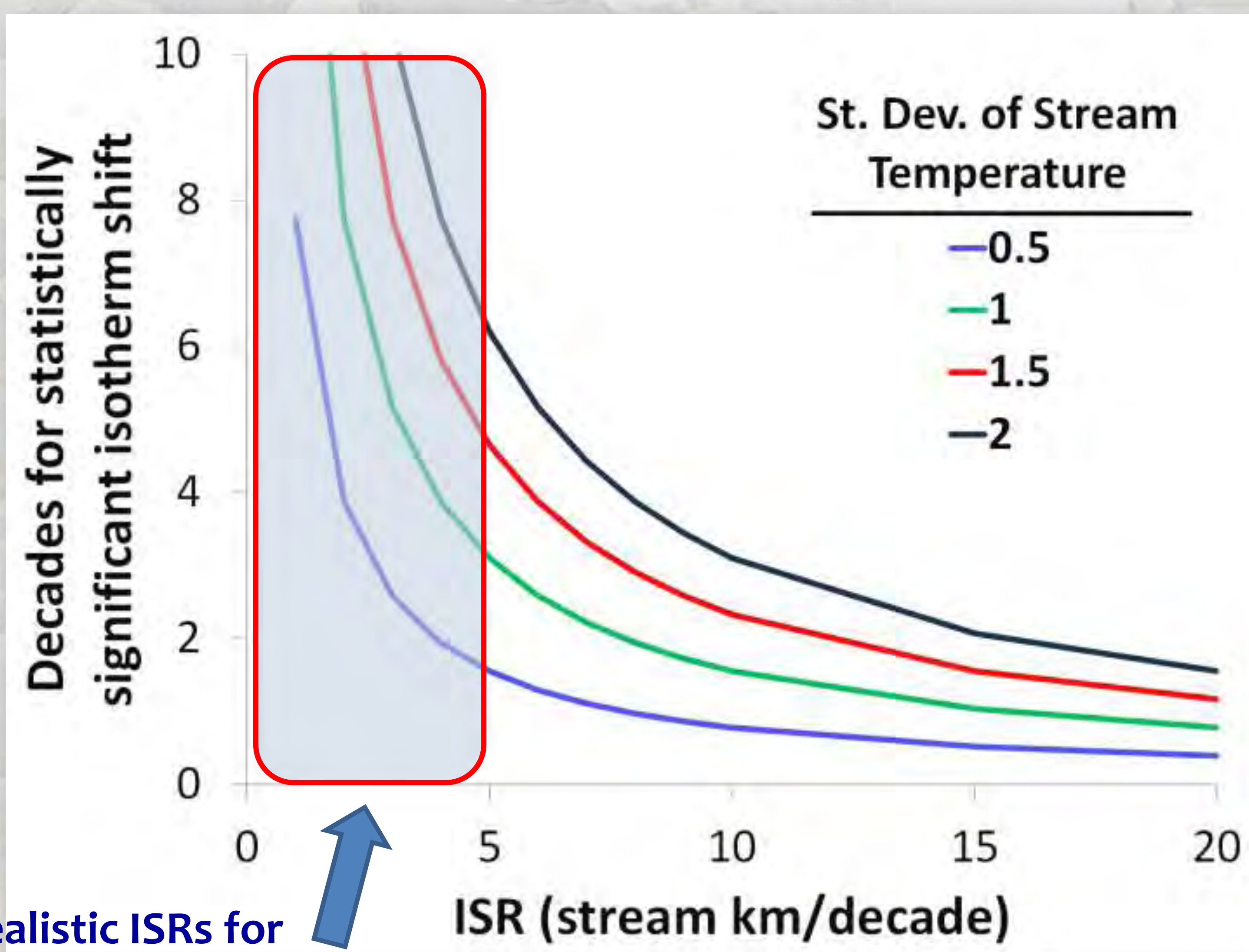
Stream	Summer SD	Annual SD
NFK Clearwater	1.41	0.70
Fir Creek	0.82	0.51
Missouri R.	1.17	0.64
SFK Bull River	0.86	0.55
NFK Bull River	0.36	0.44
Bull River	0.82	0.58



Isaak et al. 2012. *Climatic Change*

Power Curves for Isotherm Shifts

2 – 6 decades for statistically significant changes



Realistic ISRs for 1% channels

Isaak & Rieman. 2012. *Global Change Biology* **18**, doi: 10.1111/gcb.12073

Empirical Evidence in the Short-Term

Resample historical sites along stream profiles

ALTITUDINAL DISTRIBUTION OF BROWN TROUT AND OTHER FISHES IN A HEADWATER TRIBUTARY OF THE SOUTH PLATTE RIVER, COLORADO

ROBERT E. VINCENT AND WILLIAM H. MILLER[1]
Colorado Cooperative Fishery Unit, Colorado State University, Fort Collins, Colorado 80521

(MS received August 9, 1968; accepted March 10, 1969)

Mountain–Great Plains Stream: Biotic Zonation and Additive Patterns of Community Change

FRANK J. RAHEL
*Department of Zoology and Physiology, University of Wyoming
Laramie, Wyoming 82071, USA*

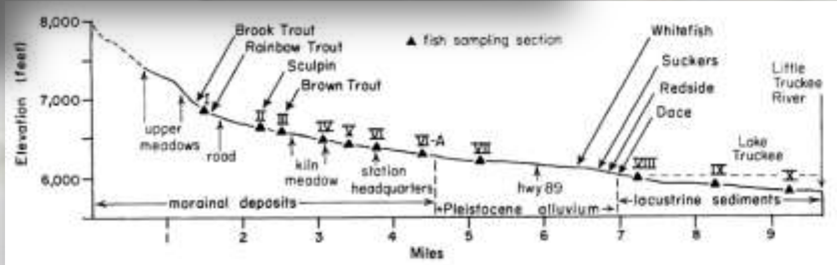
Transactions of the American Fisheries Society 120:319–332, 1991

Species	Site number and elevation (m) 1 2,234	2 2,030	3 2,015	4 1,591	5 1,559	6 1,524	7 1,510	8 1,490	9 1,470	10 1,423
Upstream species										
(1) Brook trout	100	79	72	6						
(2) Brown trout		21	24	+	+	+			2	
Species showing an additive pattern										
(1) White sucker			4	42	34	13	26	51	35	39
(2) Longnose dace				23	18	52	6		33	12
(3) Longnose sucker				2	19	12	13	1	1	2
(4) Creek chub				27	27	20	6	47	28	24
(5) Sand shiner						1	12	+		14
(6) Bigmouth shiner							6	+		4
(7) Fathead minnow							8			+
(8) Common shiner										4
(9) Brassy minnow										+

DISTRIBUTION AND ABUNDANCE OF FISHES IN SAGEHEN CREEK, CALIFORNIA

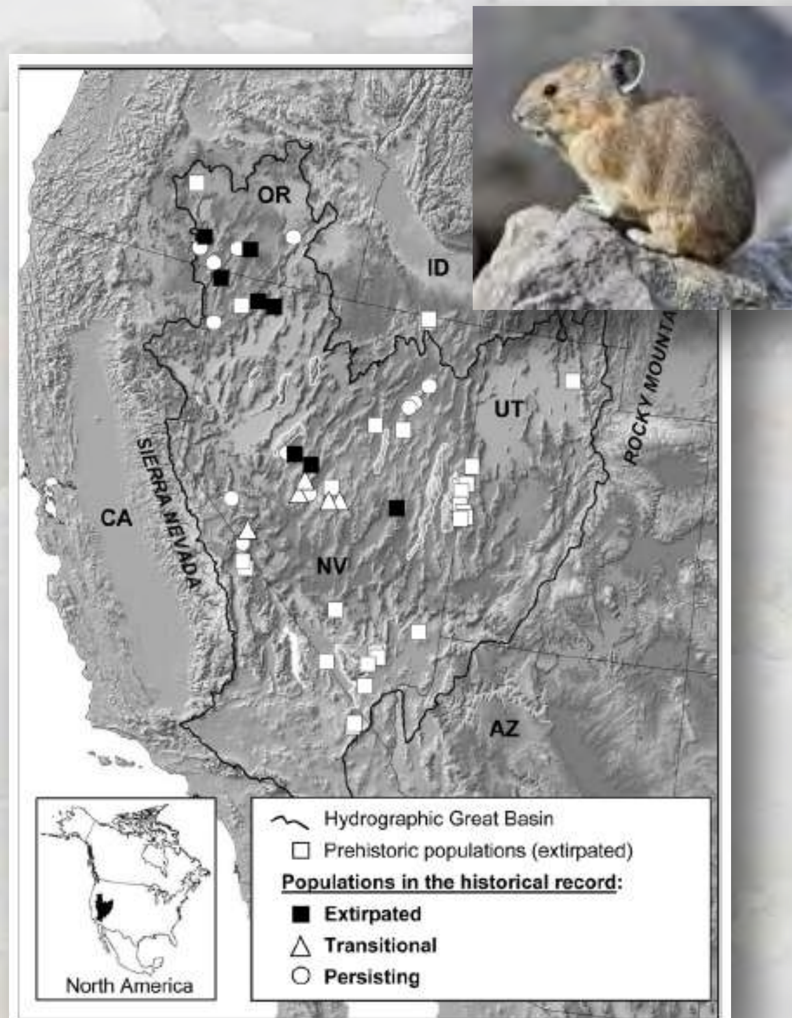
RICHARD GARD, School of Forestry and Conservation, University of California, Berkeley 94720[1]
GLENN A. FLITTNER, Bureau of Marine Sciences, California State University, San Diego 92100

