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

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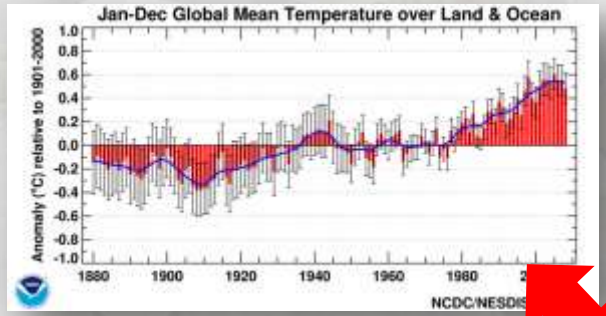
U.S. Forest Service

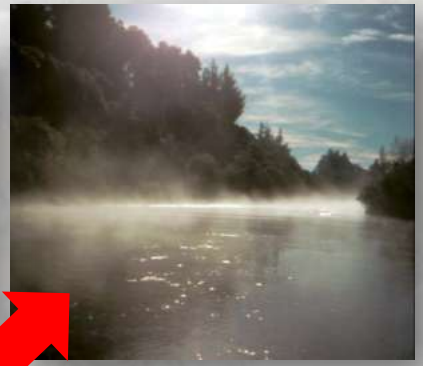
[1]Trout Unlimited

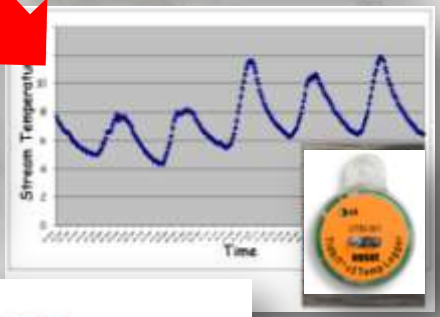
[2]CSIRO

[3]NOAA

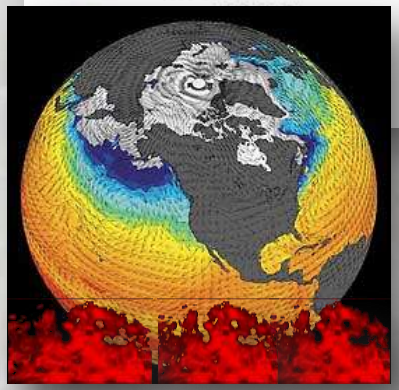
[4]USGS

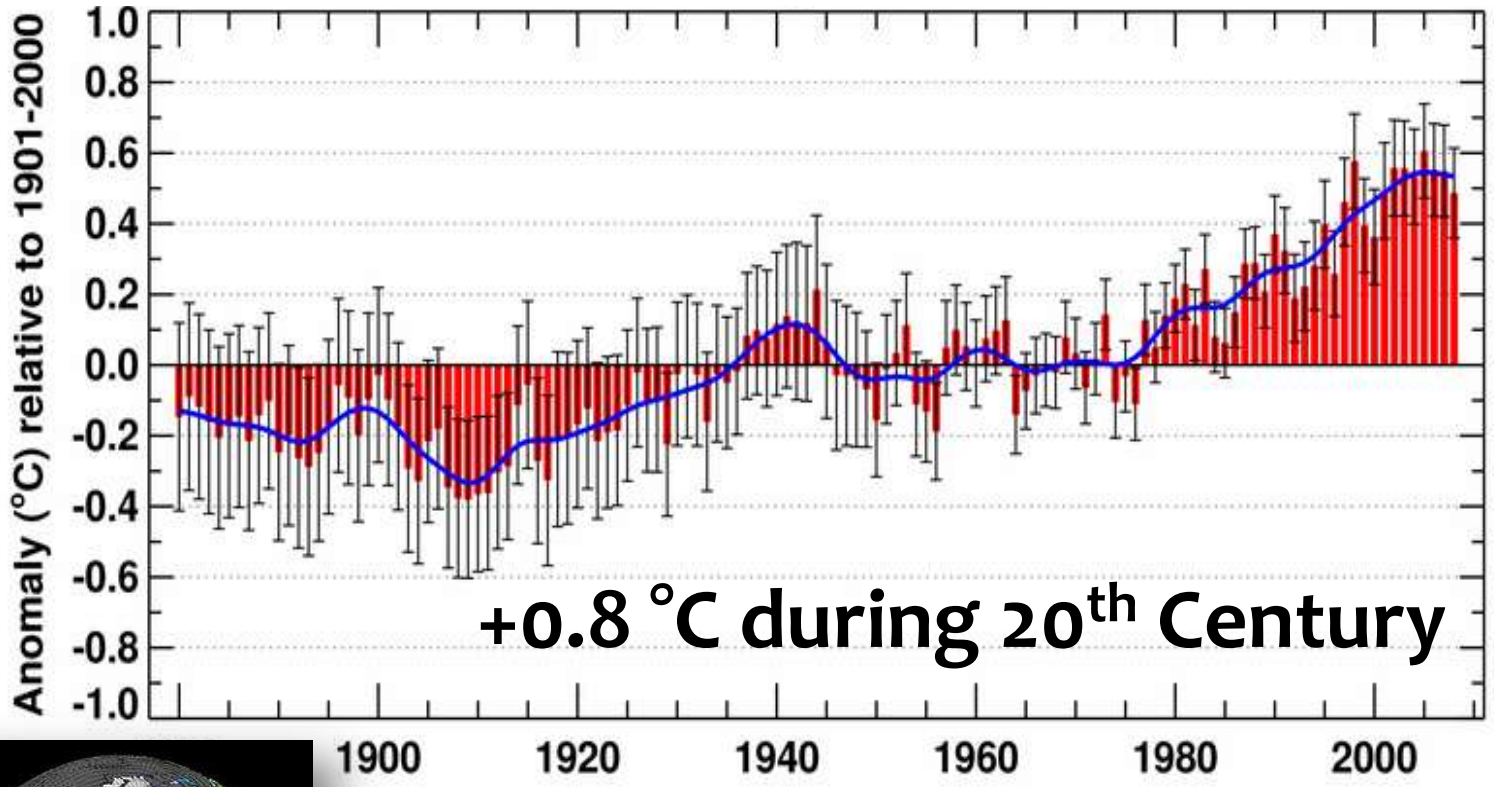






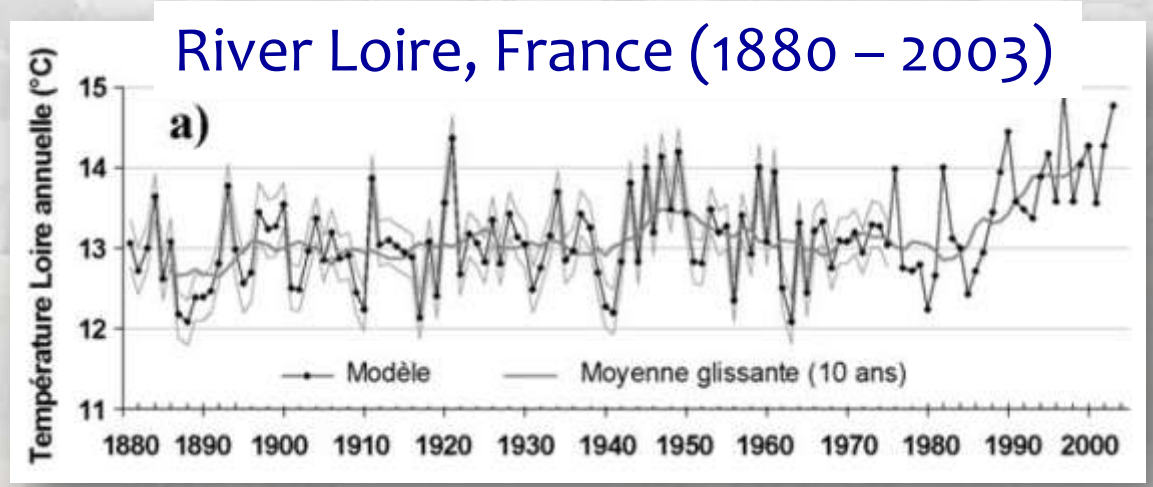
Global Trends in Air Temperatures





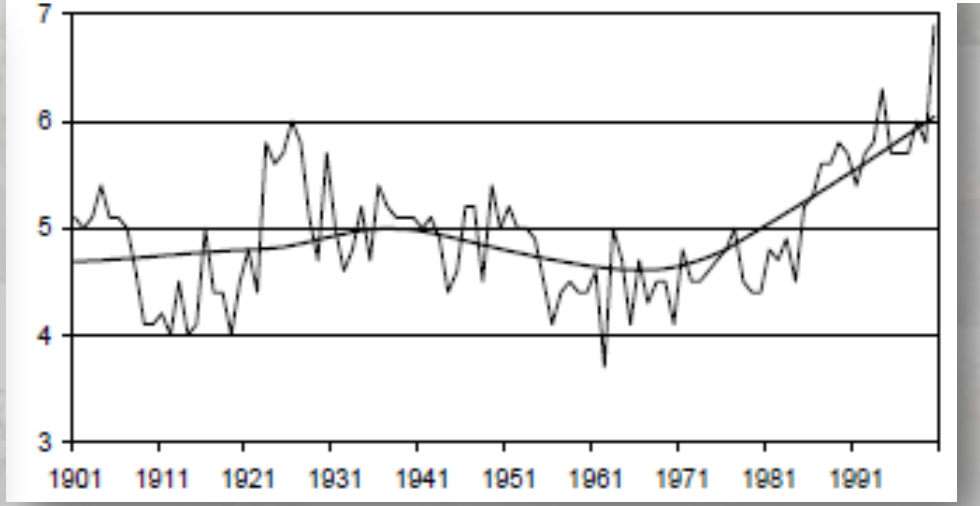
Global Trends in River Temperatures

River Loire, France (1880 – 2003)



Moatar and Gailhard 2006

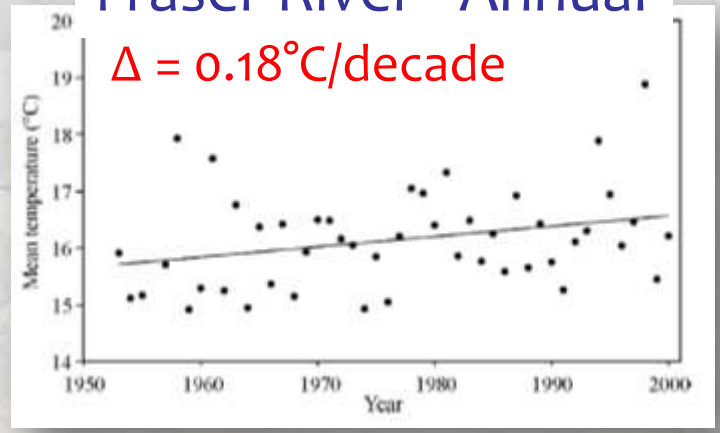
Danube River, Austria (1901 – 2000)



Webb and Nobilus 2007

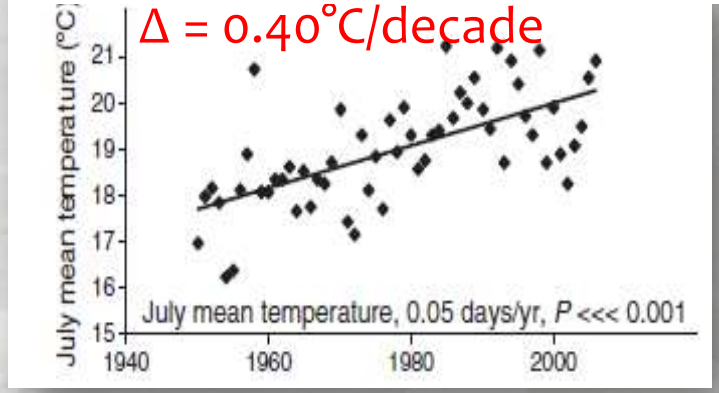
Regional Trends In Northwest Rivers

Fraser River - Annual



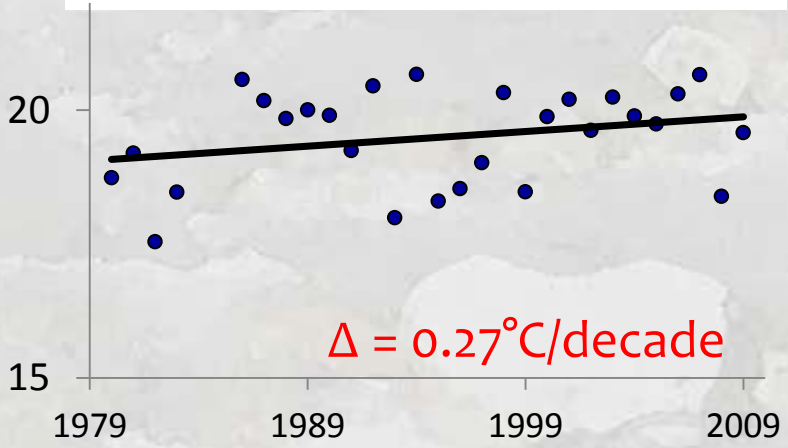
Morrison et al. 2002

Columbia River - Summer

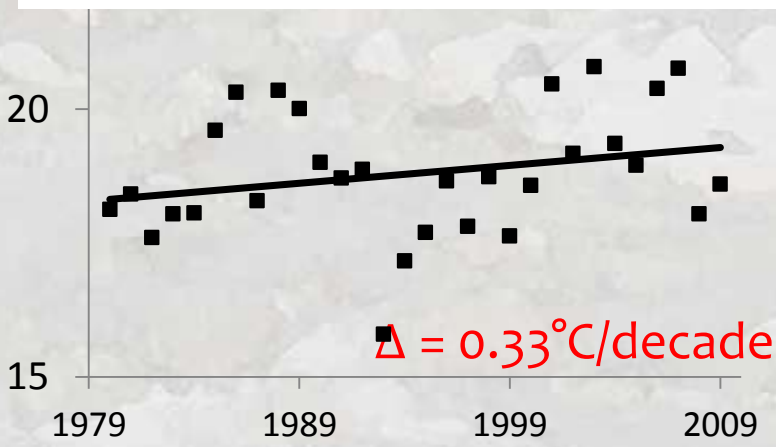


Crozier et al. 2008

Snake River, ID - Summer



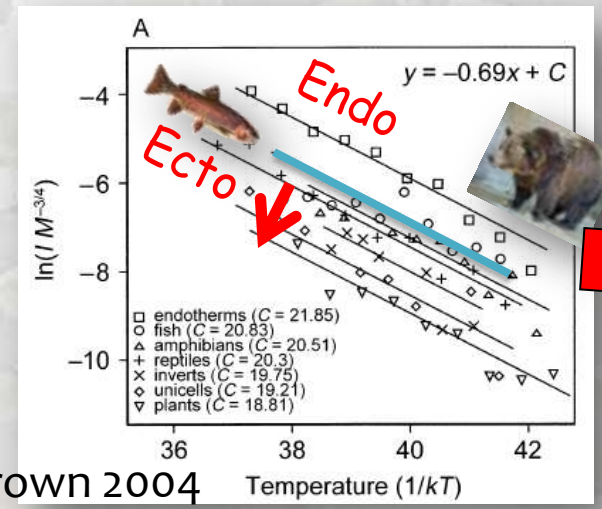
Missouri River, MT - Summer



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

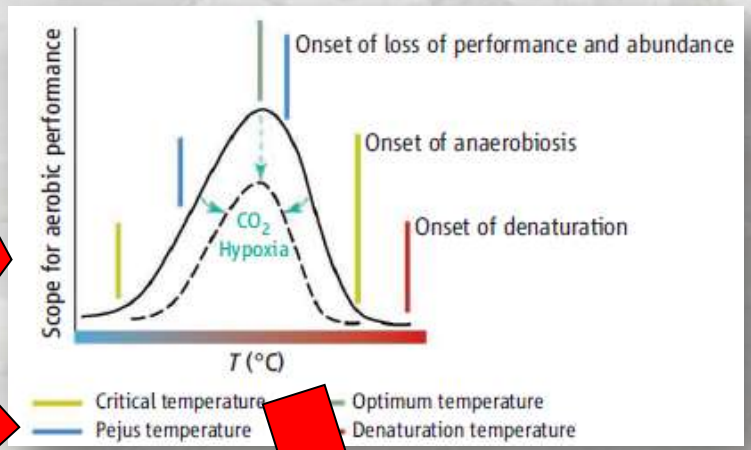
Temperature is Primary Control for Aquatic Ectotherms