J. Wildl. Manage. 38(2):1974

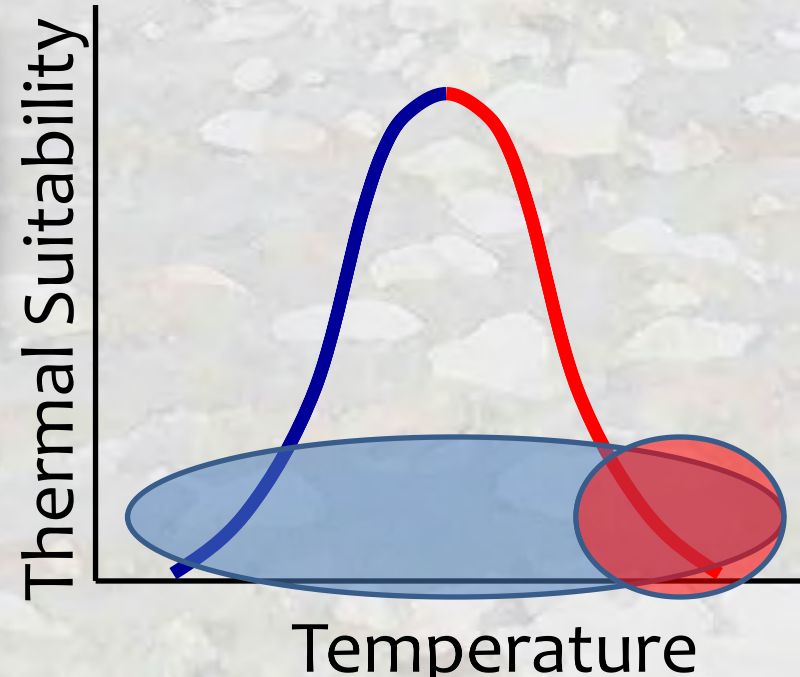


Broad Distributional Resurveys

Assess site extirpation/colonization frequencies relative to temperature



Beever et al. 2003; 2010



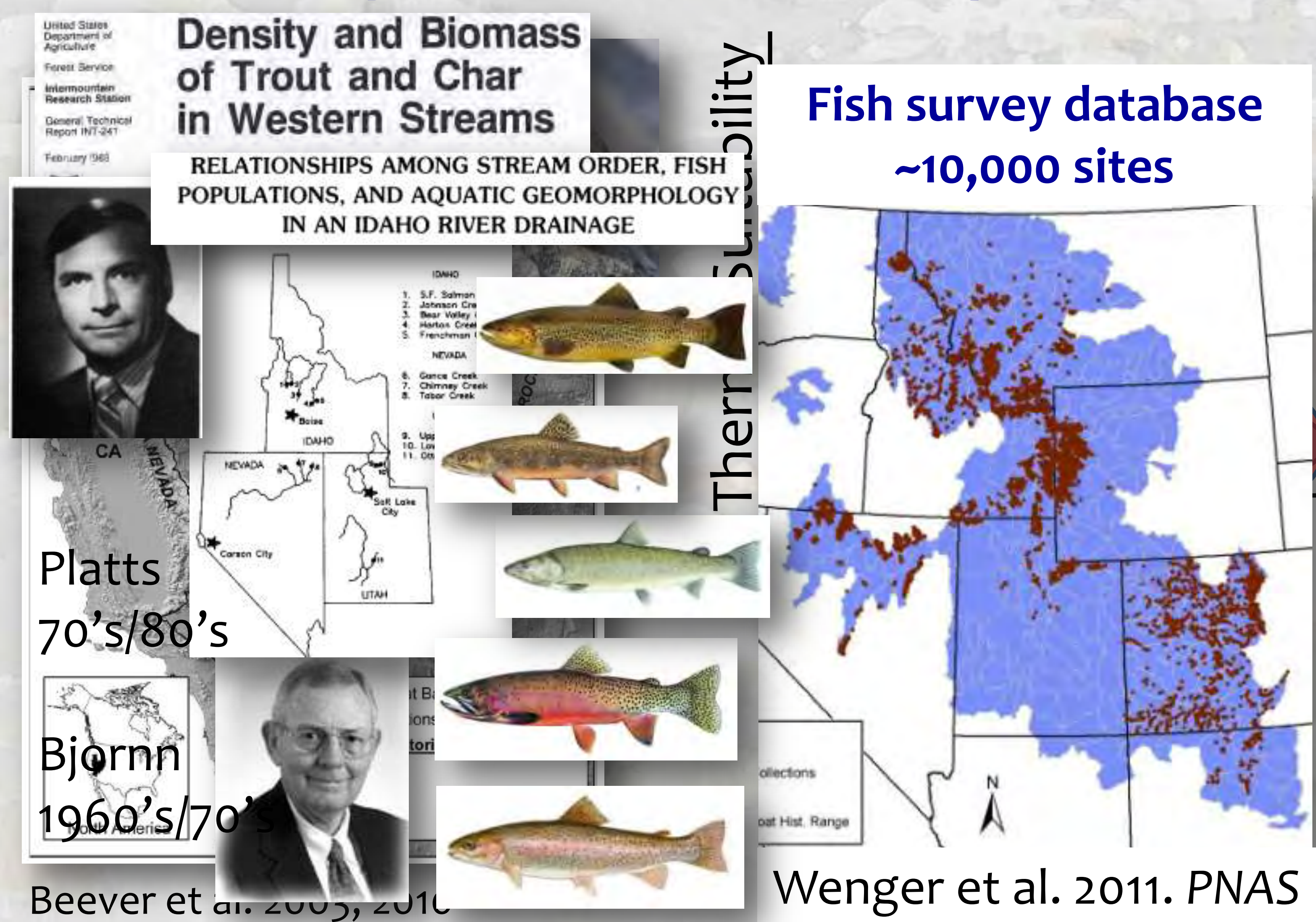
t_1 t_2

1 → 0

Site occupancy

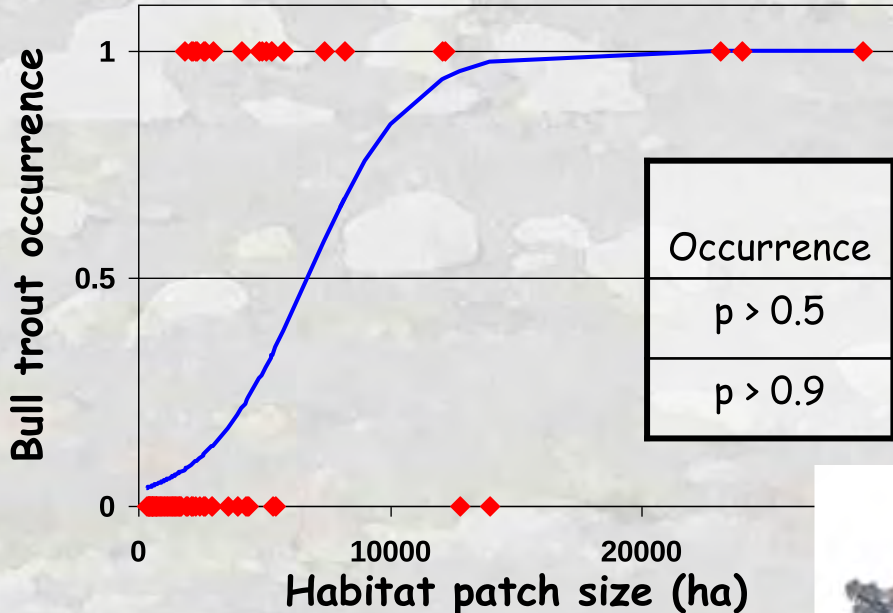
Broad Distributional Resurveys

Assess site extirpation/colonization frequencies relative to temperature



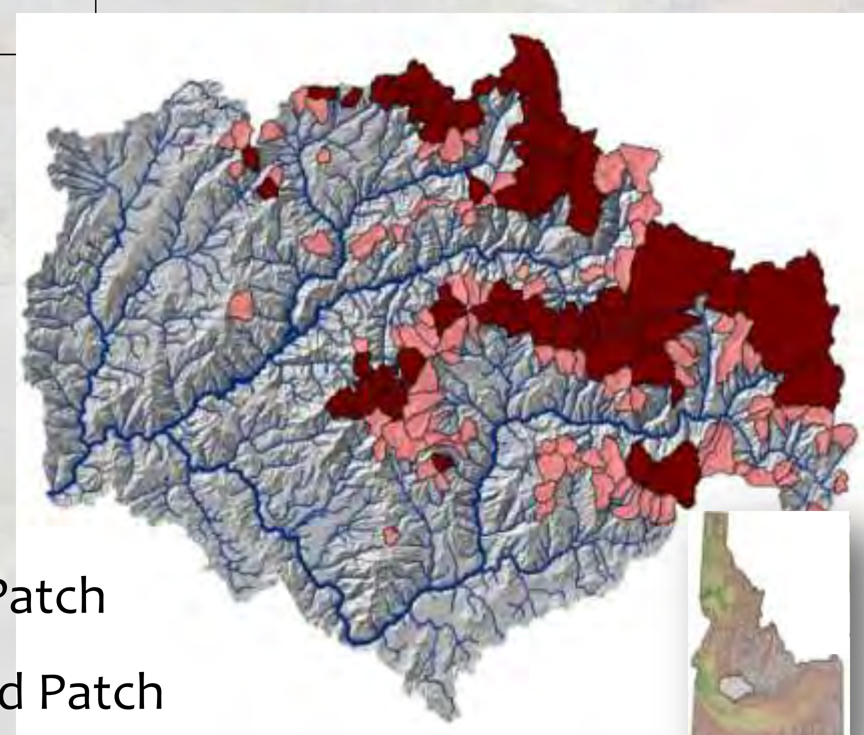
Significant Unknowns:

How Much Habitat is Needed to Persist?



Rieman & McIntyre 1995
Isaak et al. 2010

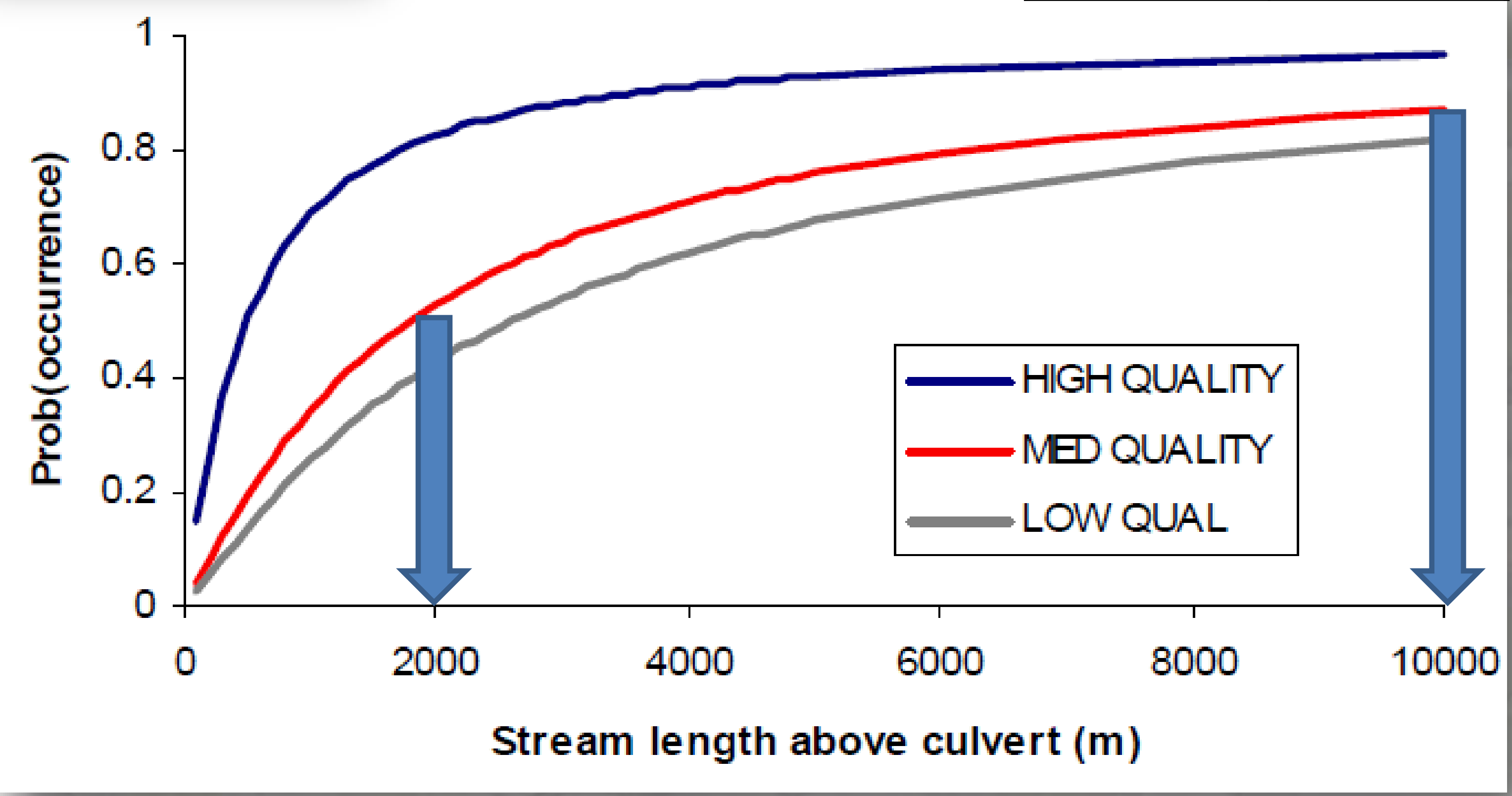
Occurrence	Watershed area (ha)	Stream length (km)
p > 0.5	~3,000	~13
p > 0.9	~10,000	~40



How Much Habitat is Needed to Persist?