Metabolism

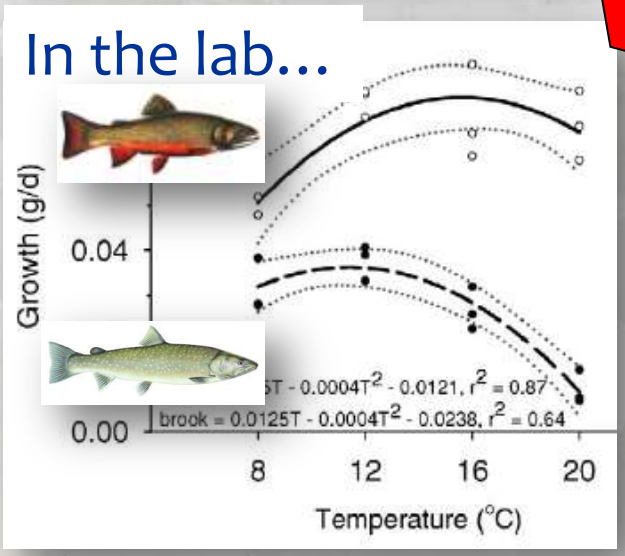


Brown 2004

Thermal Niche

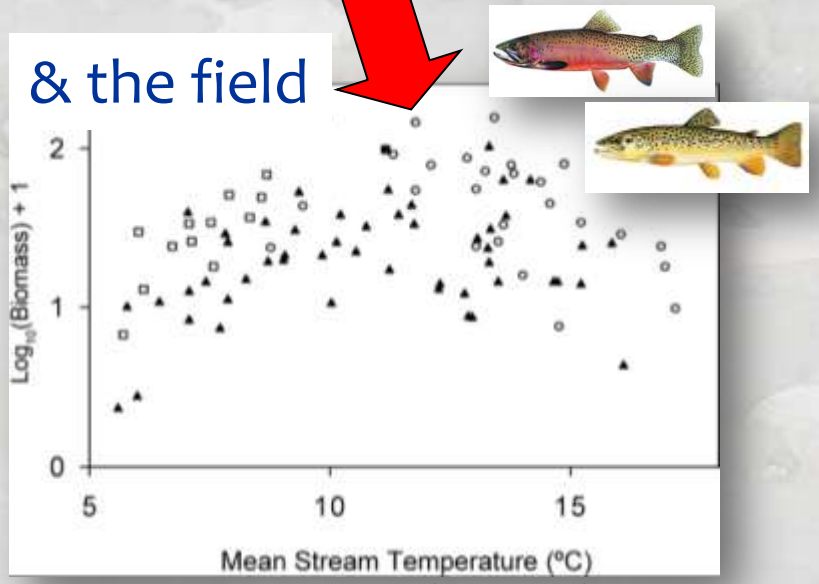


In the lab…



McMahon et al. 2007

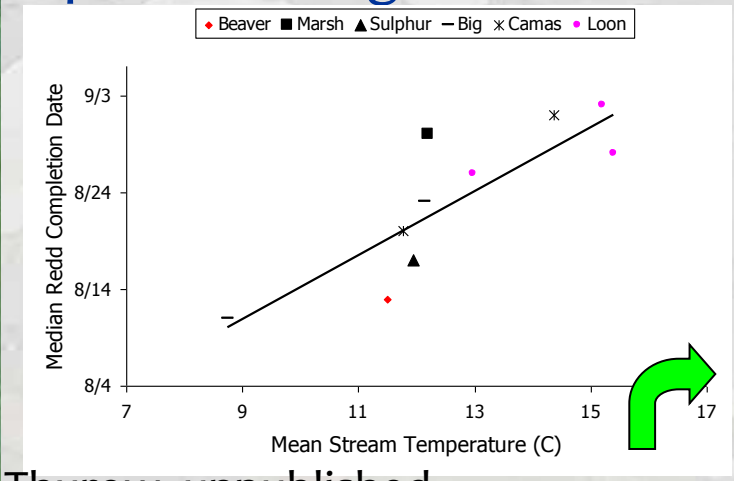
& the field



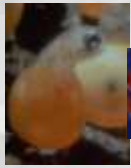
Isaak & Hubert 2004

Temperature Regulation - Life Cycle

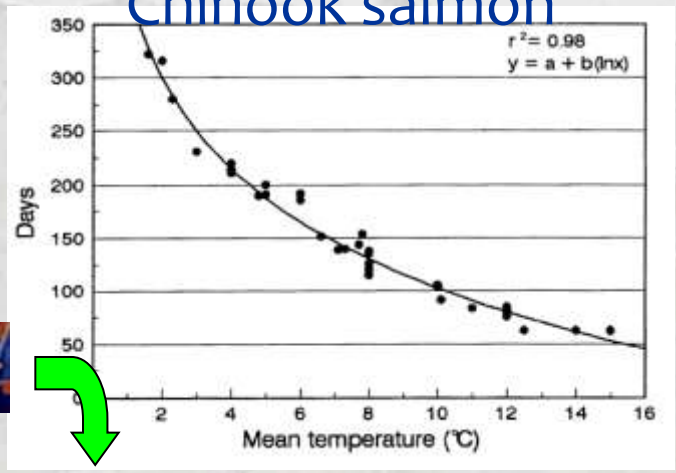
Spawn timing - Chinook salmon



Thurow, unpublished

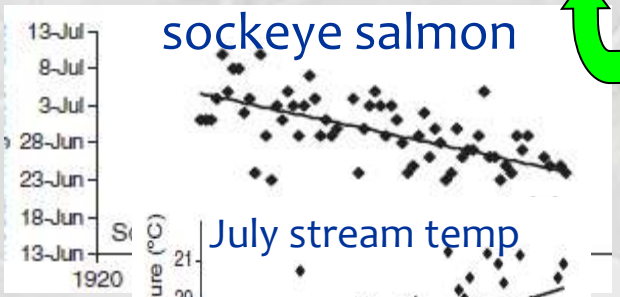


Incubation length - Chinook salmon

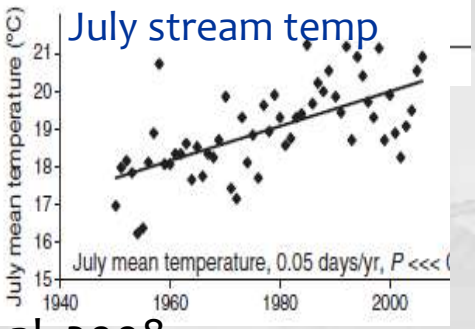


Brannon et al. 2004

Migration timing - sockeye salmon

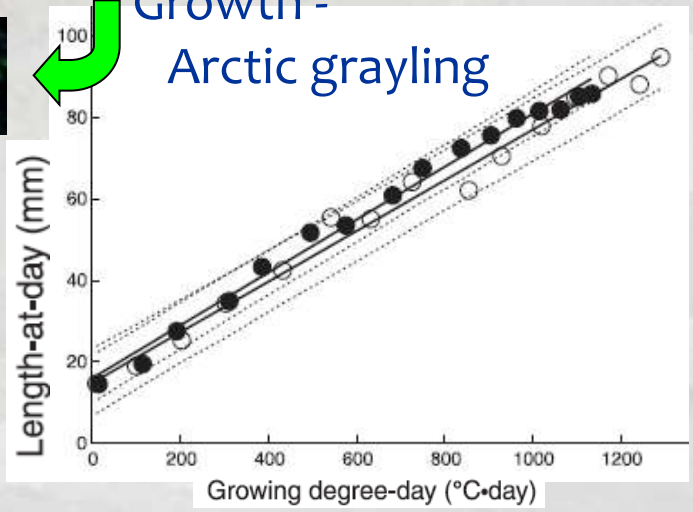


July stream temp



Crozier et al. 2008

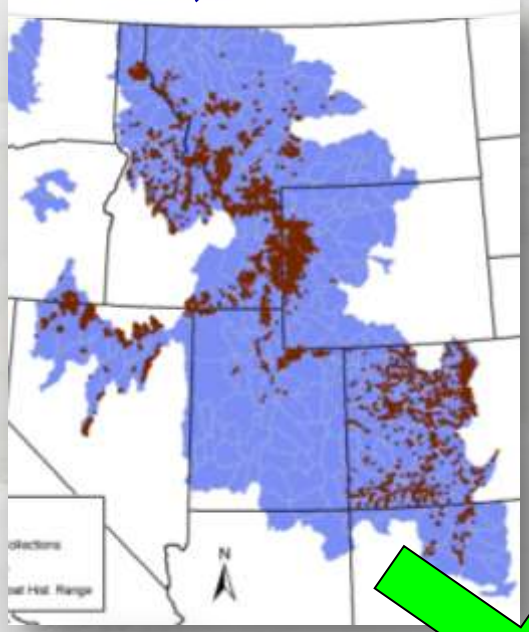
Growth - Arctic grayling



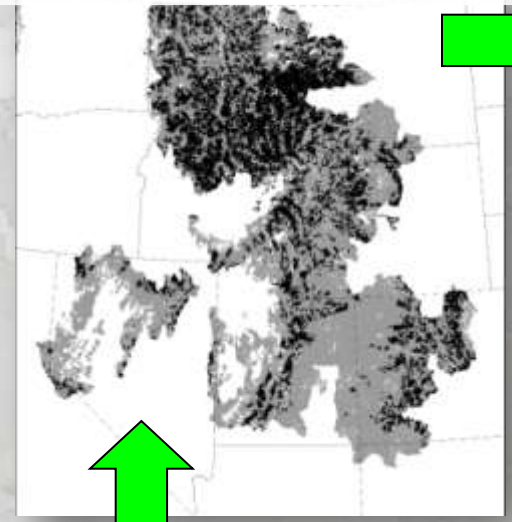
Dion and Hughes 1994

Western Trout Climate Assessment

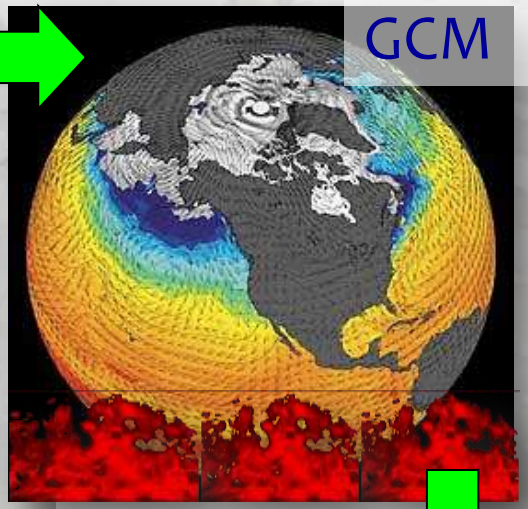
Fish survey database
~10,000 sites



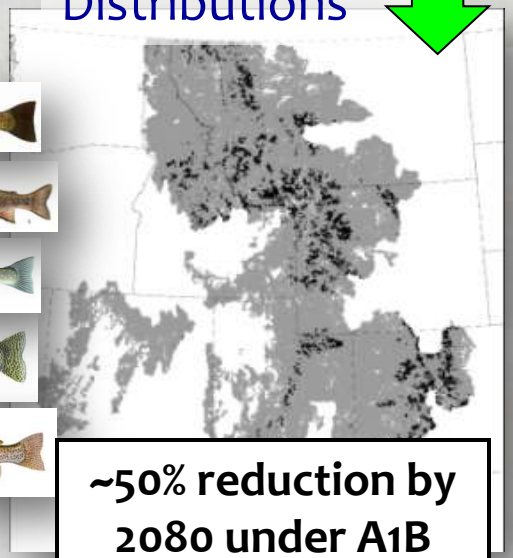
Historic Distributions



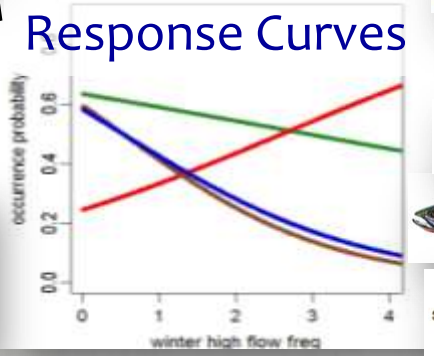
GCM



Future A1B
Distributions



Species-Specific
Habitat
Response Curves

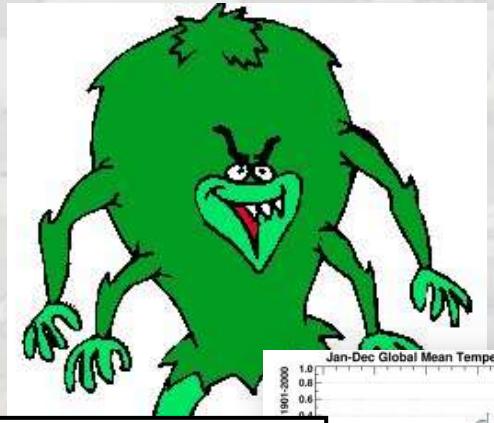


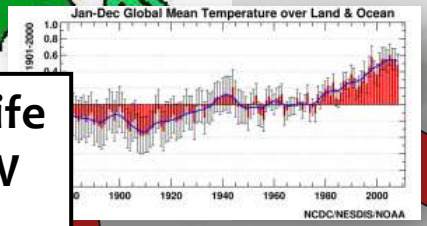
~50% reduction by 2080 under A1B

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

There's A Lot on the Line…

Climate Boogeyman





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

Recreational Fisheries

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

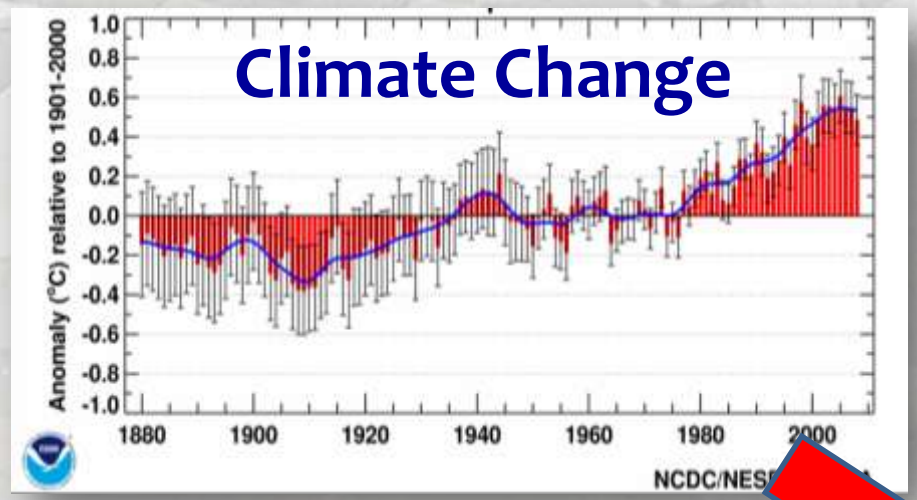
Wednesday, September 29, 2004
Fishing

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