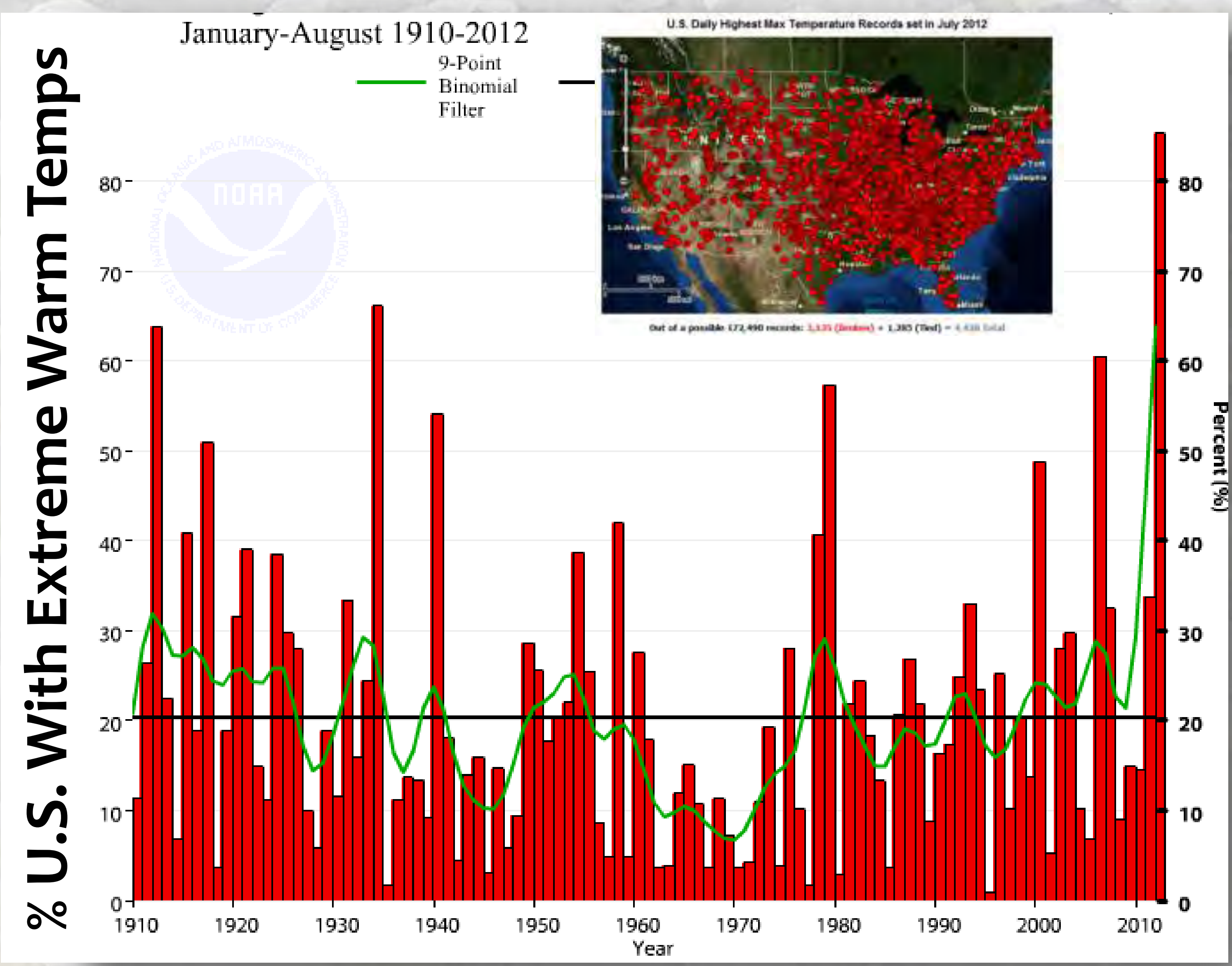
Westslope cutthroat trout

Occurrence	Stream length (km)
p > 0.5	~2
p > 0.9	~10



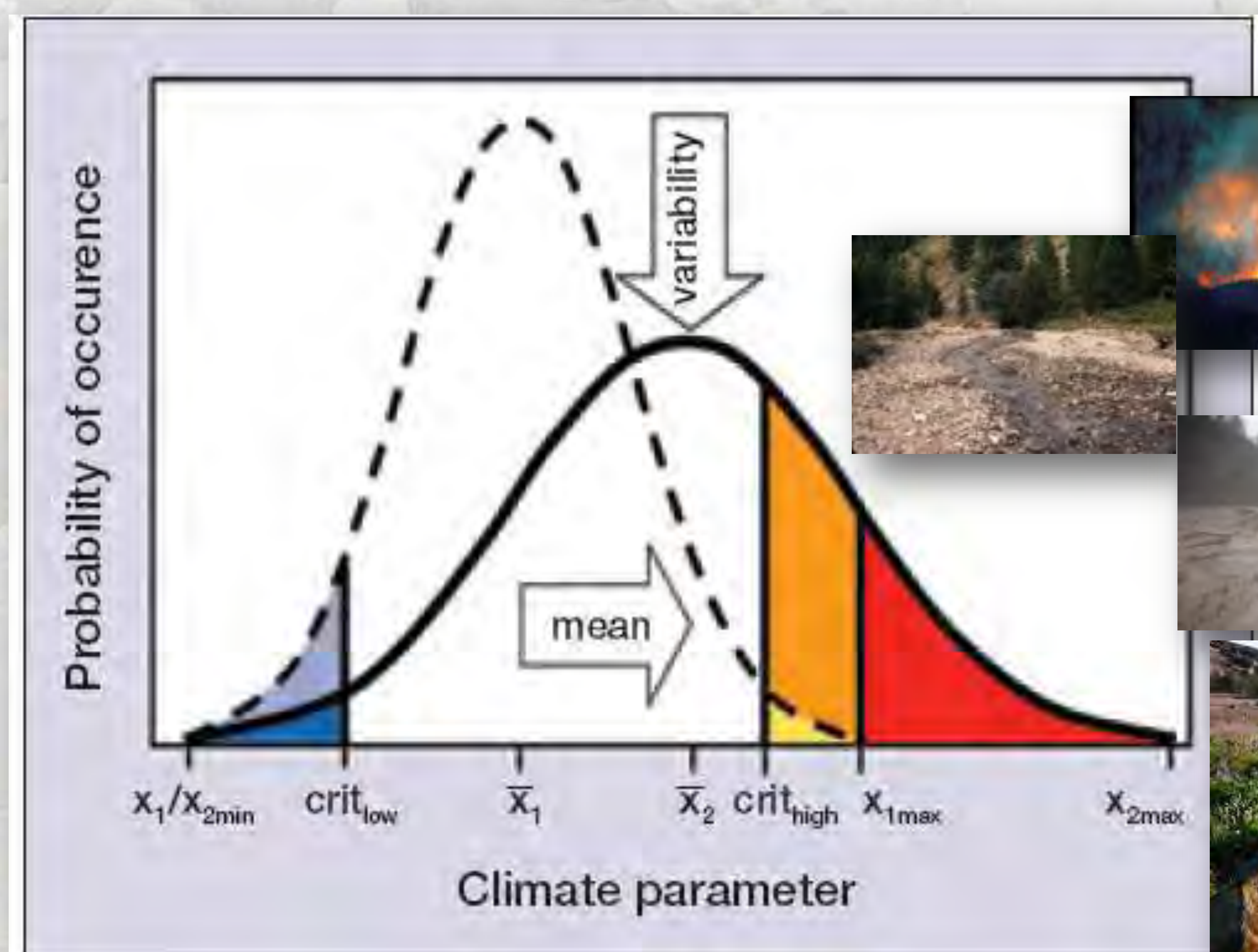
Peterson et al., In Preparation

Extremes May Become More Extreme…



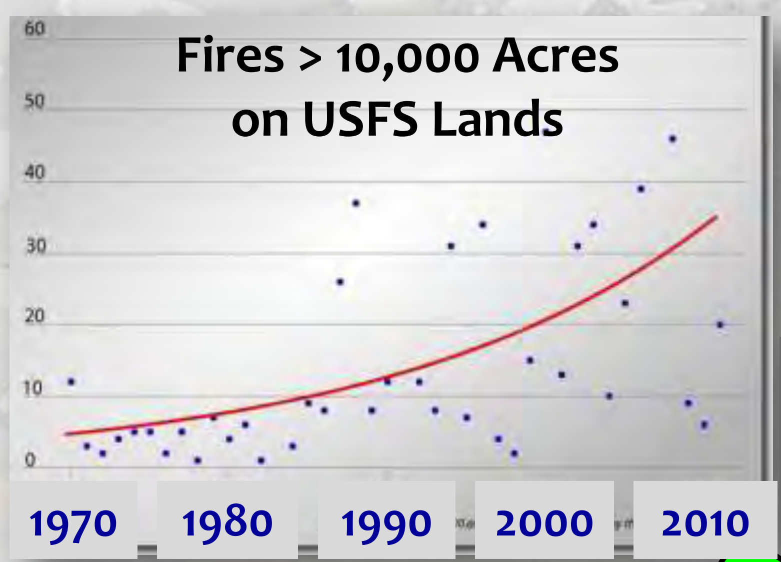
http://www.ncdc.noaa.gov/extremes/cei/graph/1c/ytd

Number of Climatic "Events" May Increase Dramatically

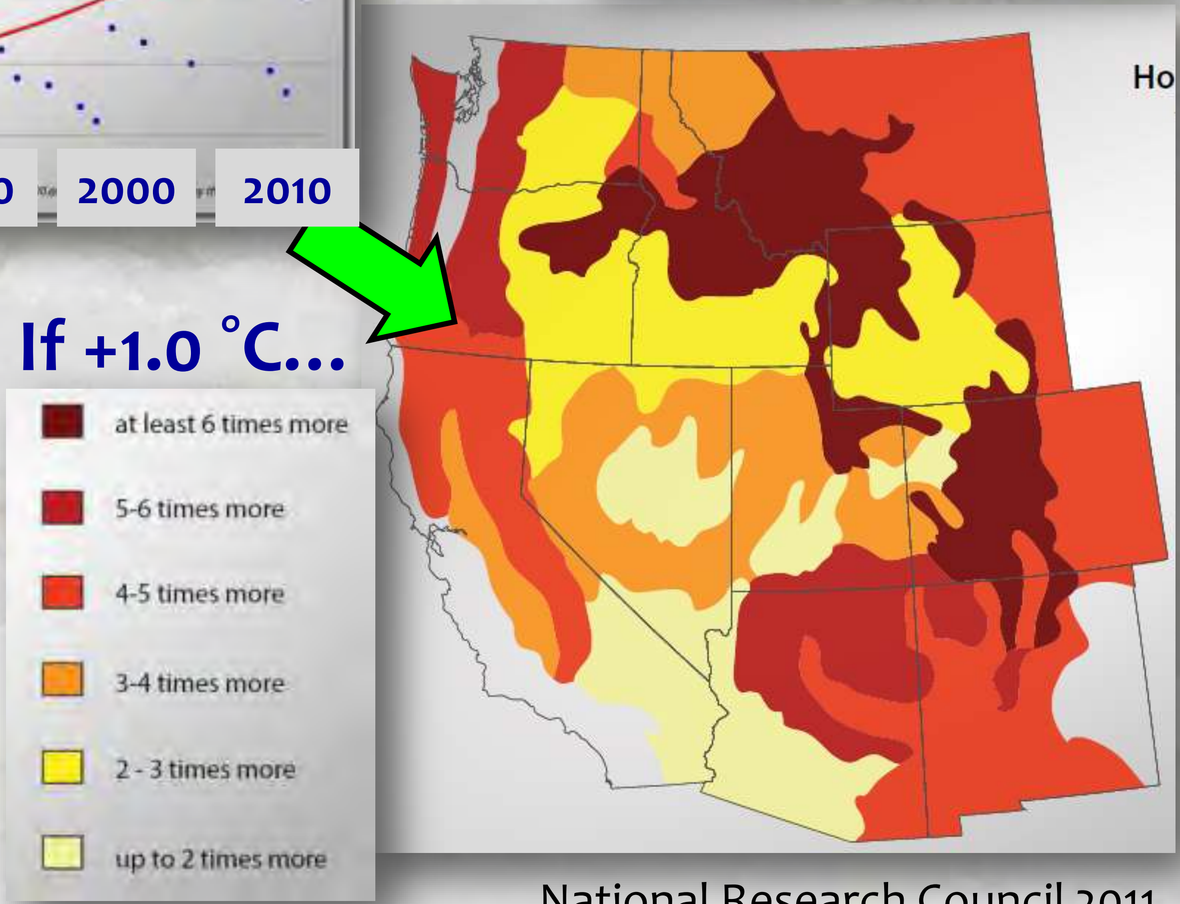


Jentsch et al. 2007

More & Bigger Wildfires



If +1.0 °C...



National Research Council 2011

Can "Bombproof" Habitats Be Developed?

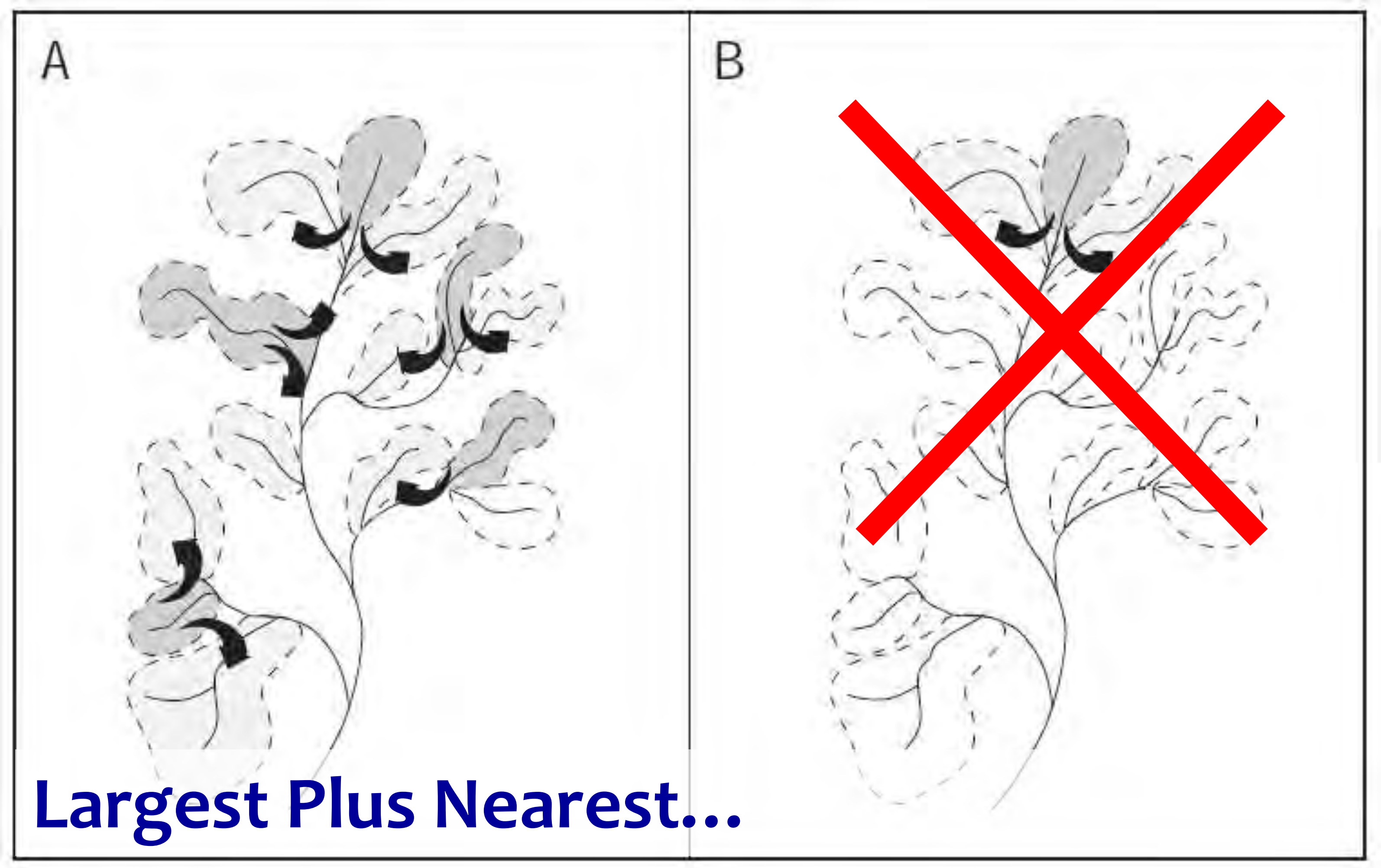
Feature:
FISHERIES MANAGEMENT

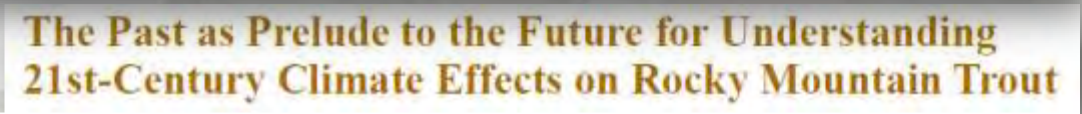
Native Fish Conservation Areas: A Vision for Large-Scale Conservation of Native Fish Communities

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

Fisheries • VOL 36 NO 6 • JUNE 2011 • WWW.FISHERIES.ORG

Can "Bombproof" Habitats Be Developed?