Land Use & Water Development

ESA Listed Species

More Pressure, Fewer Resources



Urbanization & Population Growth

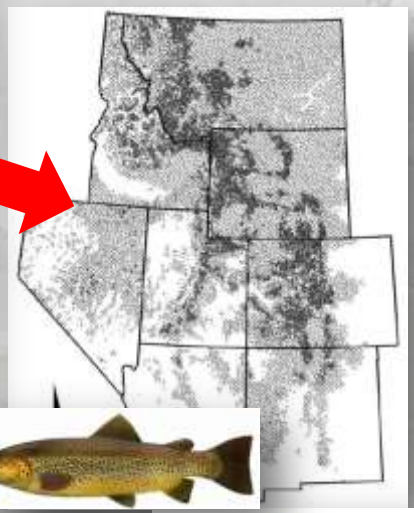
Shrinking Budgets

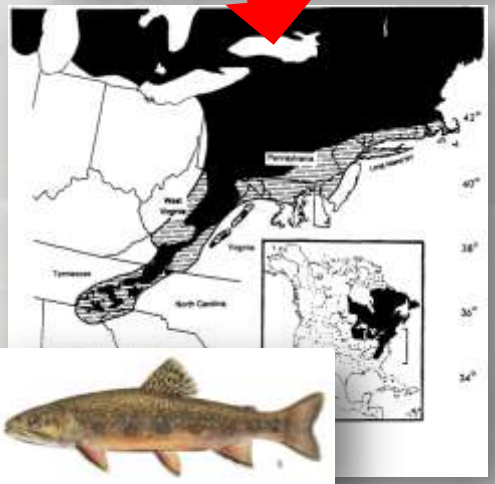
Need to do more with less

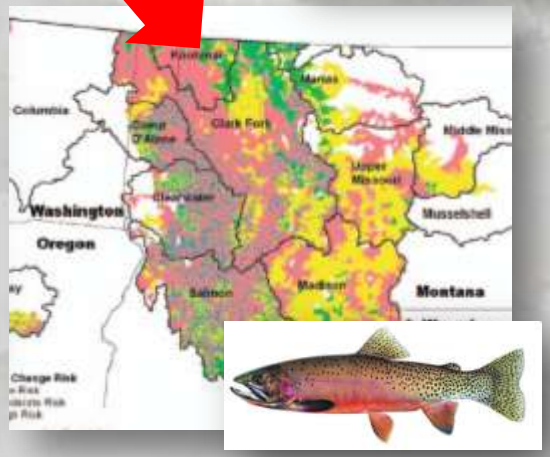
Regional BioClimatic Assessments

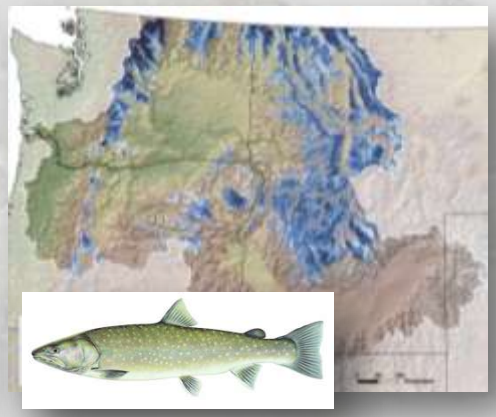
No stream temperature component

PRISM Air Map





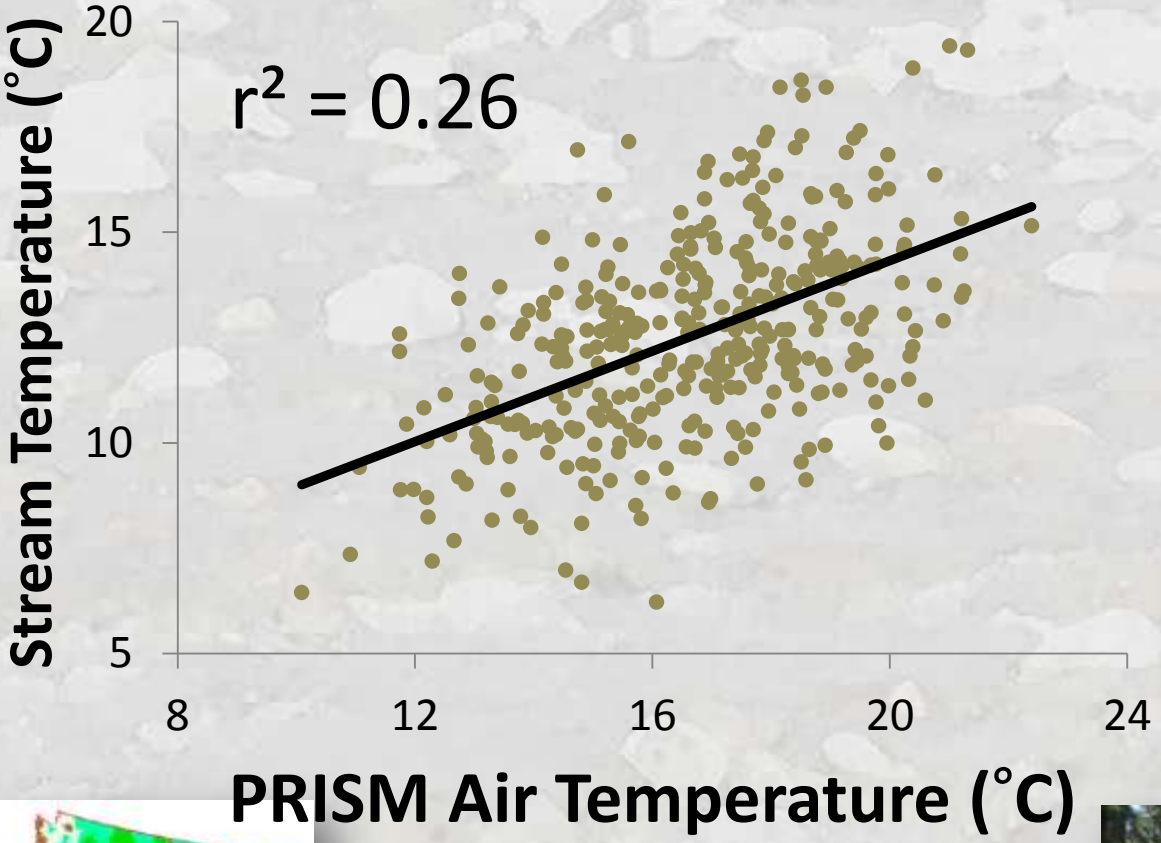


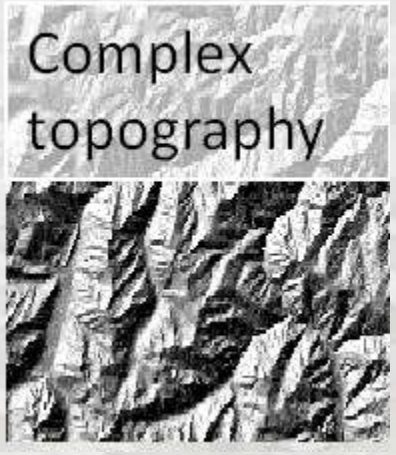


Air Temperatures…

- 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

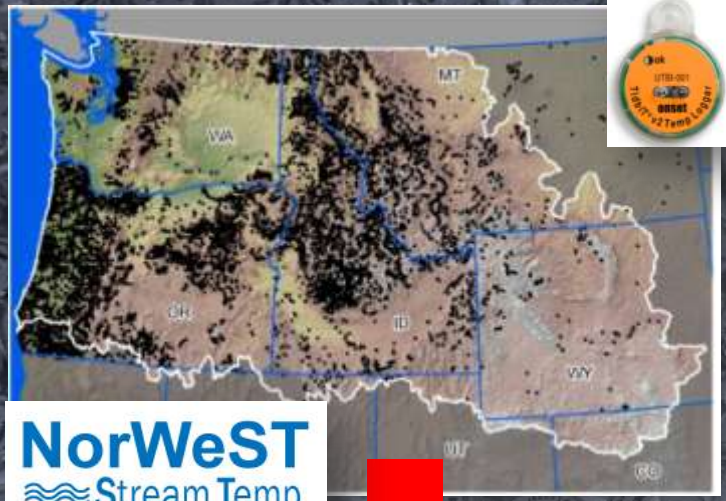
NorWeST Stream Temp

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

Stealth Sensor Network

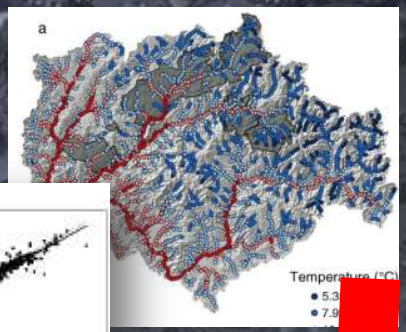
$10,000,000 value
$100,000 project cost

Regional Temperature Model



NorWeST Stream Temp

Accurate temperature models



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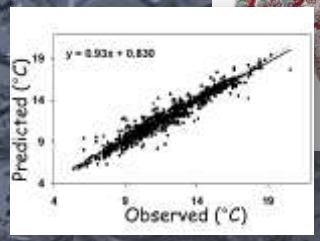
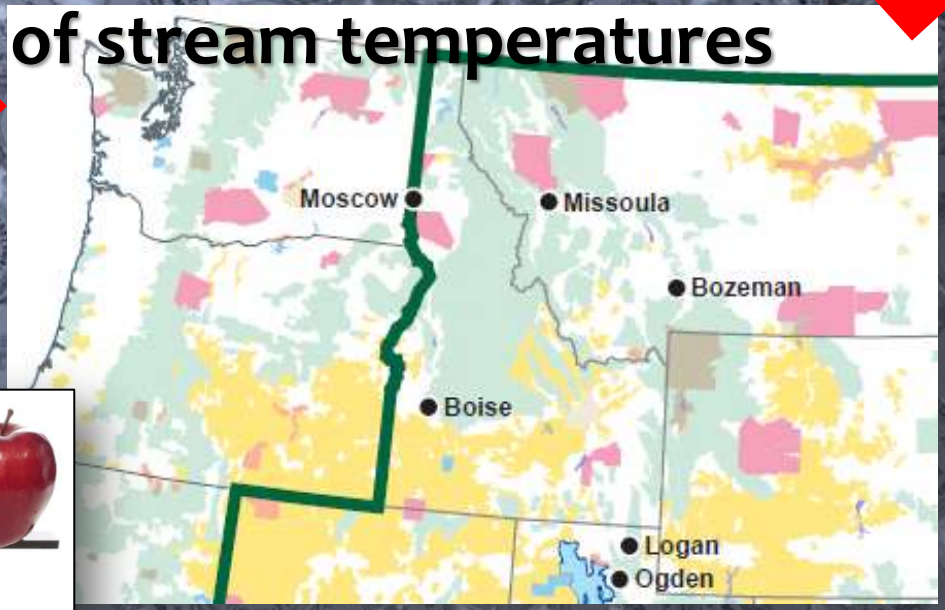
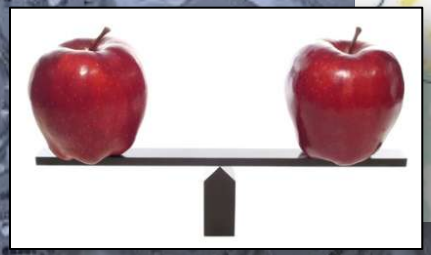


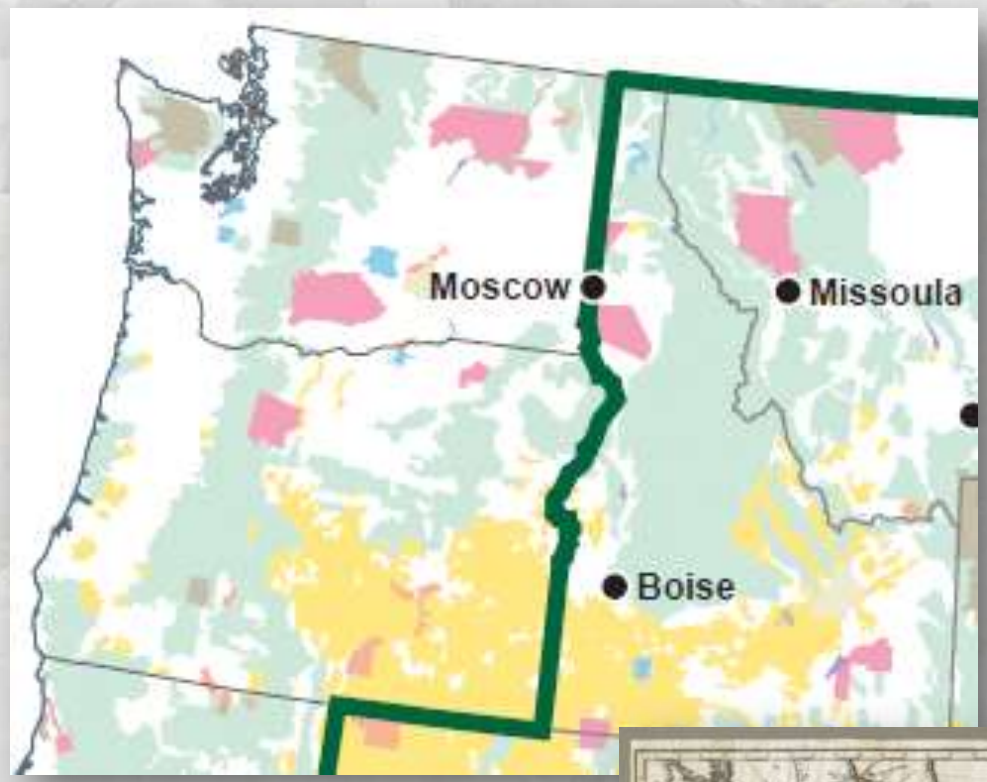
Cross-jurisdictional "maps" of stream temperatures

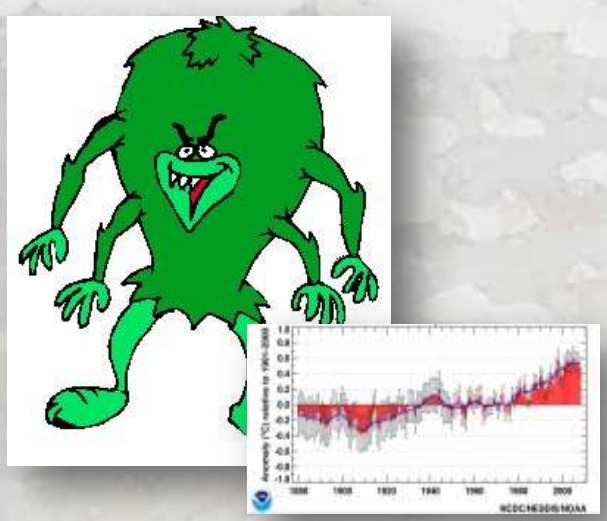


Consistent datum for strategic assessments across 350,000 stream kilometers

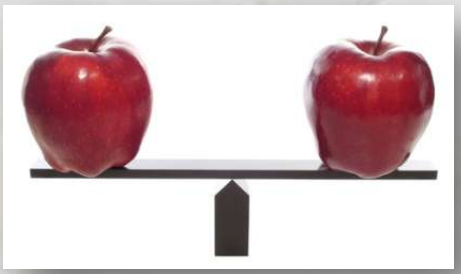


Consistent, Accurate Cross-Jurisdictional Information



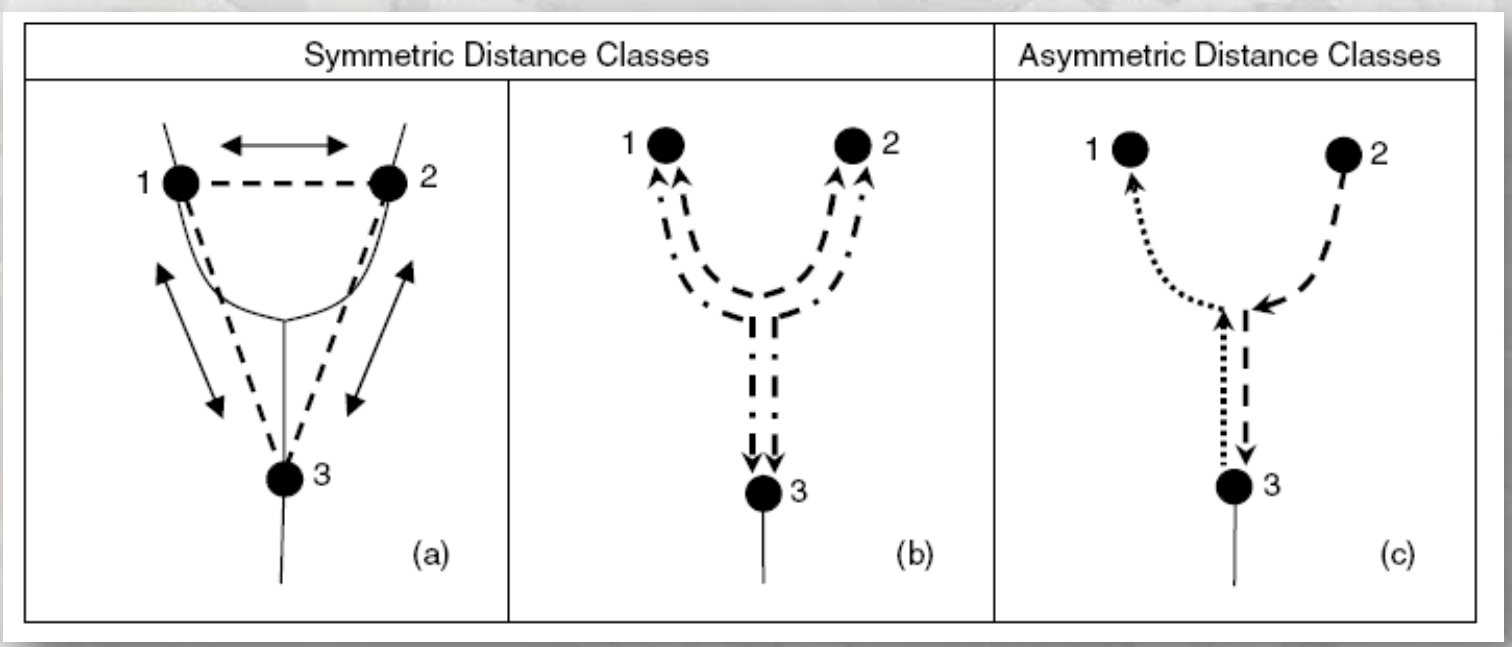


Maps are Powerful Tools



Spatial Statistical Stream Models

Valid means of estimation on networks



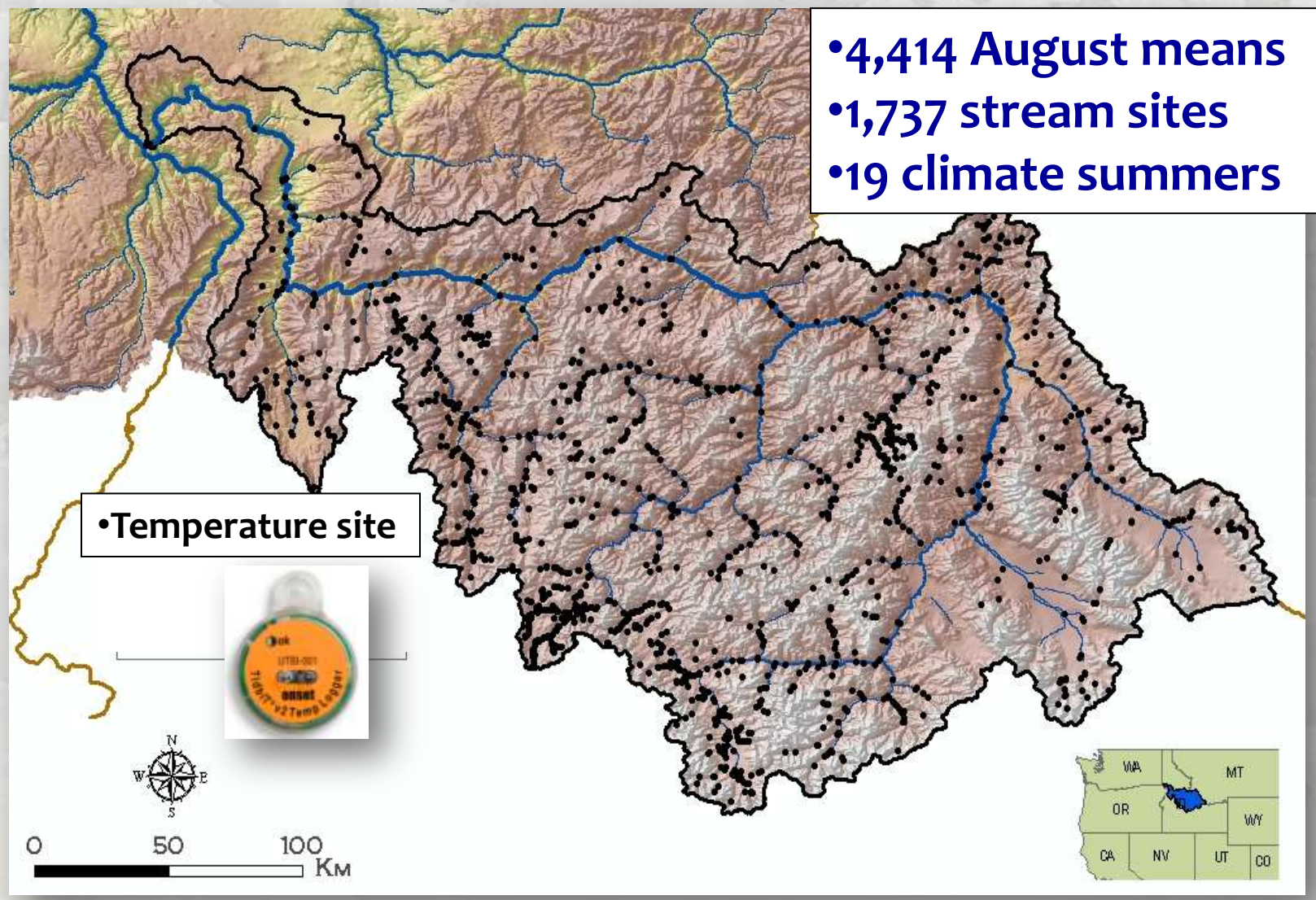
Advantages:

- 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



Salmon River Temperature Model

n = 4,414

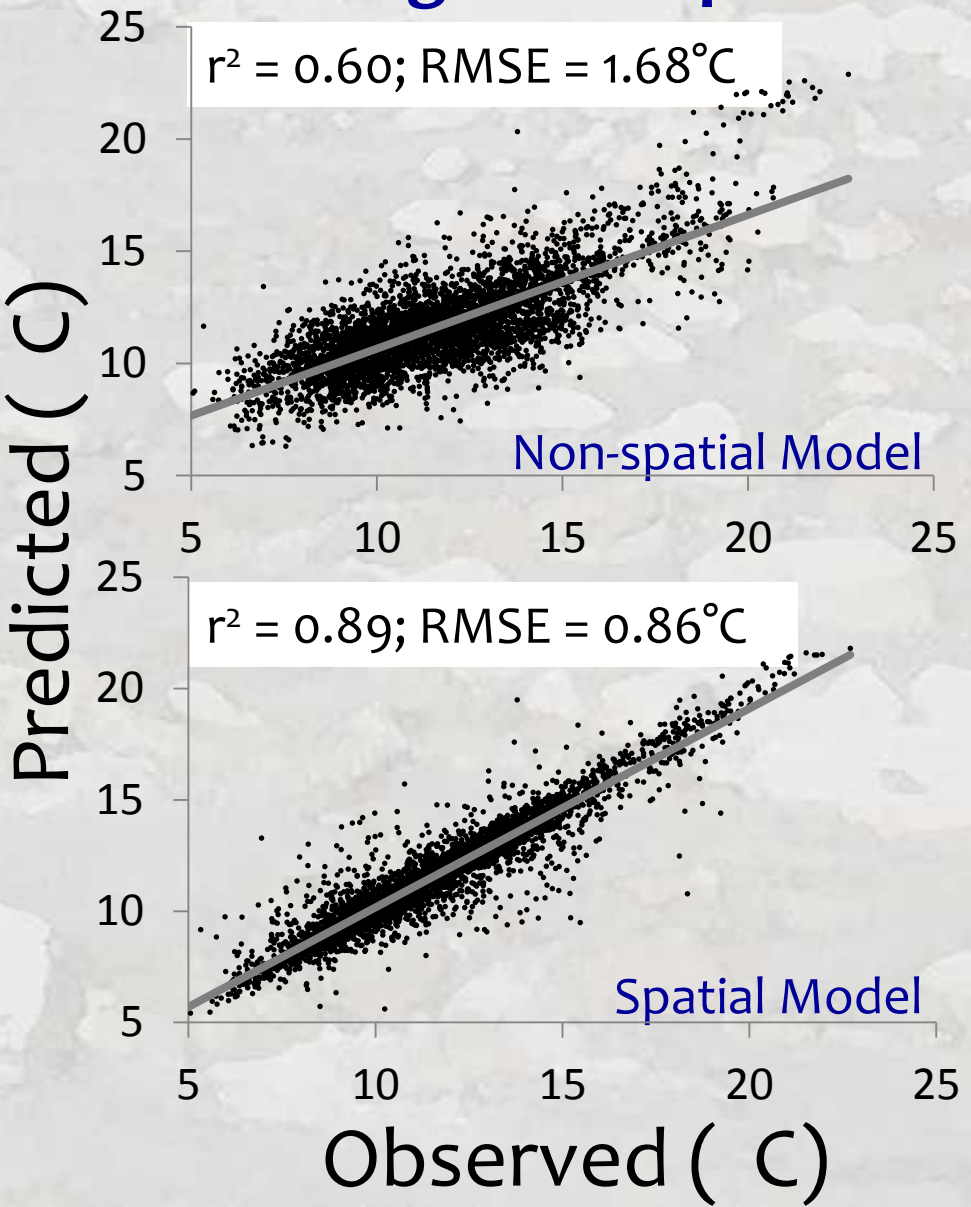
Covariate Predictors

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

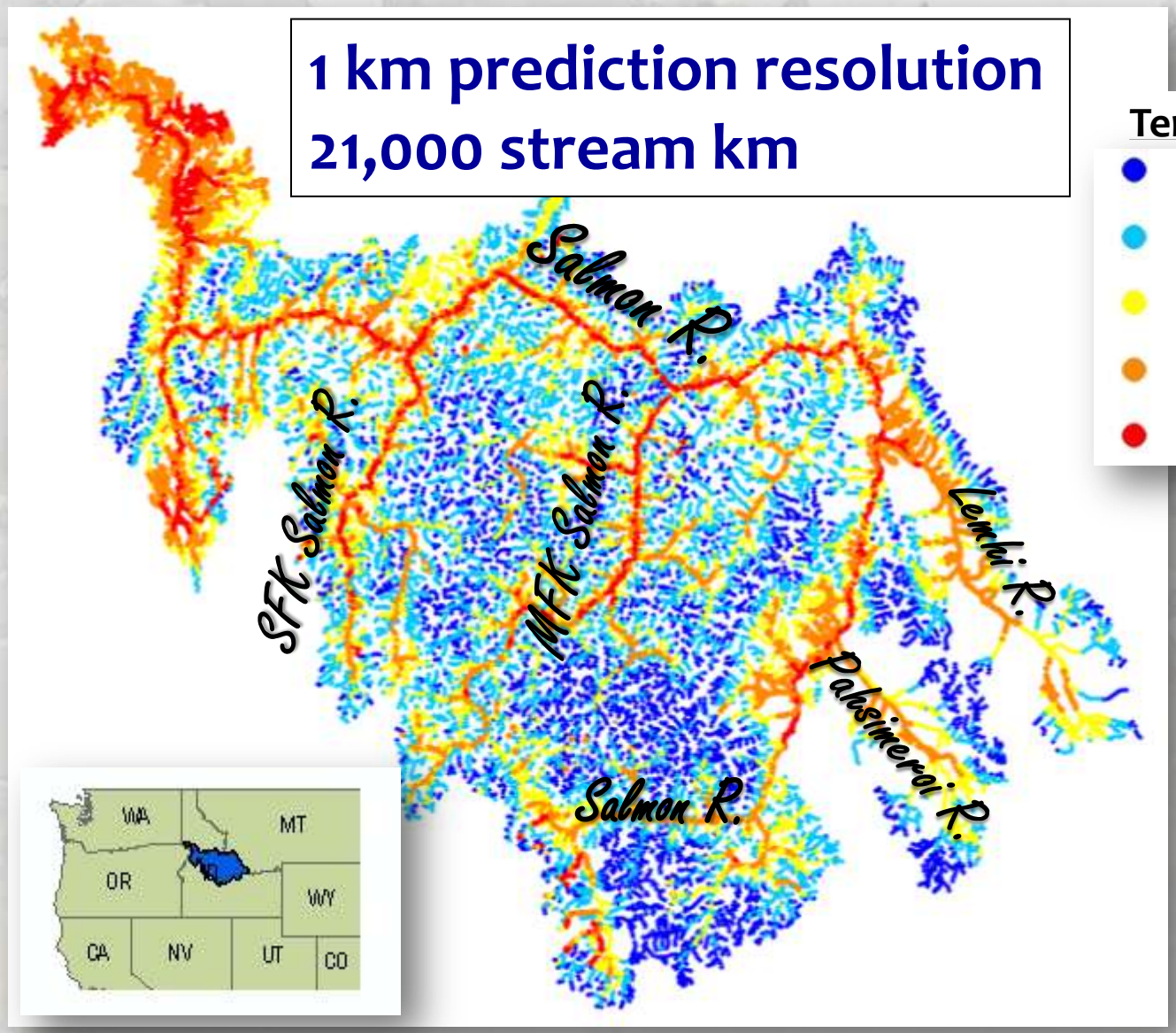
= NCEP RegCM3 reanalysis

Mean August Temperature



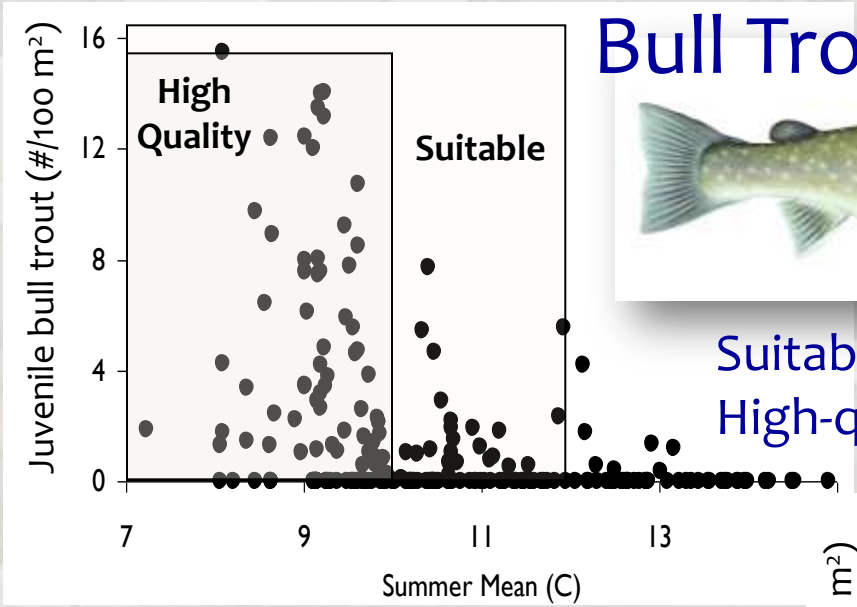
Salmon River Temperature Map

2002-2011 mean August stream temperatures



Effects on Thermal Habitat

Define using thermal criteria

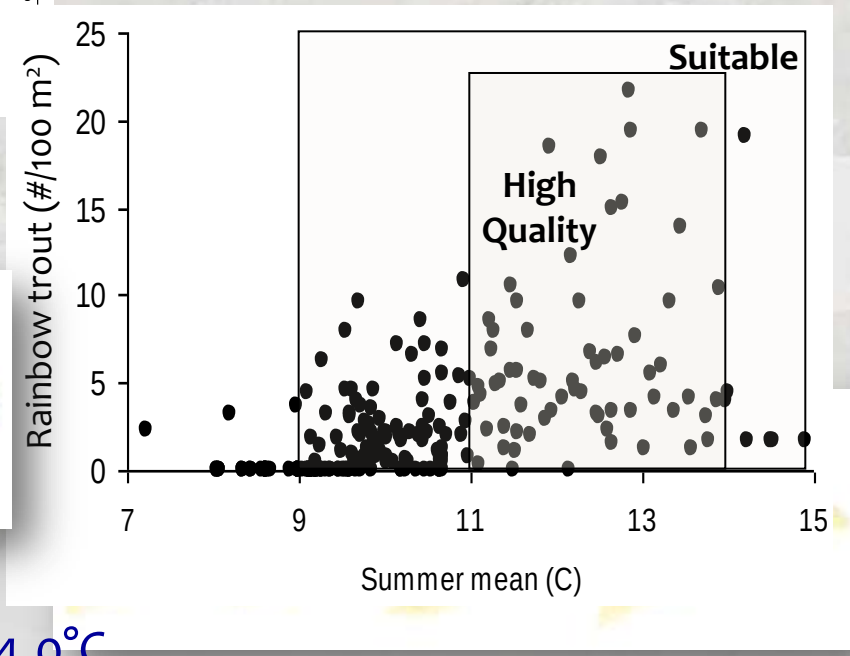


Bull Trout

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



Shifts in Rainbow Trout Thermal Habitat (1993-2006)