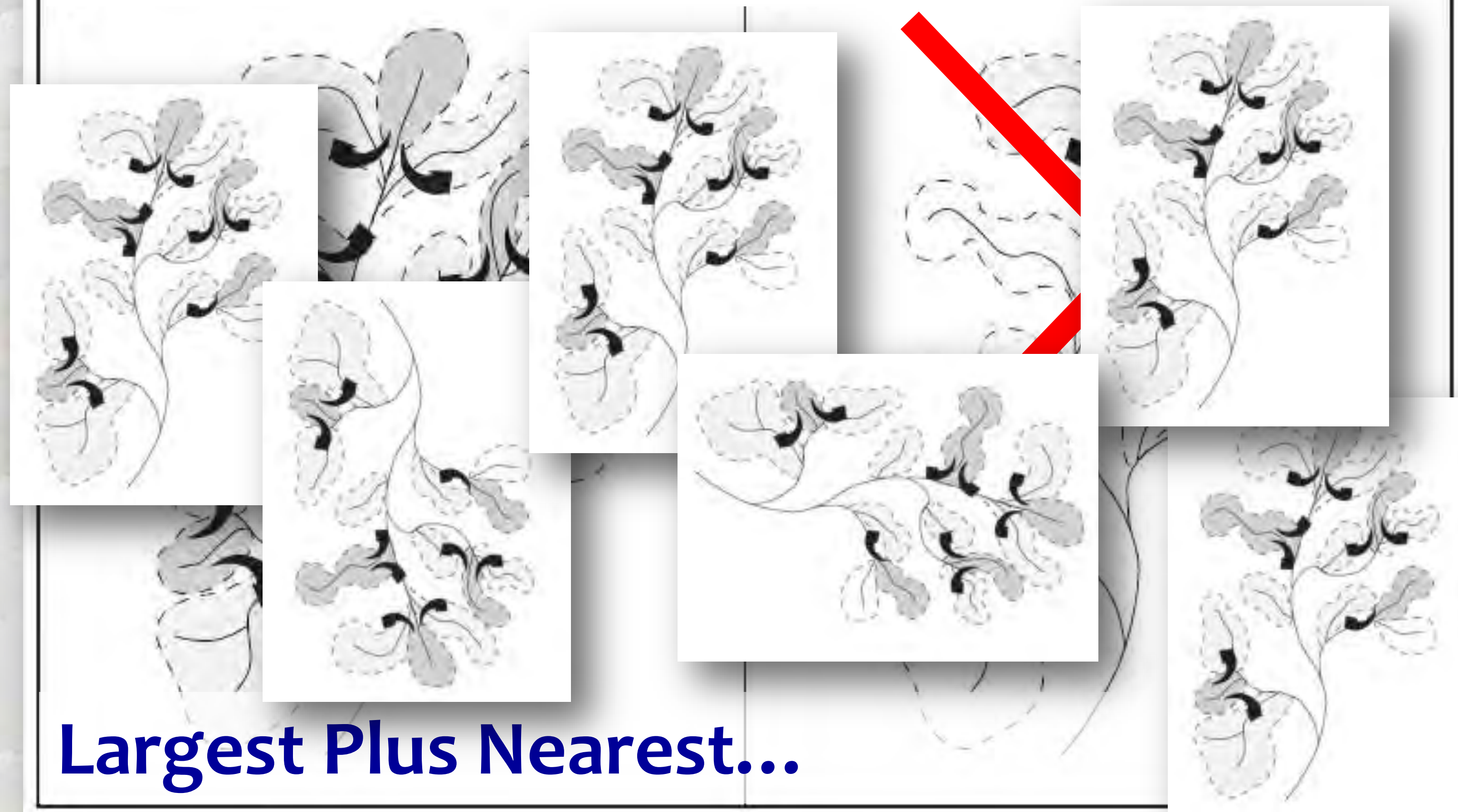




Isaak, … Roberts, … Fausch. 2012. *Fisheries* **37**: 542-556.

Can “Bombproof” Habitats Be Developed?

& Replicate Across As Many Areas as Possible



Largest Plus Nearest…

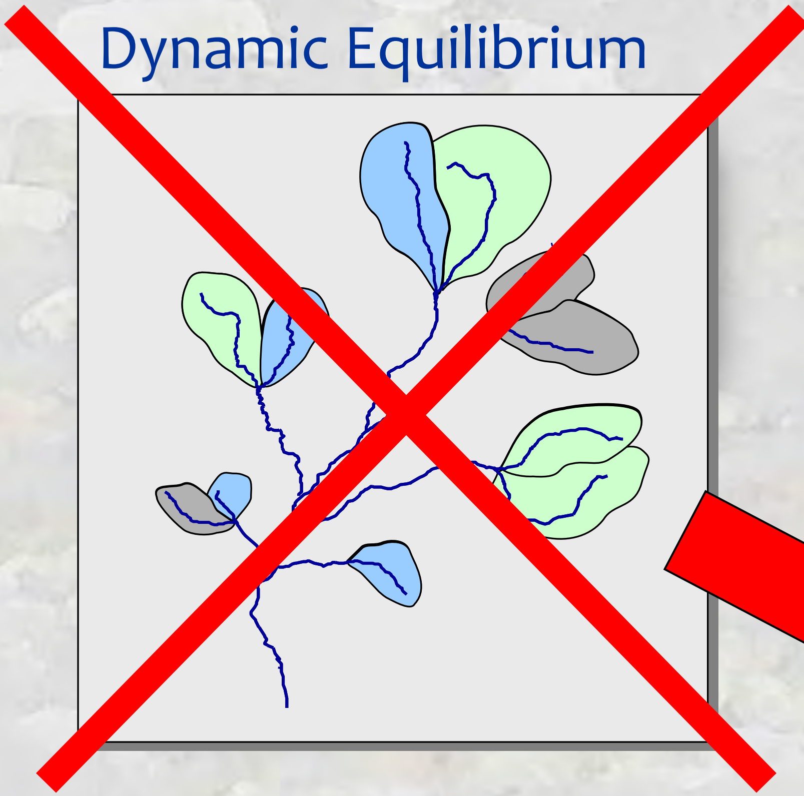
The Past as Prelude to the Future for Understanding 21st-Century Climate Effects on Rocky Mountain Trout

Isaak, … Roberts, … Fausch. 2012. *Fisheries* **37**: 542-556.

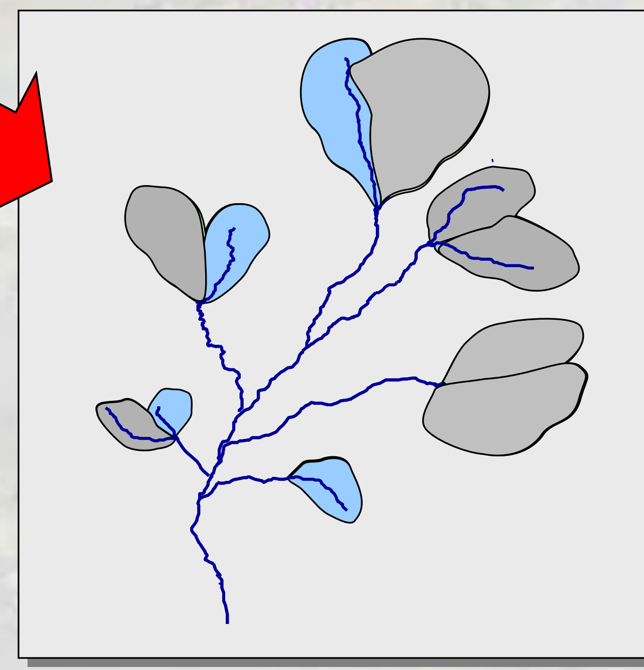
Significant Unknowns:

Can We Adjust Our Mindsets to the New Paradigm?

Dynamic Equilibrium



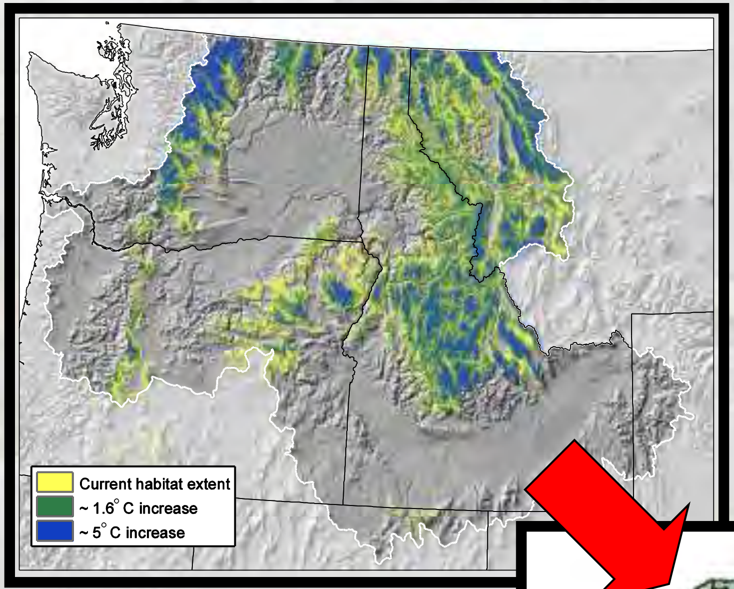
Dynamic Dis-Equilibrium



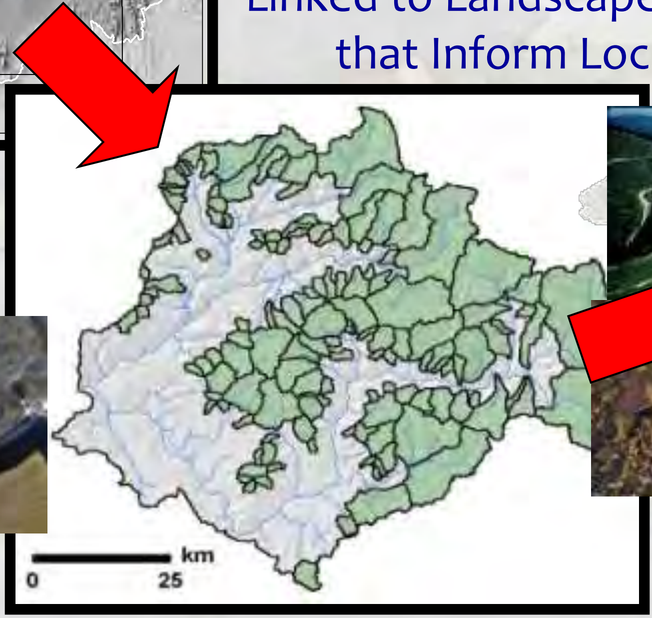
Focus Efforts Where We Make a Difference