No net gain or loss

Gain
No change
Loss

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

Salmon River Bull Trout Habitats

2002-2011 Historical

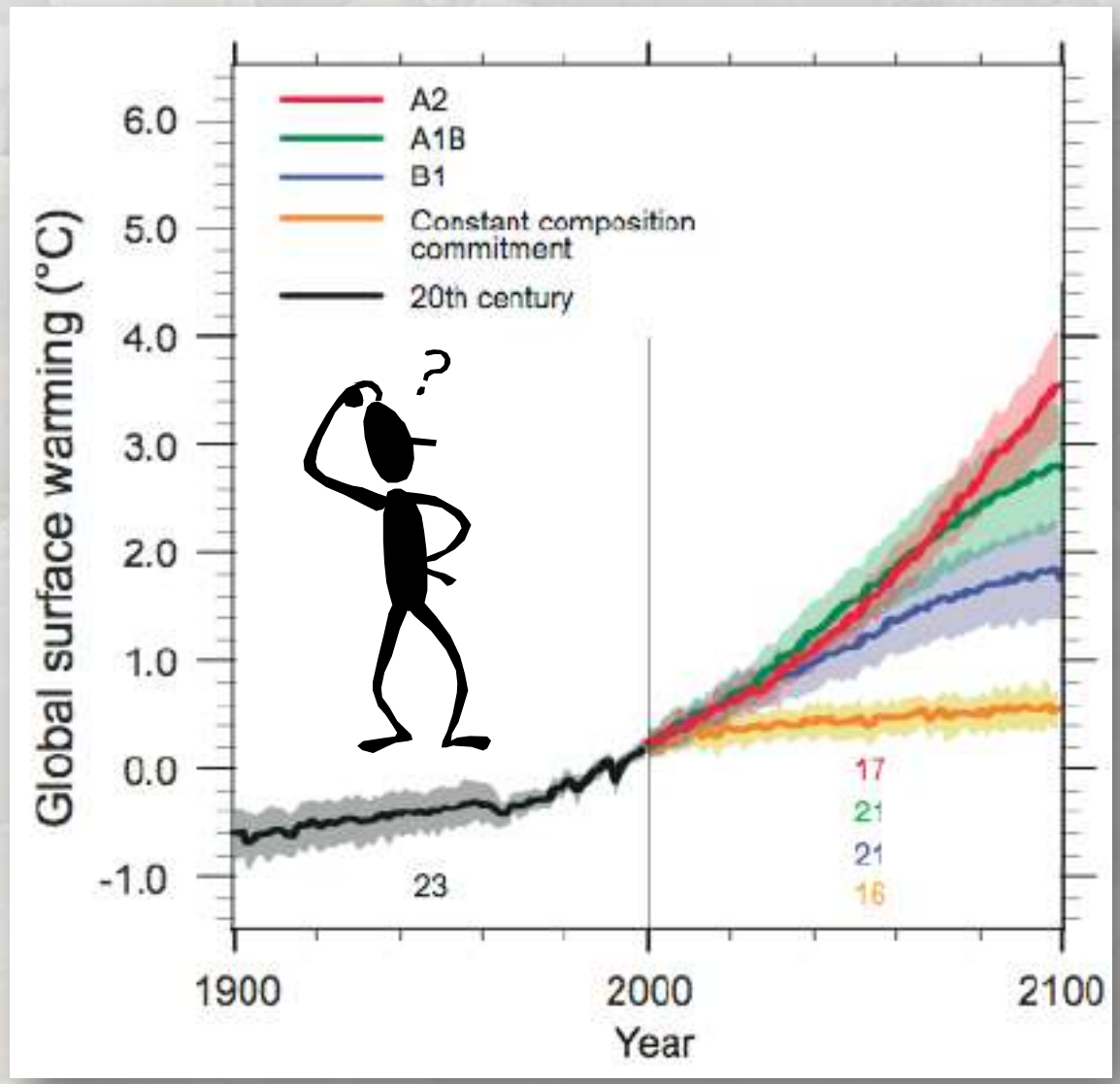
11.2 °C isotherm

Suitable

Unsuitable

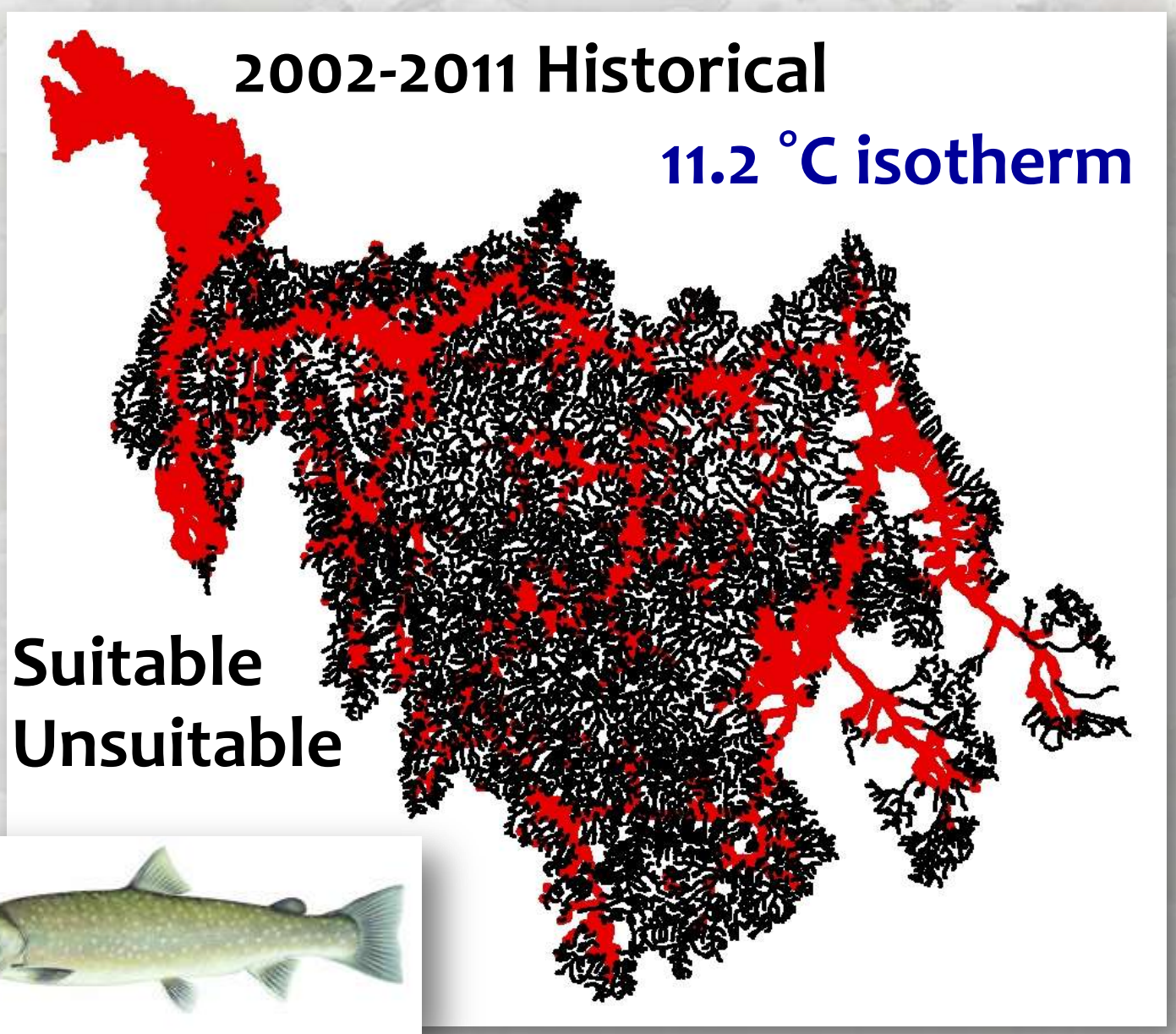
Climate Scenario Maps

Many possibilities once model exists…

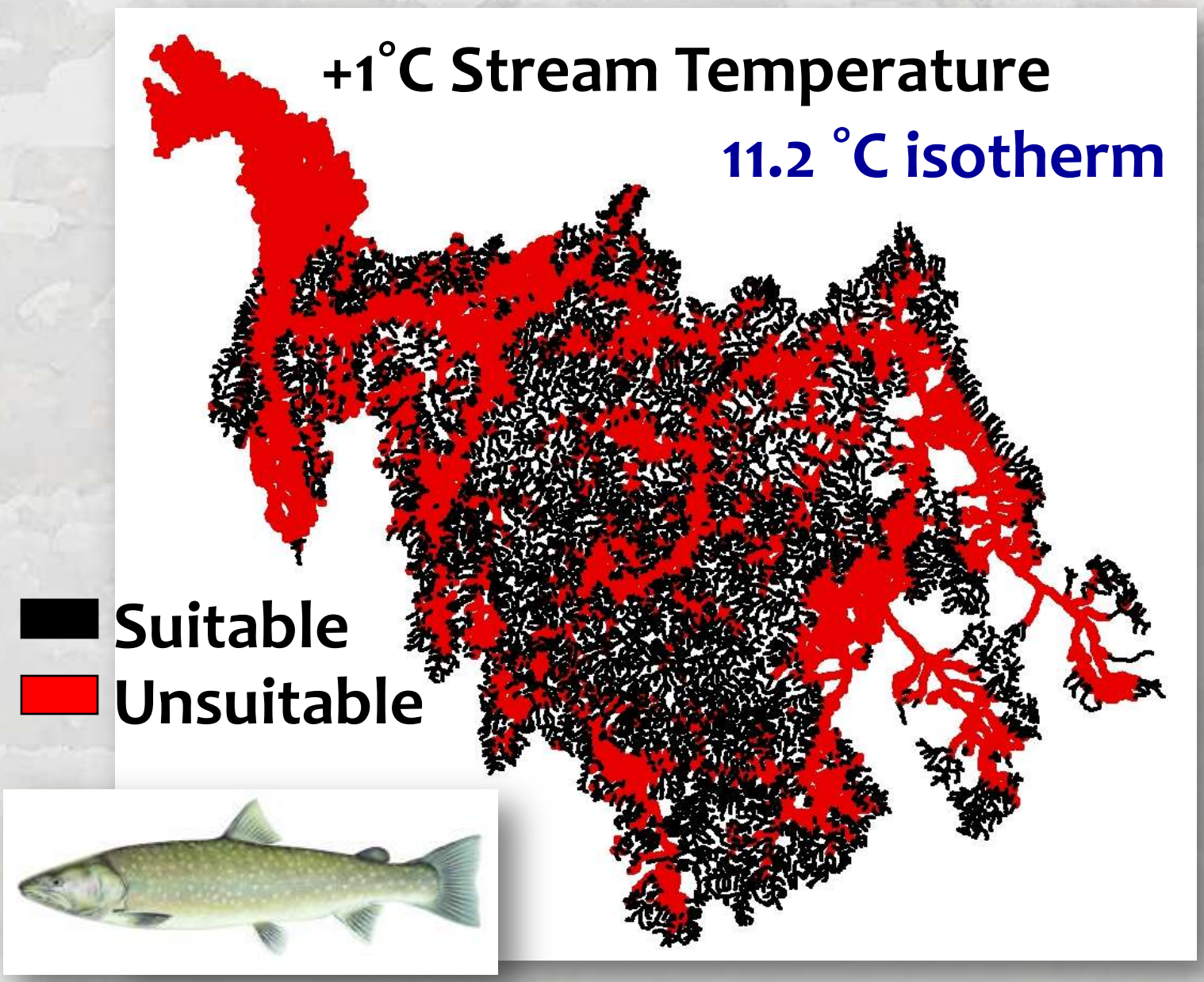


Adjust air & discharge values to represent scenarios

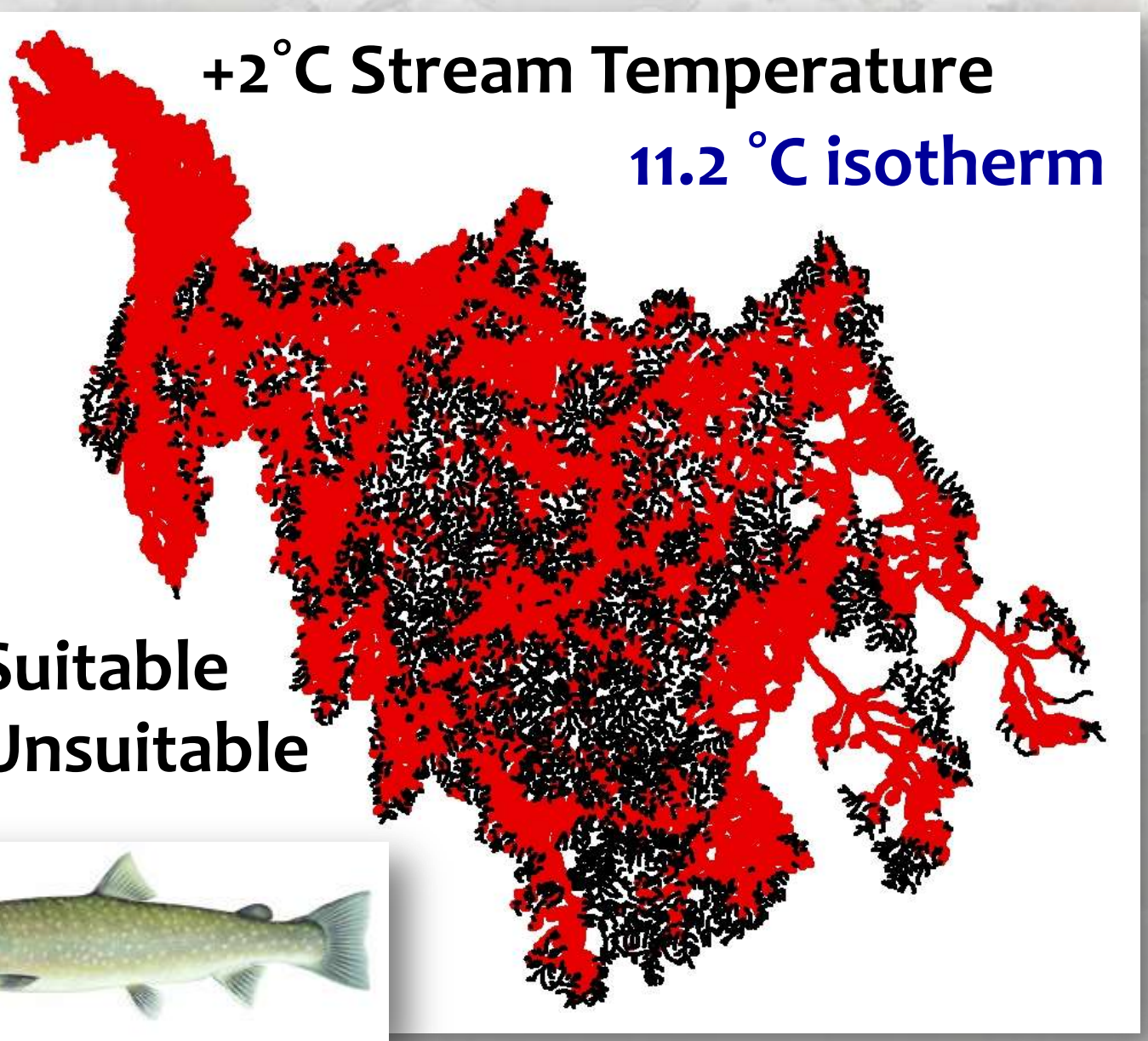
Salmon River Bull Trout Habitats



Salmon River Bull Trout Habitats

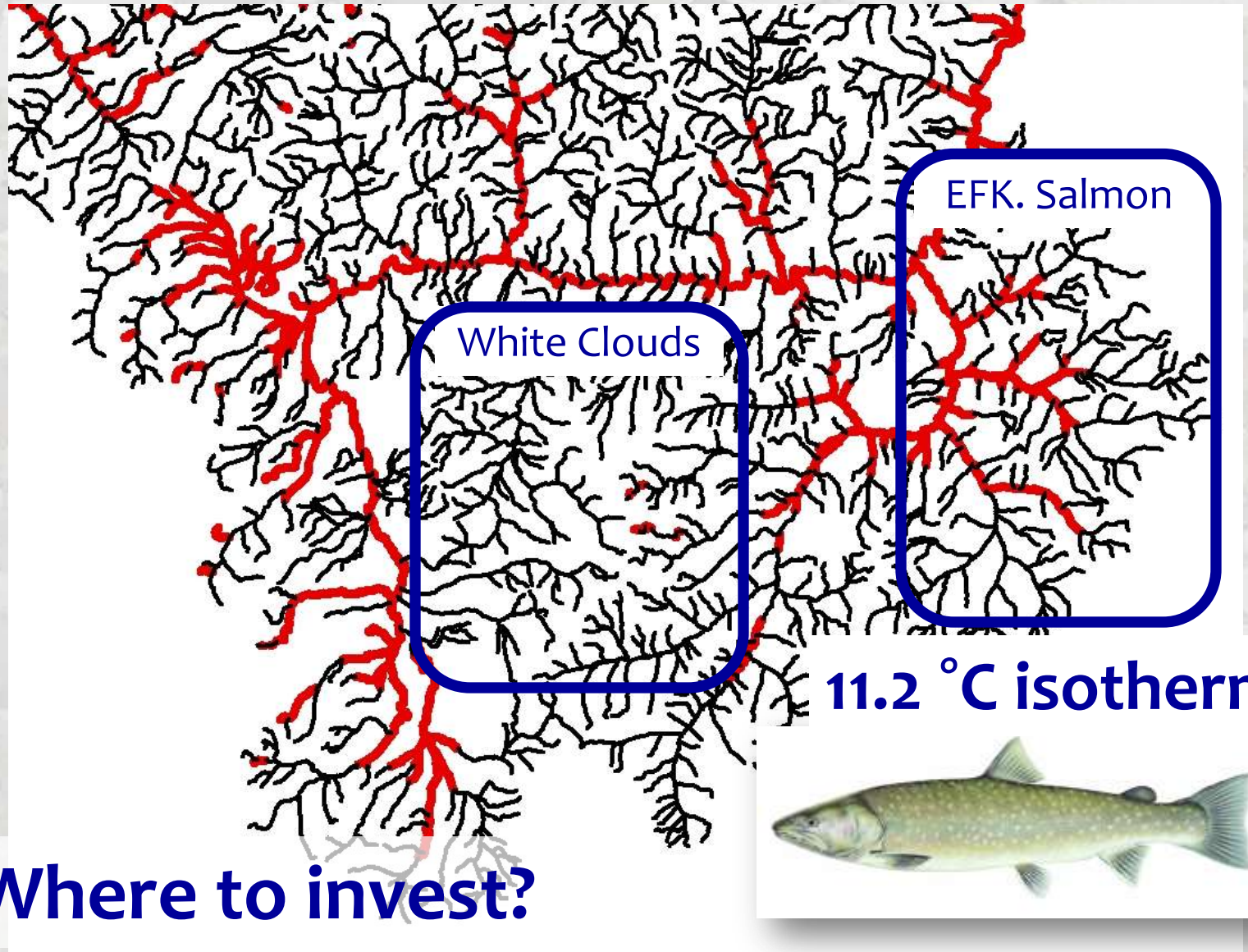


Salmon River Bull Trout Habitats



Spatial Variation in Habitat Loss

2002-2011 historical scenario

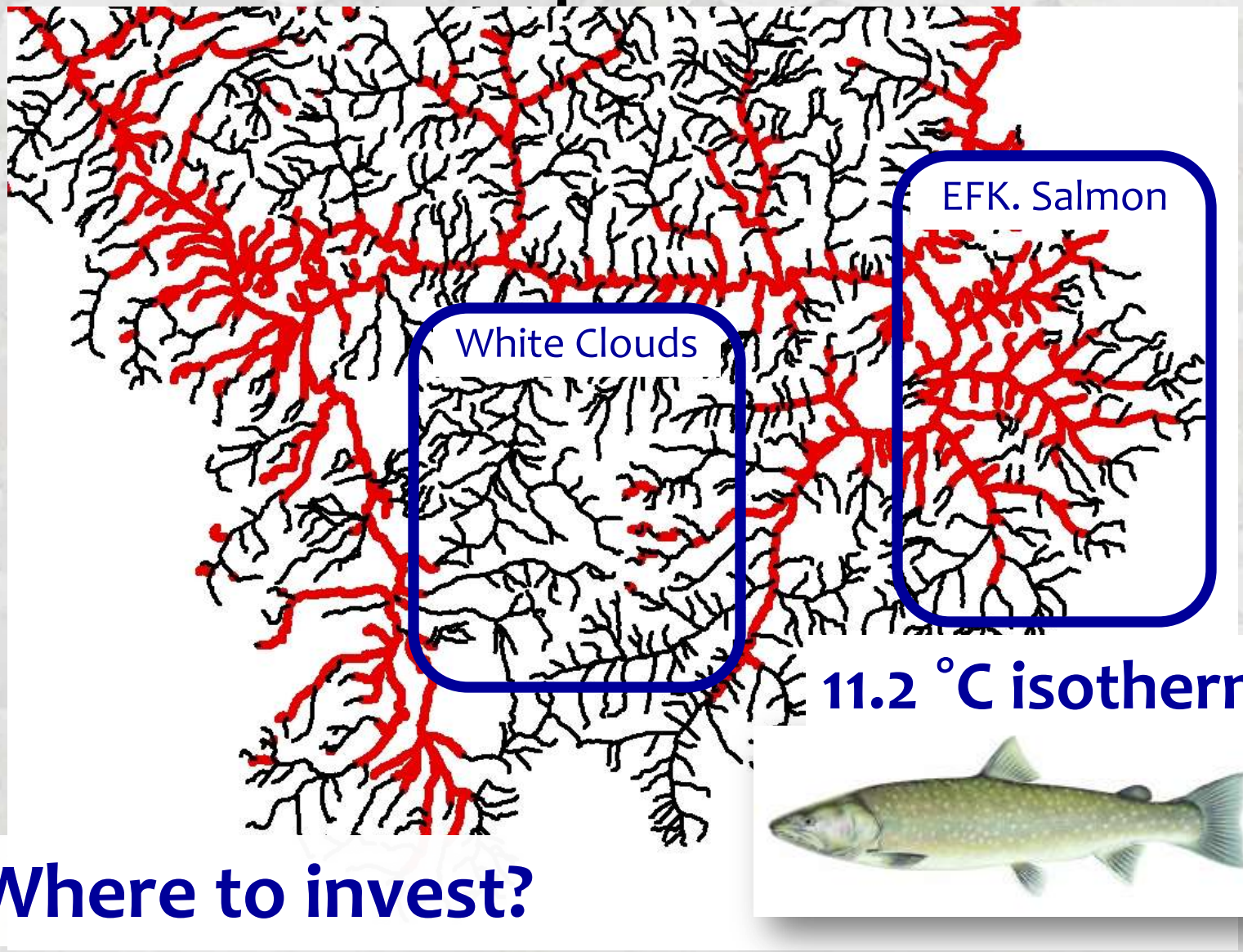


11.2 ˚C isotherm

Where to invest?

Spatial Variation in Habitat Loss

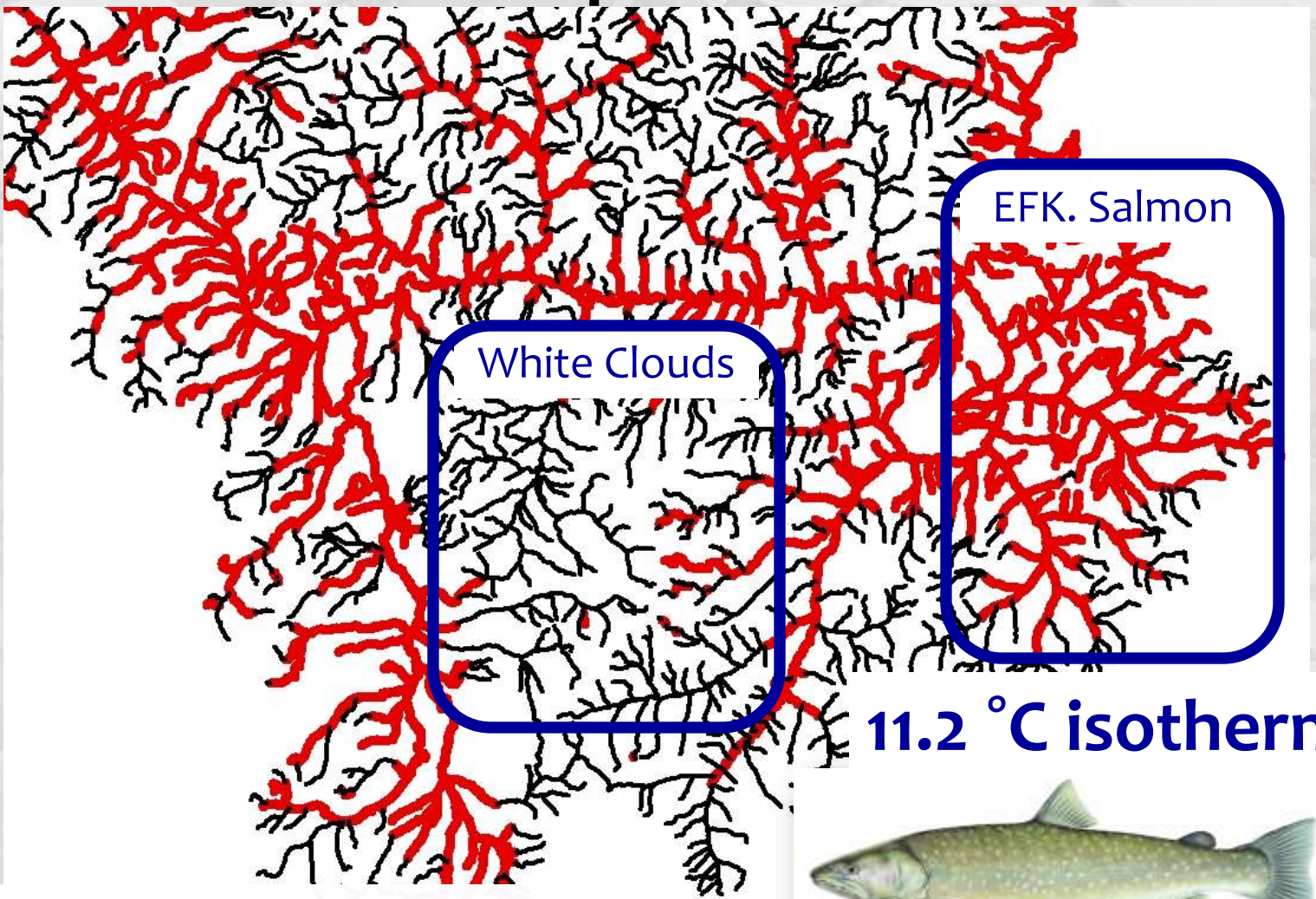
+1˚C stream temperature scenario



Where to invest?

Spatial Variation in Habitat Loss

+2˚C stream temperature scenario



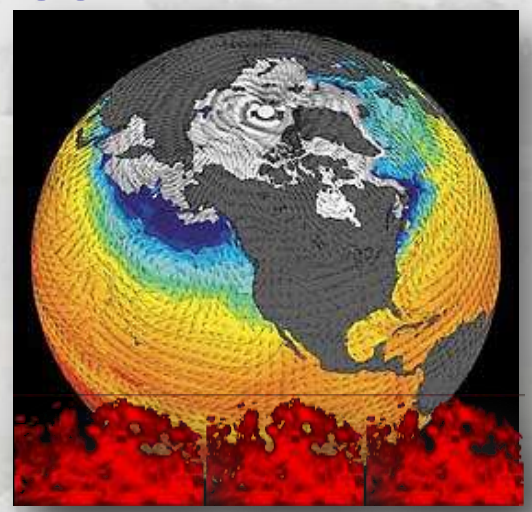
11.2 ˚C isotherm

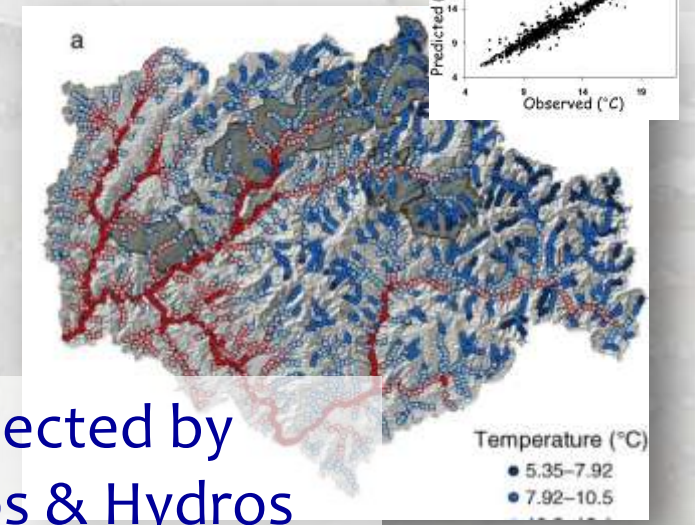
Where to invest?

Models Developed from Everyone's Data

Collaborative Management Responses?

GCM



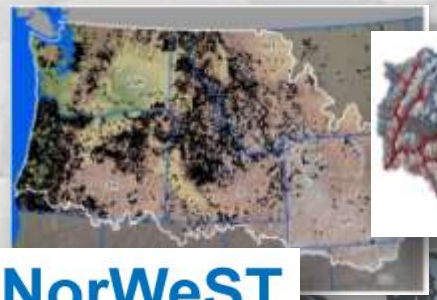


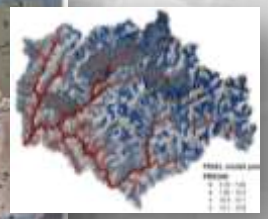
Data Collected by
Local Bios & Hydros

?

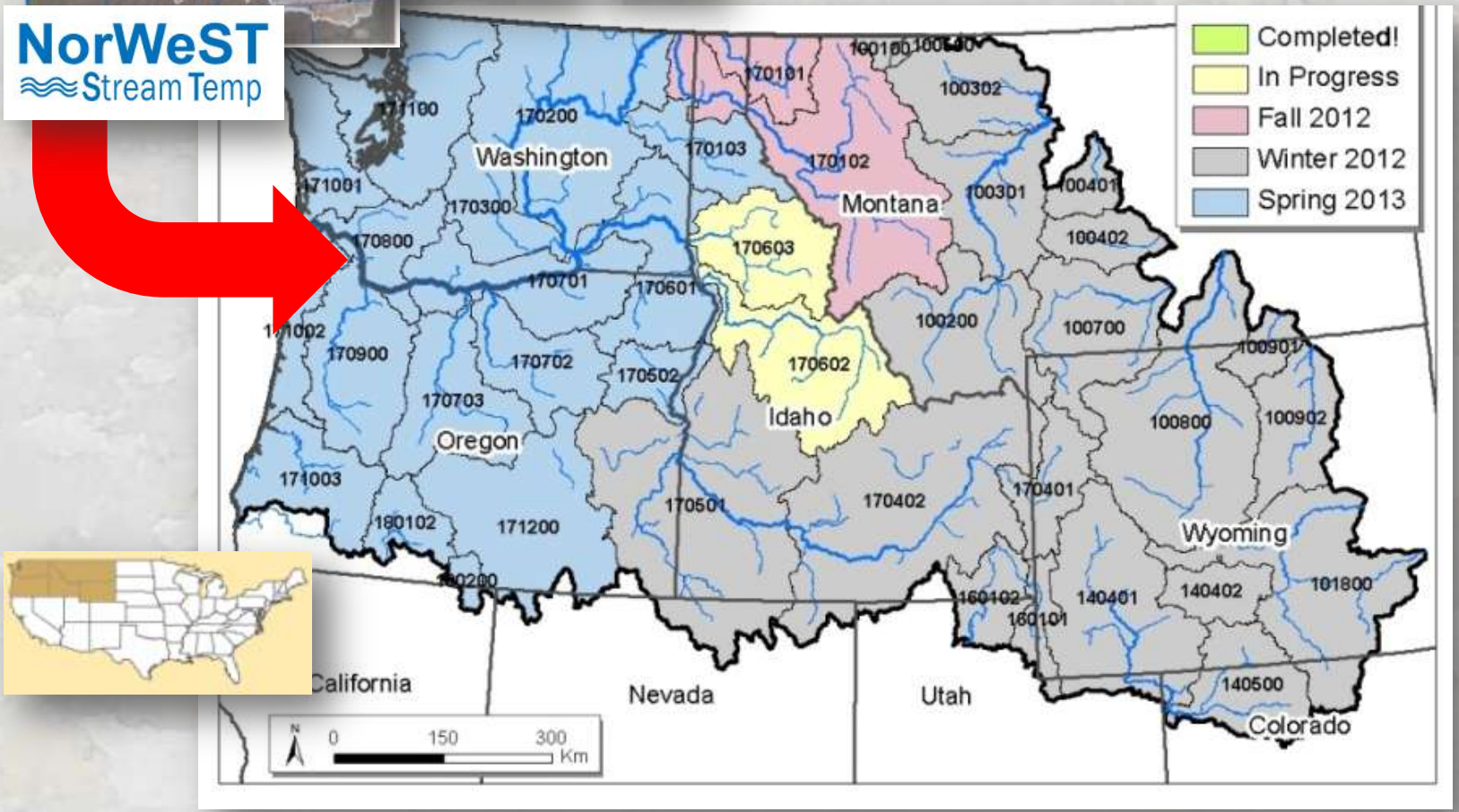
Management
Decisions

NorWeST Temperature model timelines (~3rd code HUCs)





NorWeST
Stream Temp

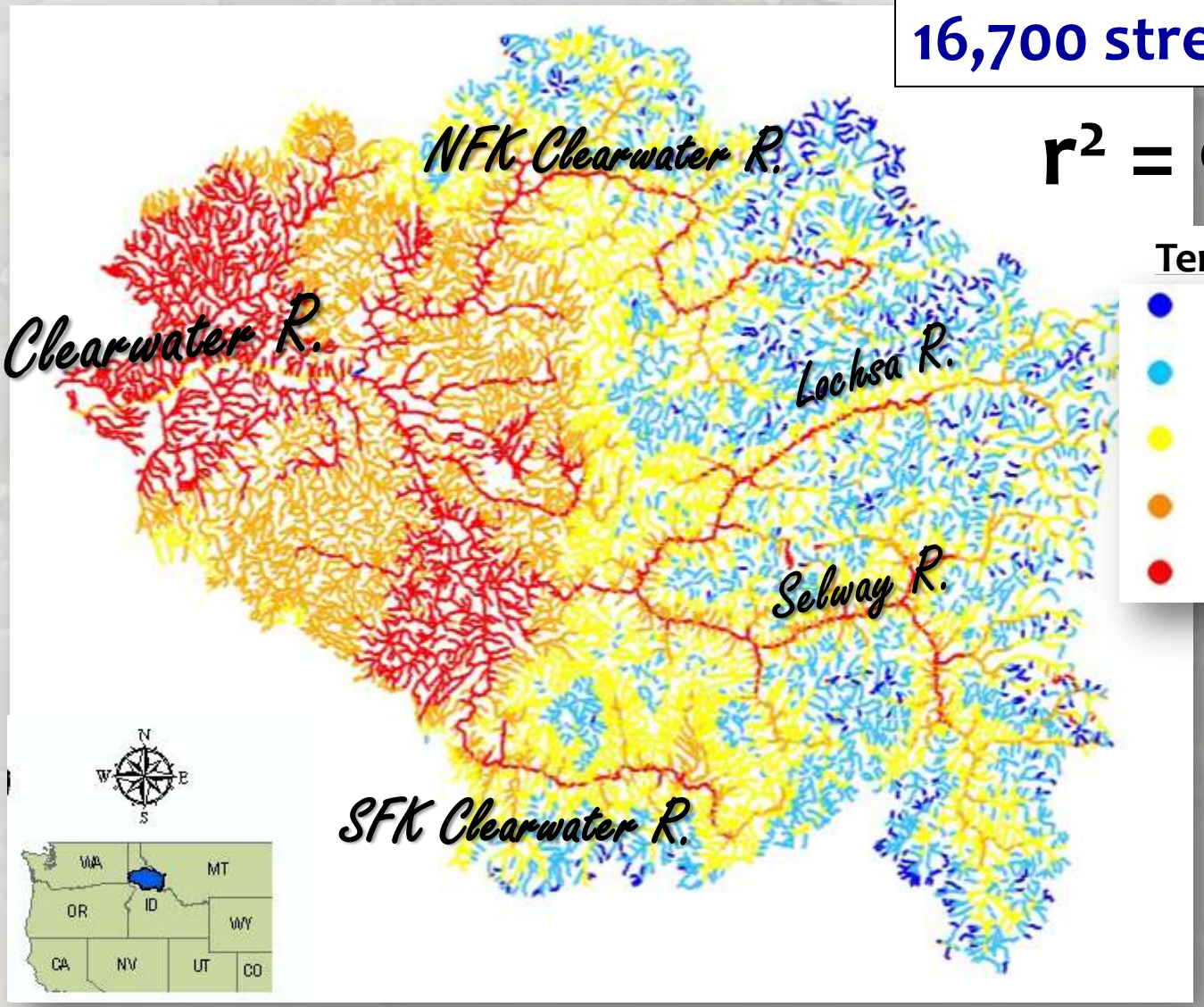


Clearwater Temperature Map

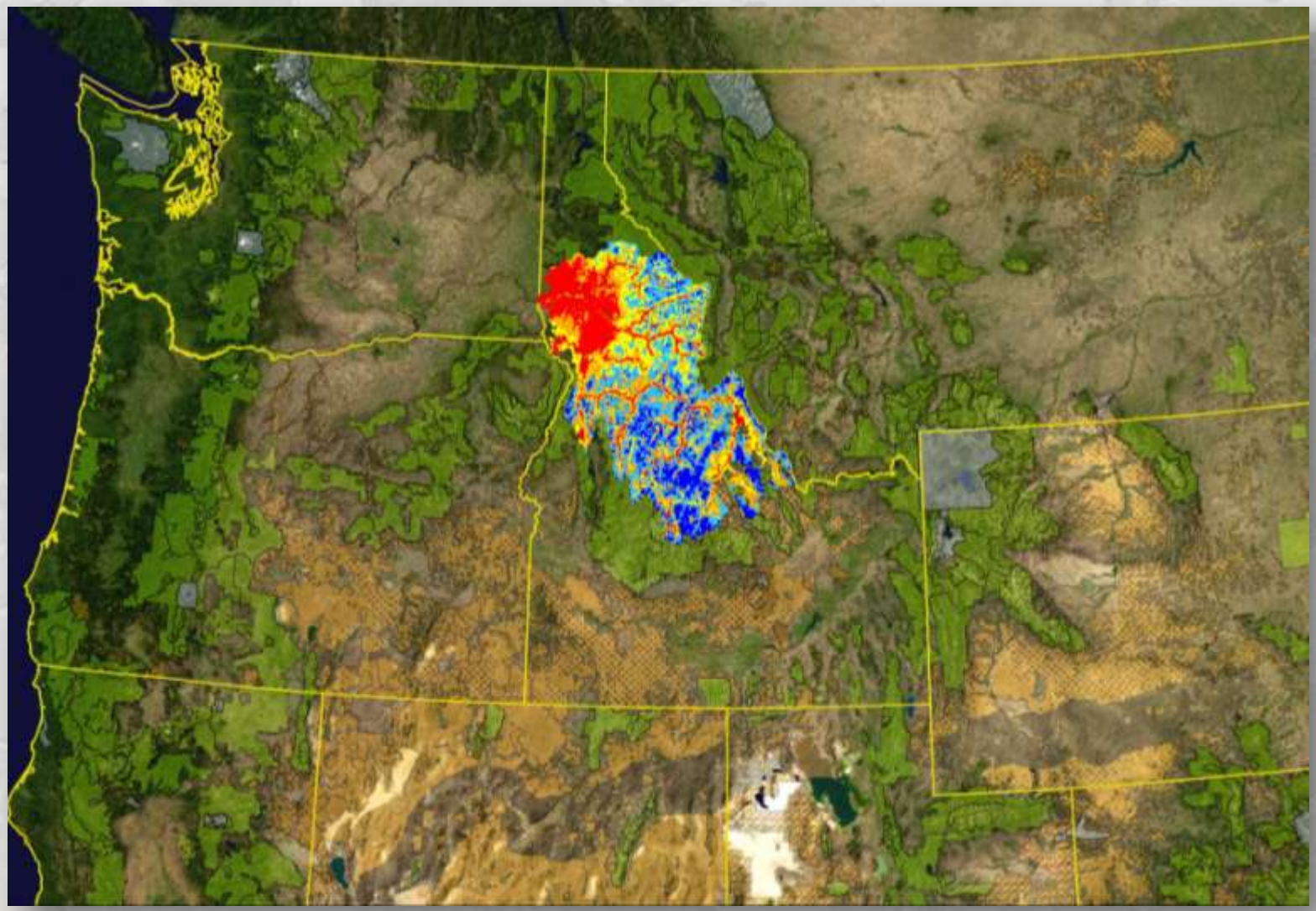
2002-2011 mean August stream temperatures

16,700 stream km

r^2 = 95%



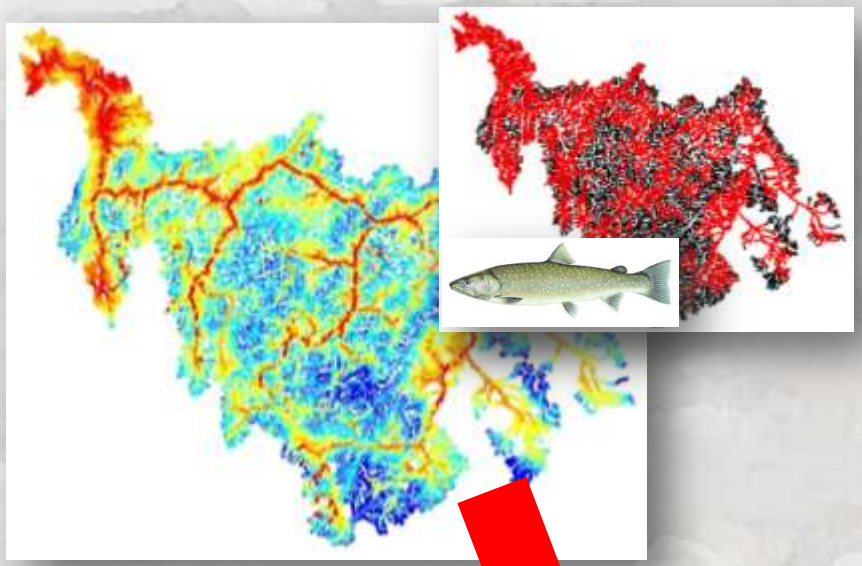
NorWeST Blob Growing…



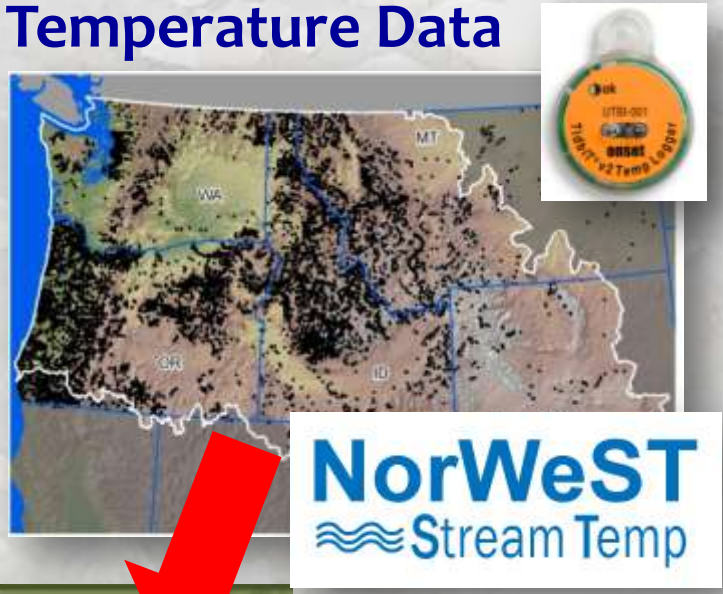
& Website Coming…

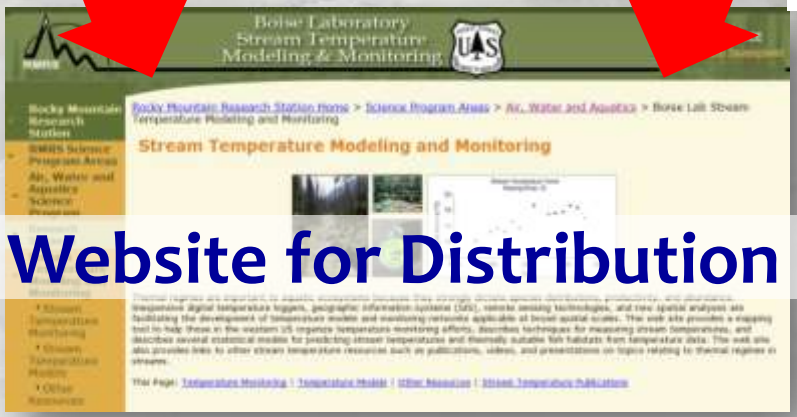
Launch scheduled late fall/early winter

GIS maps of climate scenarios



Temperature Data



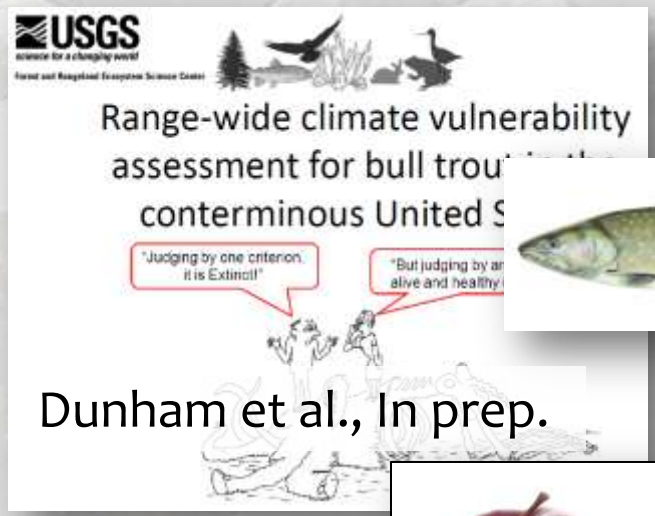


Website for Distribution

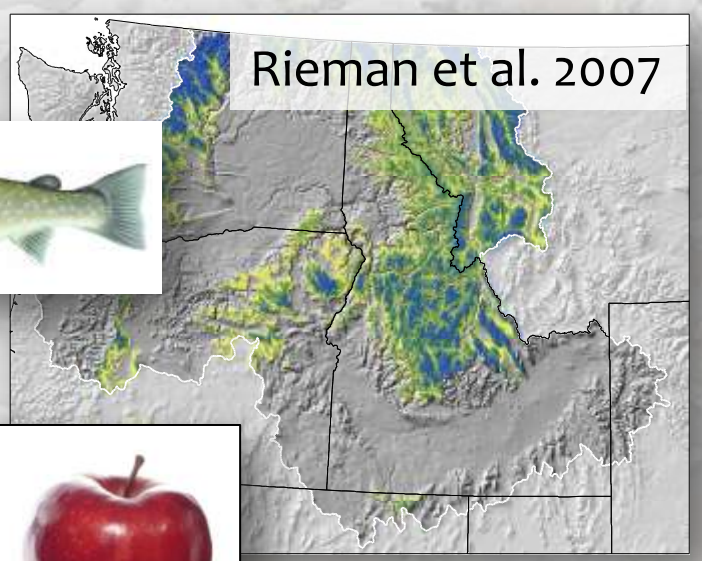
Consistent Temperature Information for Region 1 Forests…

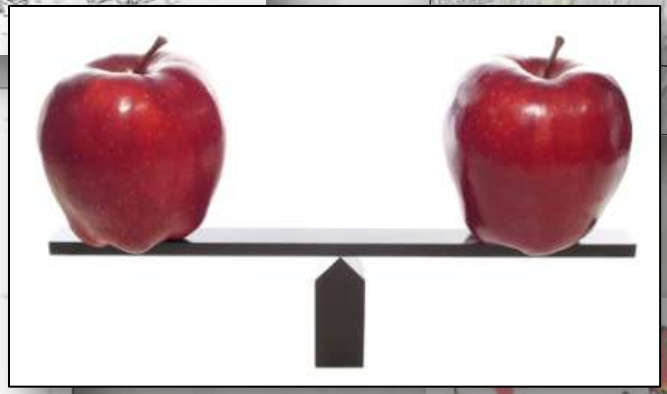
Nez Perce NF, Bitterroot NF, Clearwater NF, Panhandle NF, Lolo NF, Kootenai NF, Flathead NF, Helena NF, Lewis & Clark NF, Beaverhead NF, Deerlodge NF, Gallatin NF, Custer NF

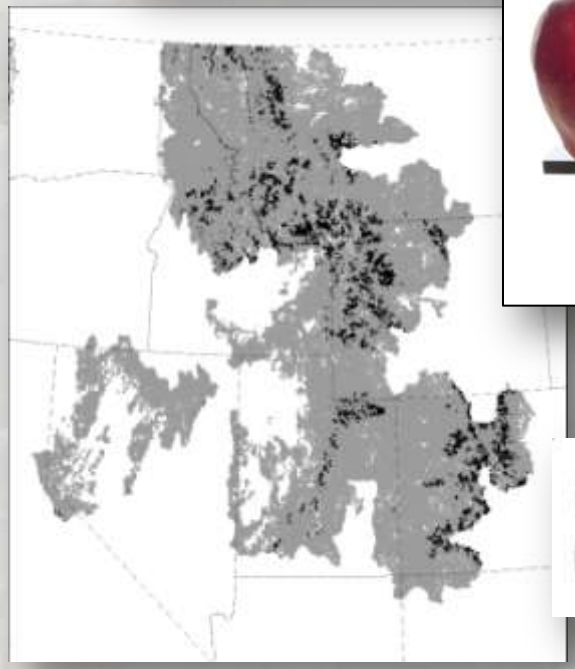
More Precise Bioclimatic Assessments



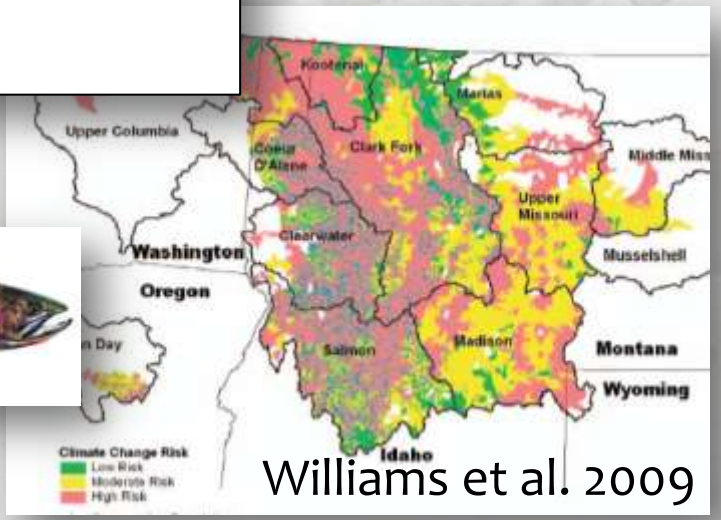
Dunham et al., In prep.