Do the Smartest Things in the Smartest Places

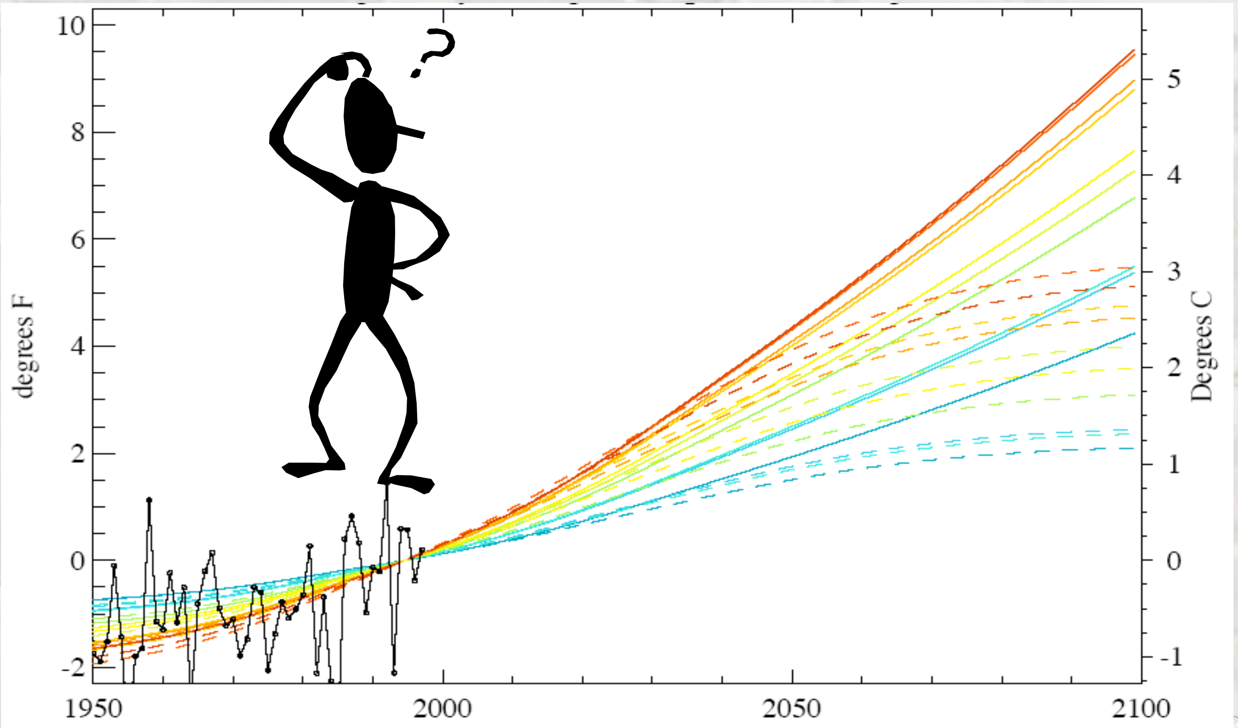
Regional Bioclimatic Context



Linked to Landscape Level Models
that Inform Local Actions

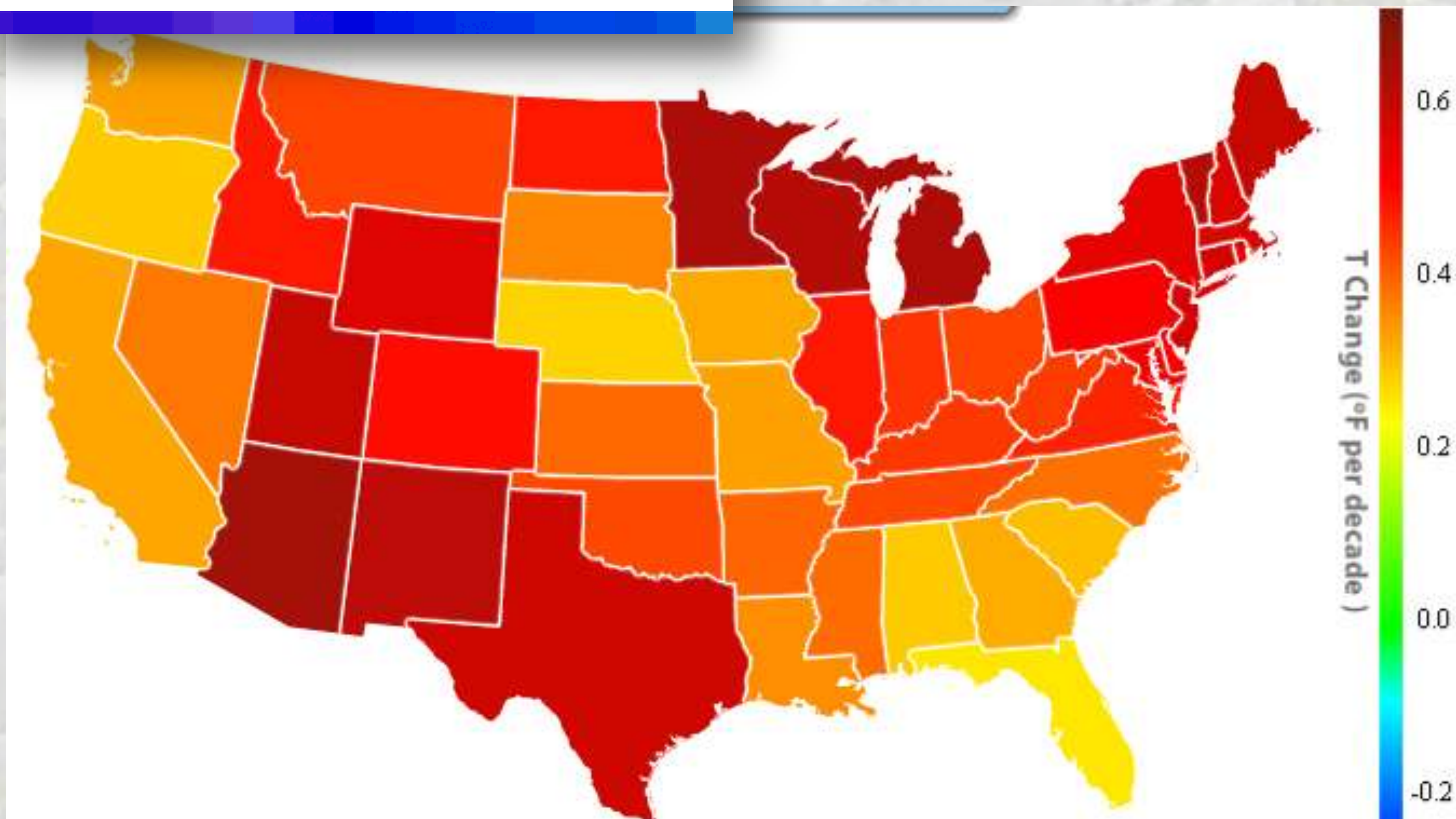


The Sooner We Act,
The Bigger The Impact



Air Temperature Warming Rates in US (1970 – 2011)…

CLIMATE CENTRAL

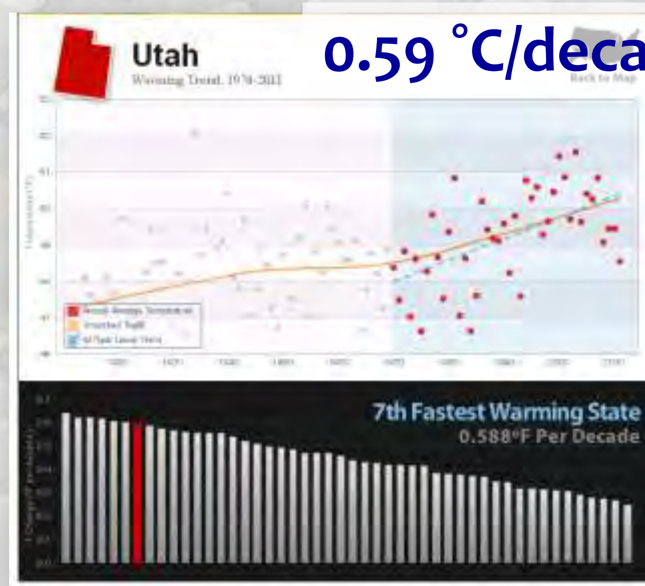


http://www.climatecentral.org/news/the-heat-is-on/

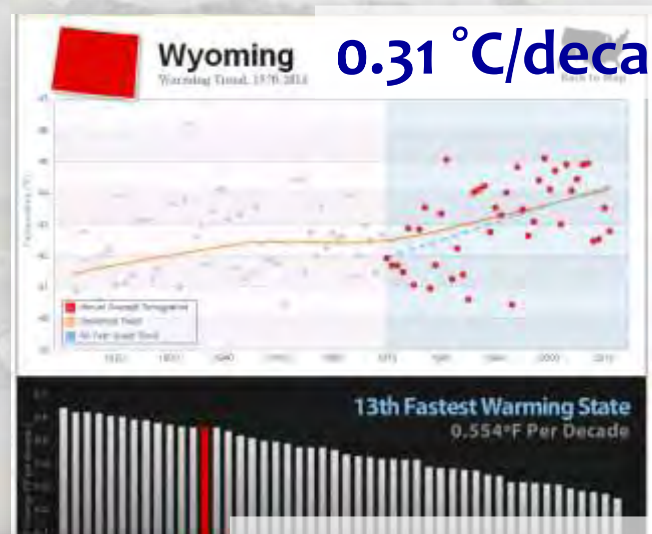
“Heat is on report” Tebaldi 2012

Air Temperature Warming Rates in CO/WY/UT (1970 – 2011)…

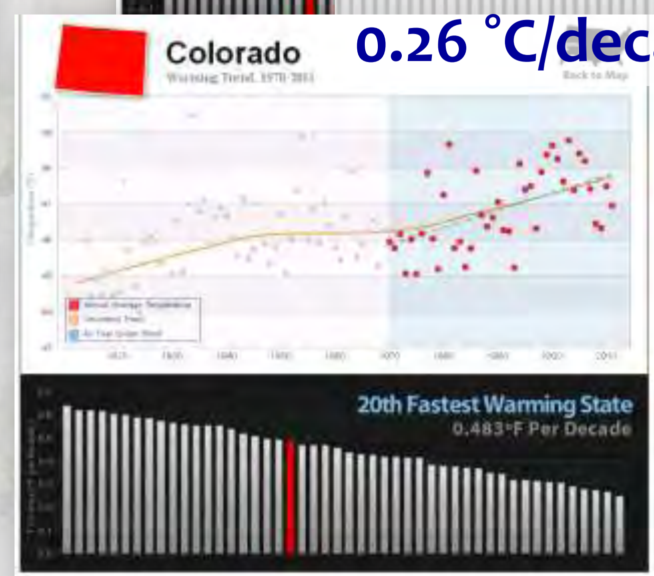
0.59 °C/decade



0.31 °C/decade



0.26 °C/decade

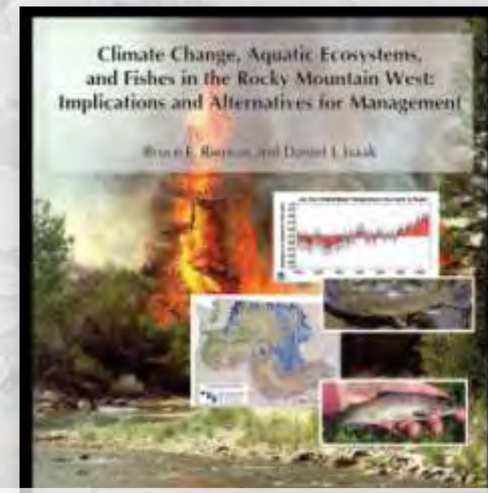


Relevant Publications…

FEATURE
Socio-economics

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

Isaak, … Roberts, … Fausch. 2012. *Fisheries* **37**: 542-556.



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?***

Rieman & Isaak 2010. USFS Report.

Predicting isotherm shifts in streams…

Global Change Biology

Global Change Biology (2012), doi: 10.1111/gcb.12073

Stream isotherm shifts from climate change and implications for distributions of ectothermic organisms

DANIEL J. ISAAK* AND BRUCE E. RIEMAN†

**U.S. Forest Service, Rocky Mountain Research Station, Boise Aquatic Sciences Laboratory, 322 E. Front St., Suite 401, Boise, Idaho †U.S. Forest Service, Rocky Mountain Research Station (retired), P.O. Box 1541, Seeley Lake, MT*

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

Stream Temperature Publications…

Stream Temperature Modeling Approach…

Ecological Applications, 20(5), 2010, pp. 1350–1371
© 2010 by the Ecological Society of America

Effects of climate change and wildfire on stream temperatures and salmonid thermal habitat in a mountain river network

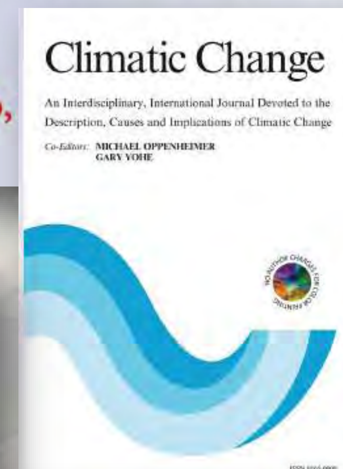
Daniel J. Isaak,[1,3] Charles H. Luce,[1] Bruce E. Rieman,[1] David E. Nagel,[1] Erin E. Peterson,[2] Dona L. Horan,[1] Sharon Parkes,[1] and Gwynne L. Chandler[1]

[1]*U.S. Forest Service, Rocky Mountain Research Station, Boise Aquatic Sciences Laboratory, 322 E. Front Street, Suite 401, Boise, Idaho 83702 USA*
[2]*Commonwealth Scientific and Industrial Research Organisation (CSIRO), Division of Mathematical and Information Sciences, Indooroopilly, Queensland, Australia*

Regional Stream Temperature Trends…

Climate change effects on stream and river temperatures across the northwest U.S. from 1980–2009 and implications for salmonid fishes

D. J. Isaak, S. Wollrab, G. Chandler



Epoxy field test and validation work …

An Evaluation of Underwater Epoxies to Permanently Install Temperature Sensors in Mountain Streams

Daniel J. Isaak* and Dona L. Horan
U.S. Forest Service, Rocky Mountain Research Station, B
322 East Front Street, Suite 401, Boise, Idaho 83702, US

RMRS — Air, Water, and Aquatic Environments Science Program

A Simple Method Using Underwater Epoxy to Permanently Install Temperature Sensors in Mountain Streams

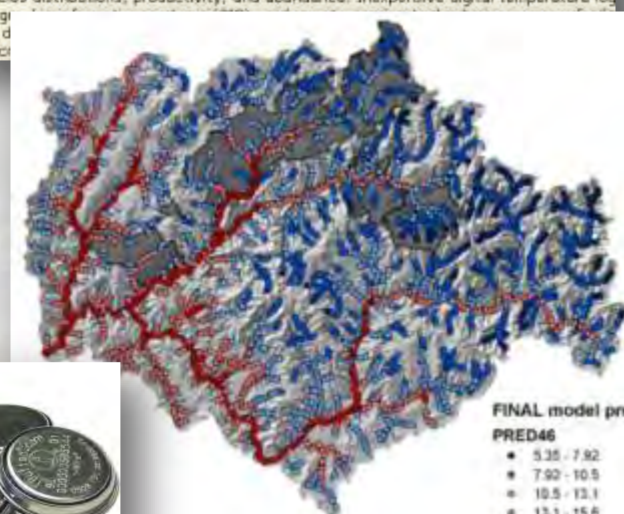
(Version 3.12; updated 2/02/2012)

Dan Isaak (disaak@fs.fed.us), Dona Horan (dhoran@fs.fed.us), and Sherry Wollrab (sherrywollrab@fs.fed.us)

Epoxy "How-to" protocol…

Stream Temperature Website

Google " Forest Service Stream Temperature"



- Stream temperature publications & project descriptions & recent talks
- Protocols for temperature data collection & demonstration videos
- Processing macro for temperature data
- Dynamic GoogleMap showing current temperature monitoring sites


The End