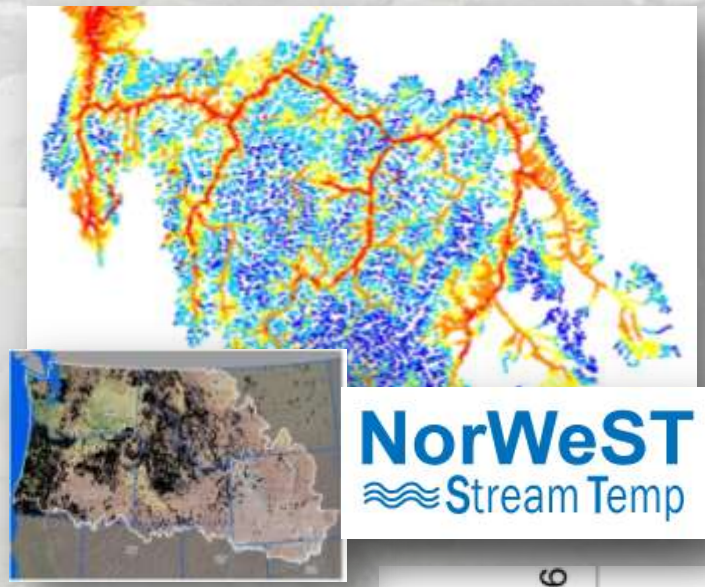
Wenger et al. 2011. *PNAS*.



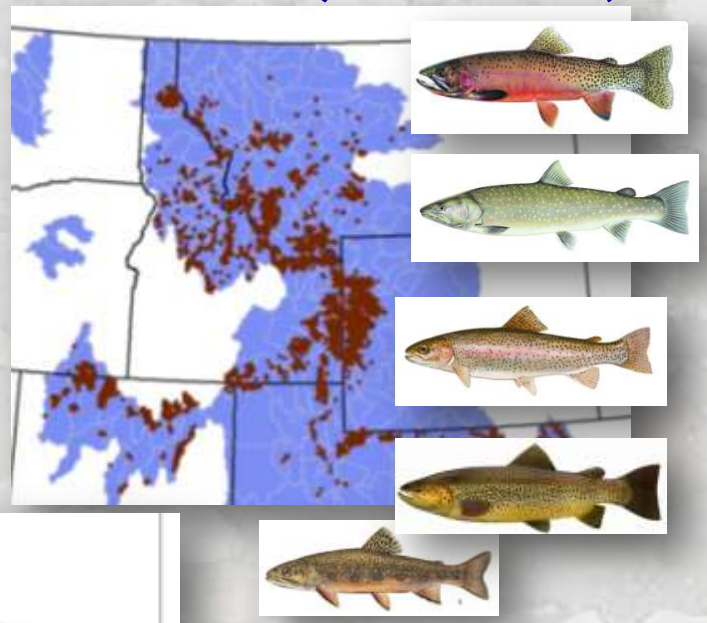
Williams et al. 2009

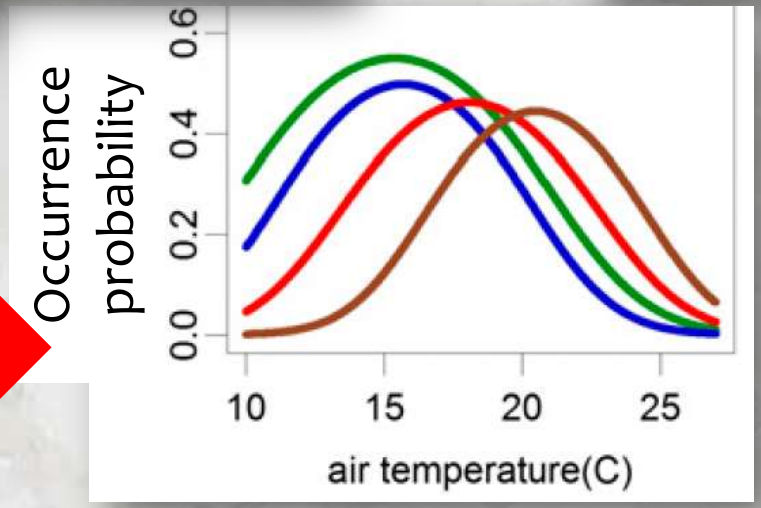
Consistent Thermal Niche Definitions

Stream temperature maps



Regional fish survey databases (n = 10,000)



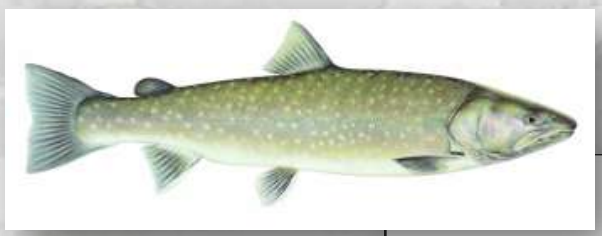


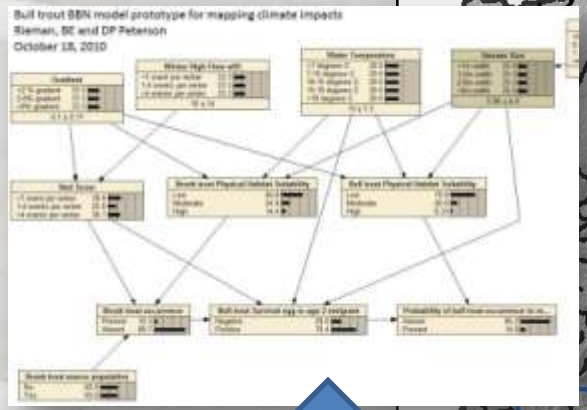
Wenger et al. 2011a. *PNAS* **108**:14175-14180

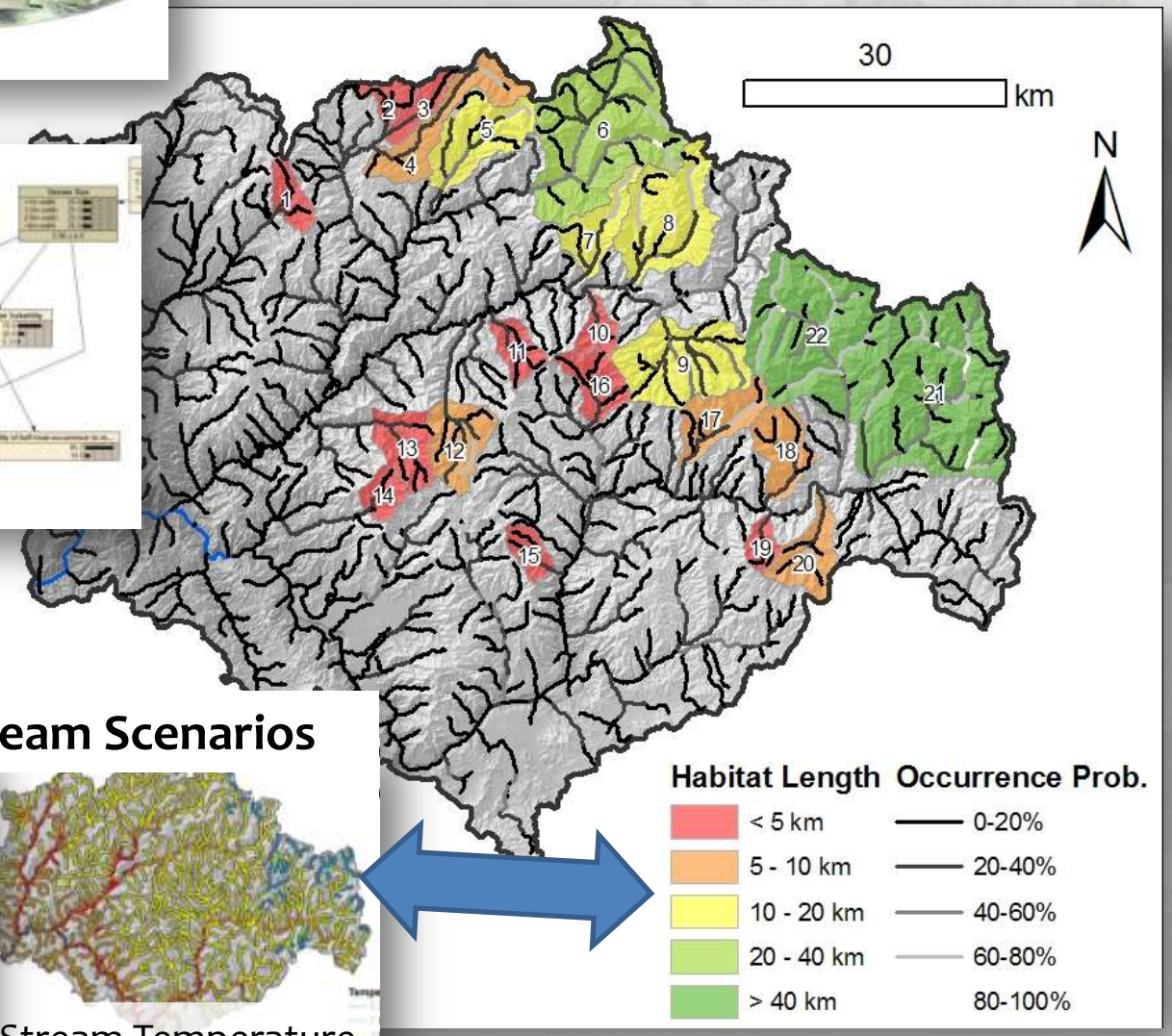
Wenger et al. 2011b. *CJFAS* **68**:988-1008; Wenger et al., *In Preparation*

Bull Trout Climate Decision Support Tool

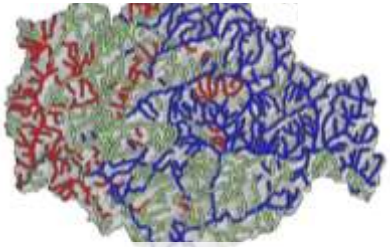
Tool runs on regionally consistent data layers







Downscaled Stream Scenarios



Streamflow

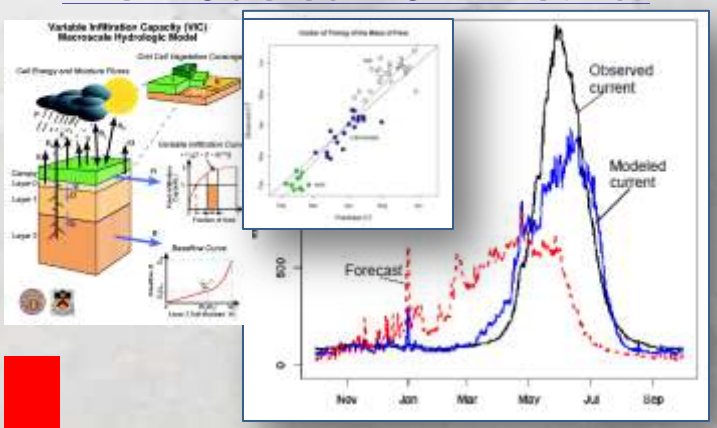
Stream Temperature

Peterson et al. In Press. *Fisheries*

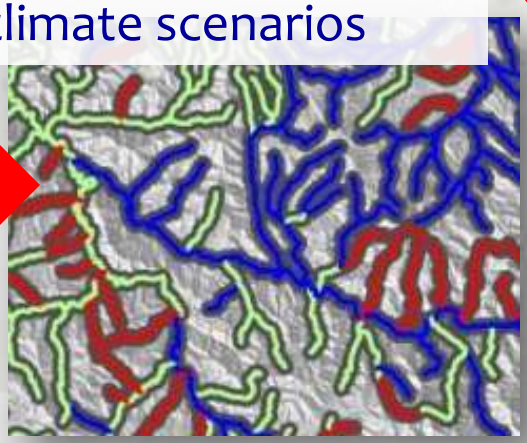
Western U.S. Flow Metrics Webpage

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

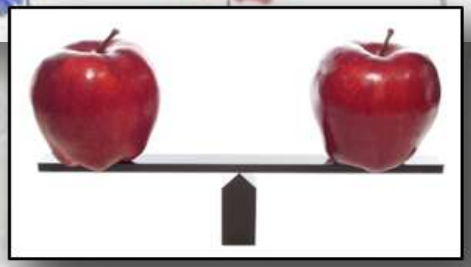
VIC Modeled Flow Metrics



NHD+ stream segments & climate scenarios



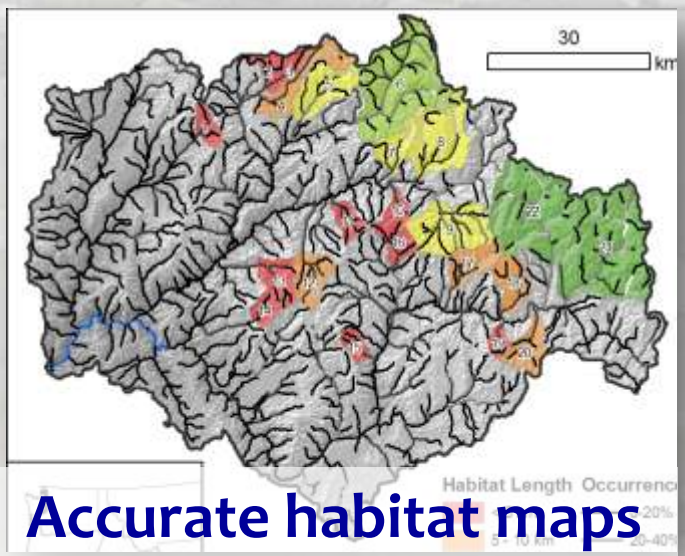
…for the western U.S.



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

Efficient Biological Monitoring

Distributional status & trend

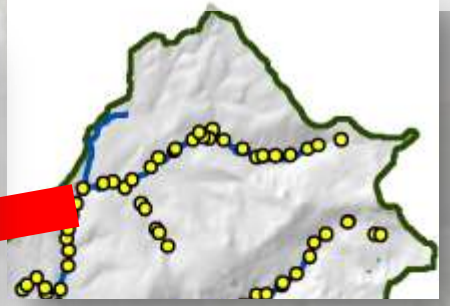


Accurate habitat maps from stream models

=

Map

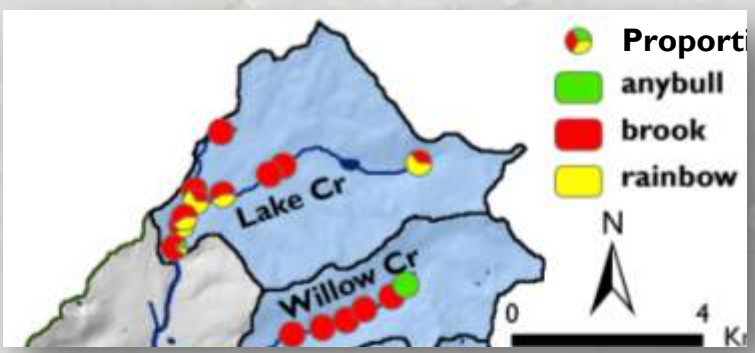
Probabilistic sample (i.e., EMAP GRTS)



Dunham & Peterson 2002

Biological survey

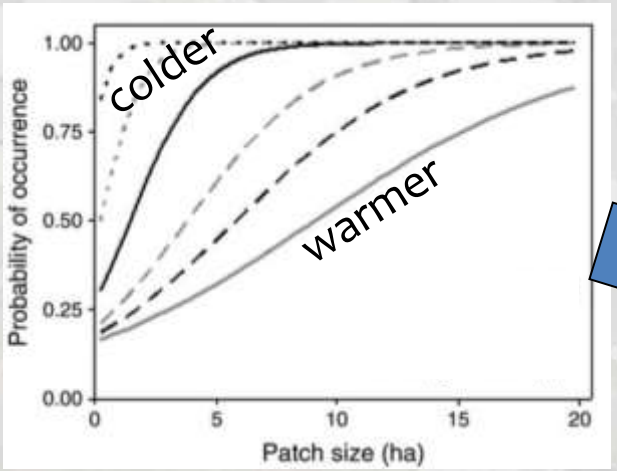
Precise, representative sample



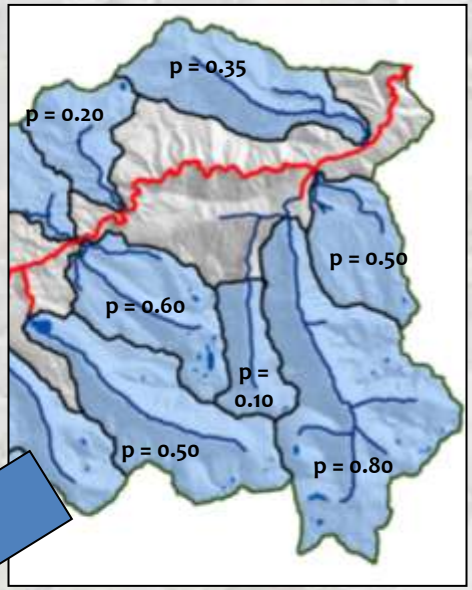
Optimizing Biological Monitoring:

Covariate Effects on Detection Efficiencies

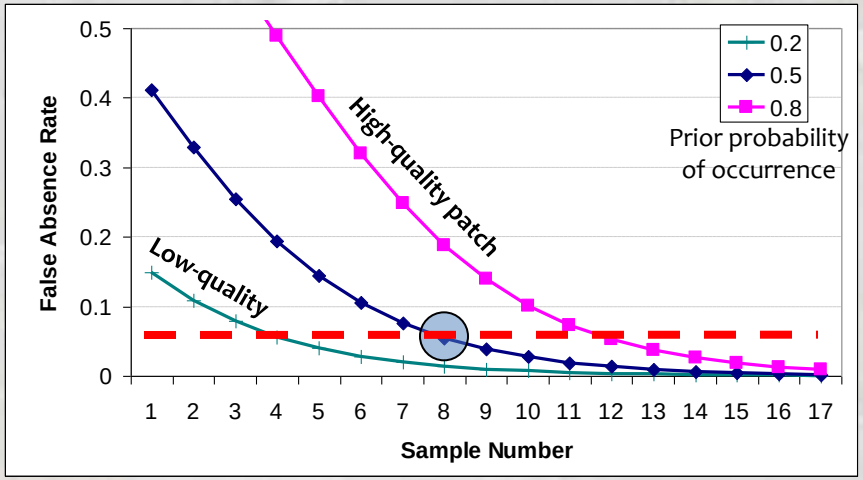
Habitat Suitability Curves

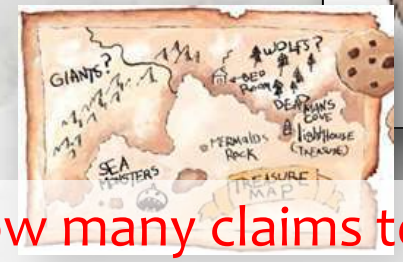


Prior probabilities of occurrence



Modified false absence rates



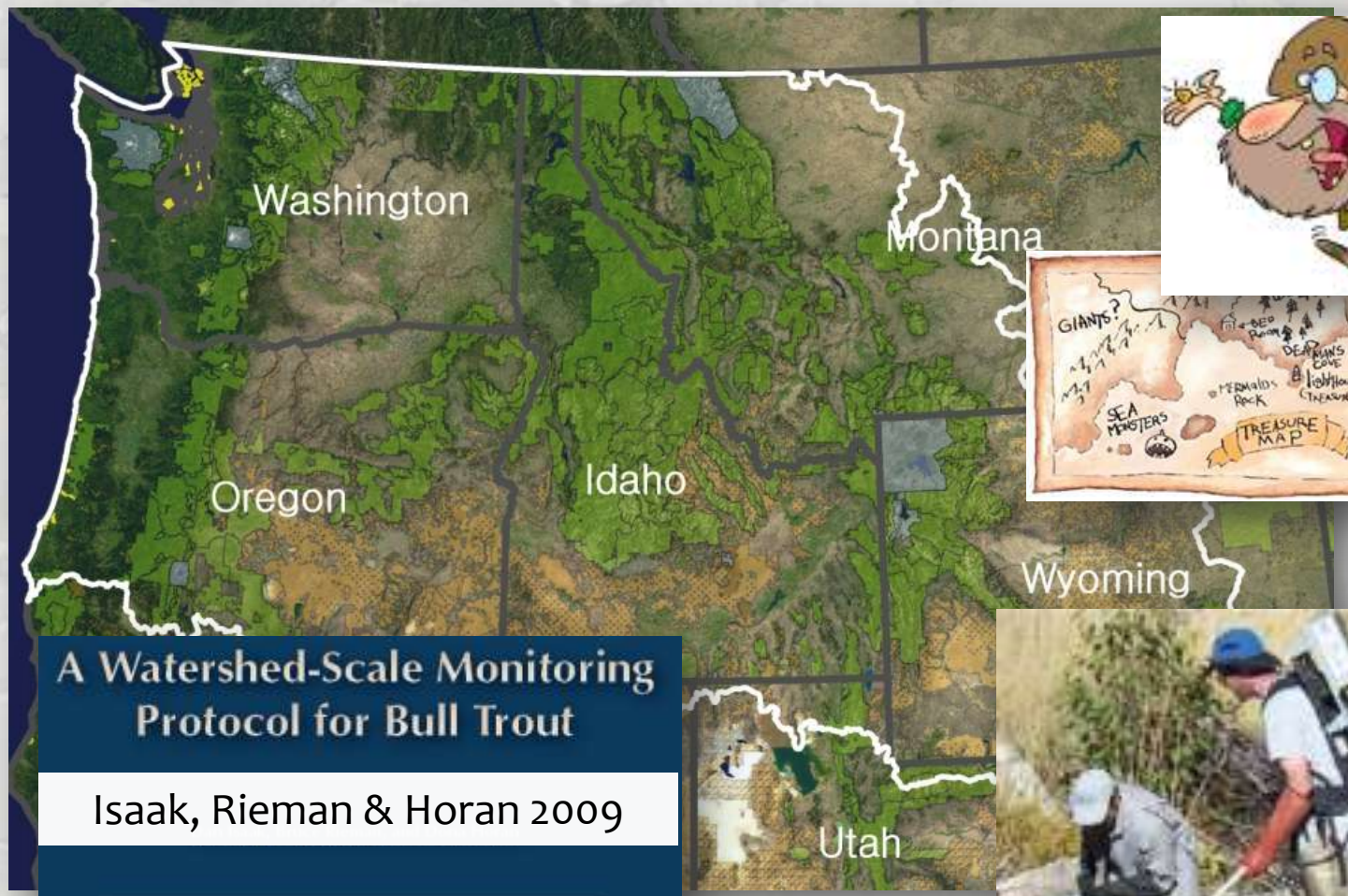


Peterson & Dunham 2003

How many claims to stake?

Regionally Consistent Framework

Bull trout status & trend monitoring



A Watershed-Scale Monitoring Protocol for Bull Trout

Isaak, Rieman & Horan 2009

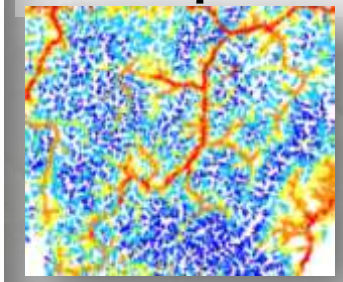
Real-time Access to Stream Spatial Data Anytime, Anywhere

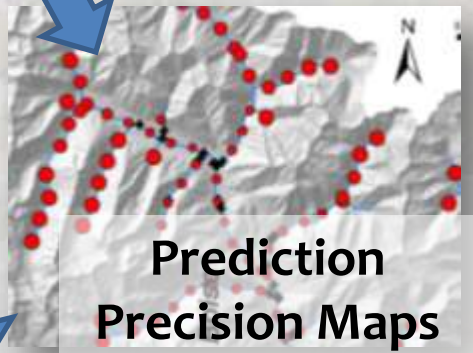
Smartphones as field computers

ArcGIS app

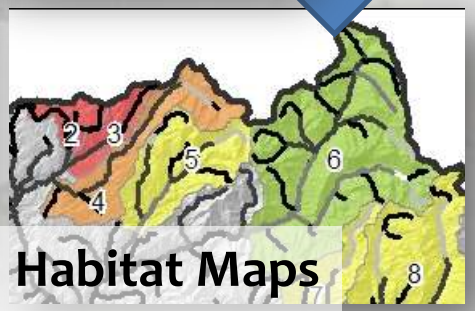
ESRI

Temperature Maps

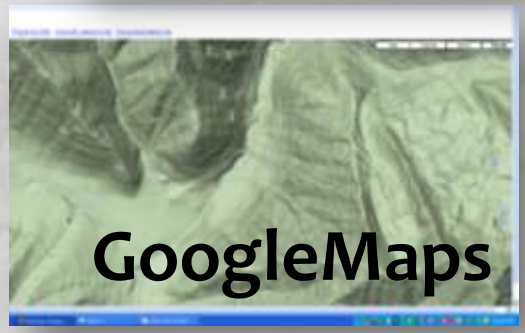




Prediction Precision Maps



Habitat Maps



GoogleMaps

First "Killer Apps" but more coming…

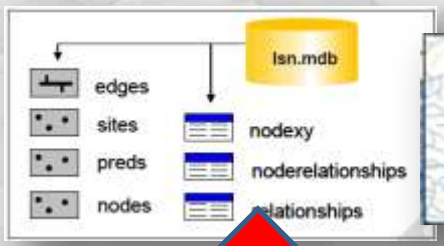
1st Generation Apps

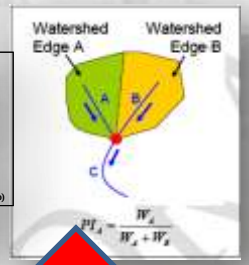
In the Pipeline…

- Bull trout climate decision support tool
- Improved monitoring designs for biological & water quality parameters
- Improved fish distribution maps & models
- Precise thermal niche definitions for trout
- Improved climate vulnerability assessments

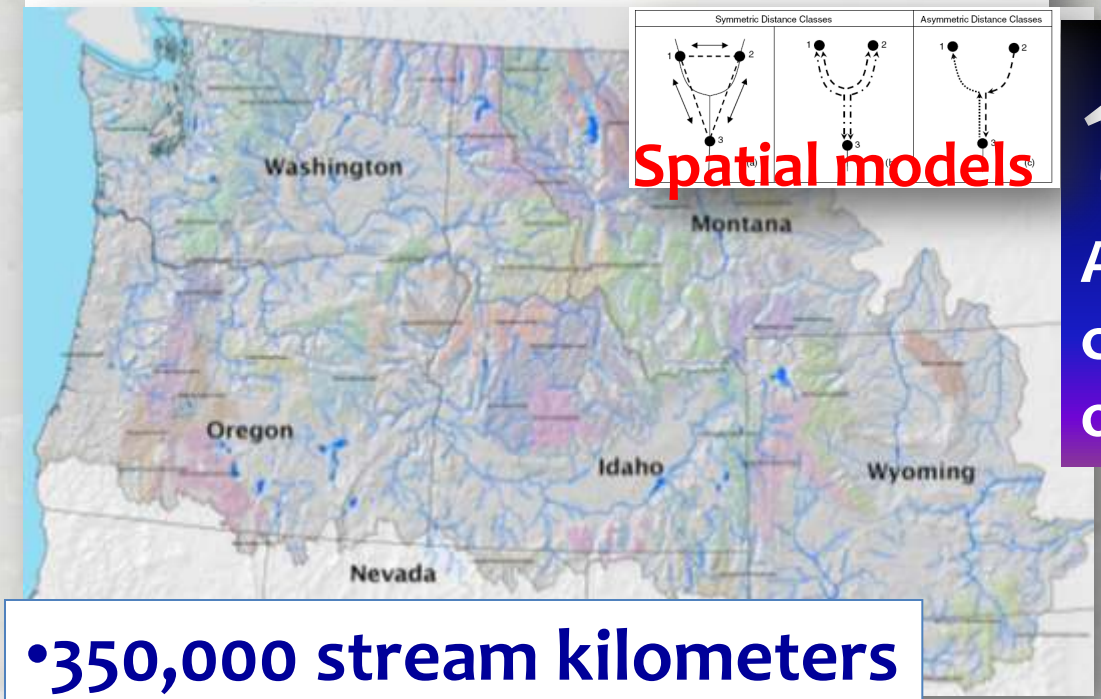
An InterNet for Stream Data

GIS infrastructure now exists…





Great Northern
LANDSCAPE CONSERVATION COOPERATIVE



Spatial models

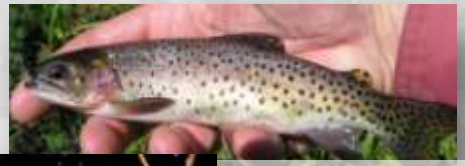
1G LCC

Accurate & consistent scaling of information

•350,000 stream kilometers

Boise Spatial Streams Group

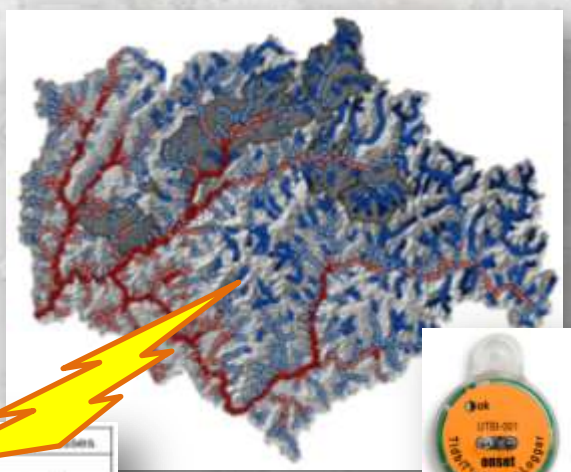
Temperature Data, but also…

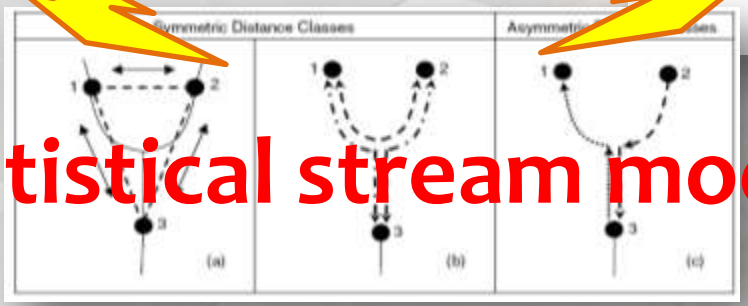


Distribution & abundance

Response Metrics

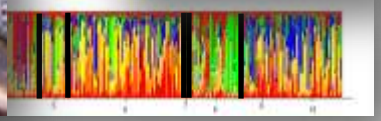
- Gaussian
- Poissan
- Binomial





Statistical stream models

Genetic Attributes

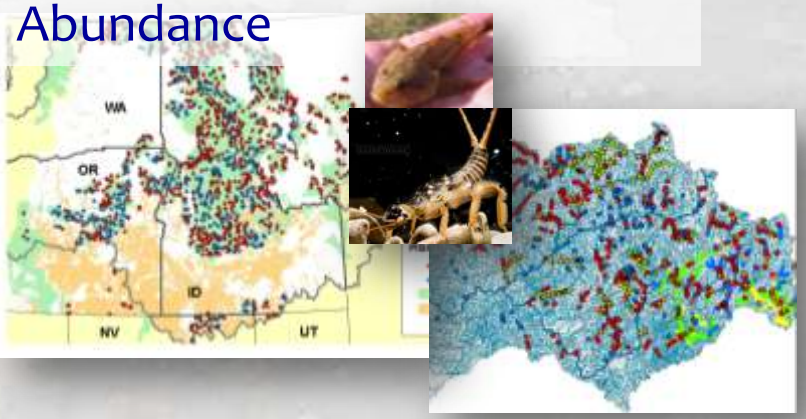


Water Quality Parameters

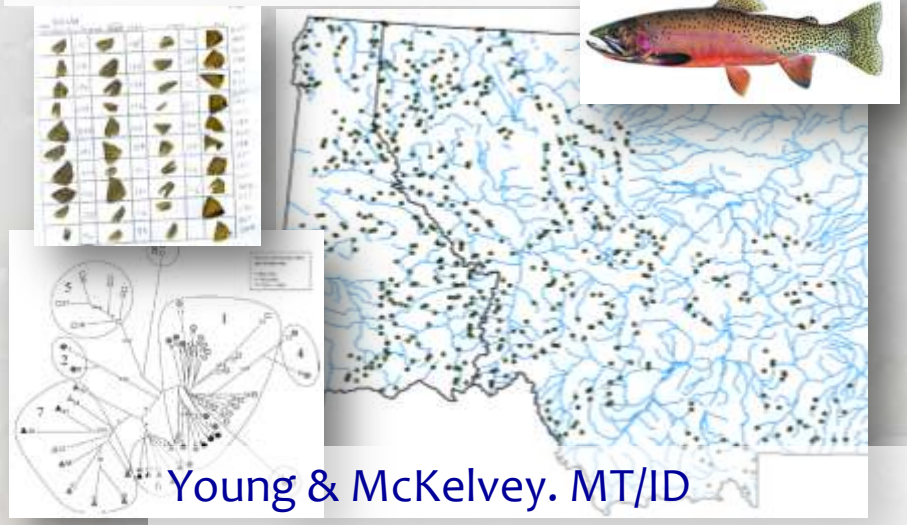
Existing Databases for Streams

Massive information extraction is possible

1) Organism Distribution & Abundance

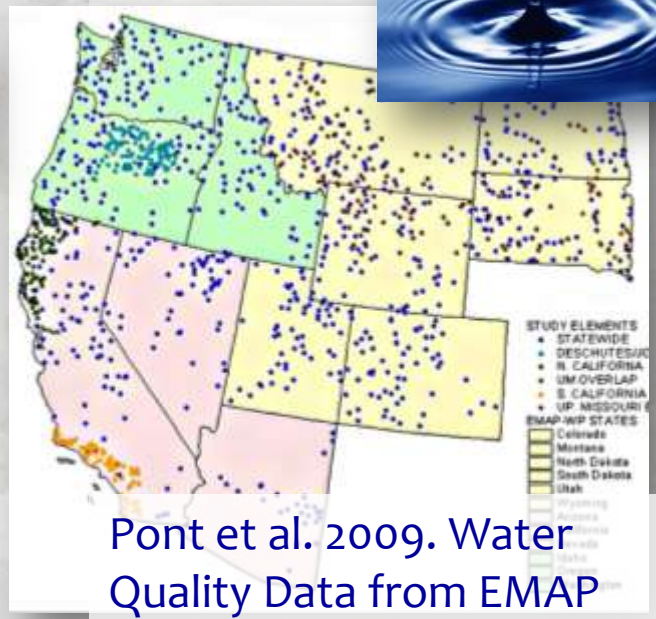


2) Genetic Attributes



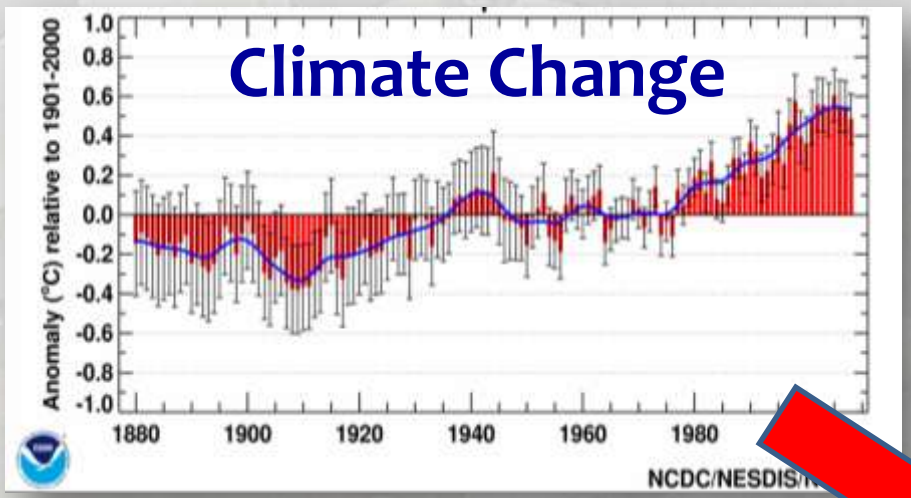
Young & McKelvey. MT/ID Cutthroat trout genetic surveys

3) Water Quality Data & TMDL Standards



Pont et al. 2009. Water Quality Data from EMAP

More With Less, but perhaps… Much More?



Urbanization & Population Growth

Shrinking Budgets

Supporting Research…

Stream Temperature Modeling Approach…

Ecological Applications, 20(5), 2010, pp. 1350–1371
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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*

A Moving Average Approach for Spatial Statistical Models of Stream Networks

Jay M. Ver Hoef and Erin E. Peterson

Journal of the American Statistical Association
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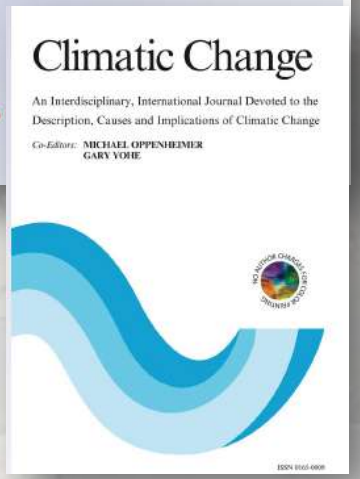
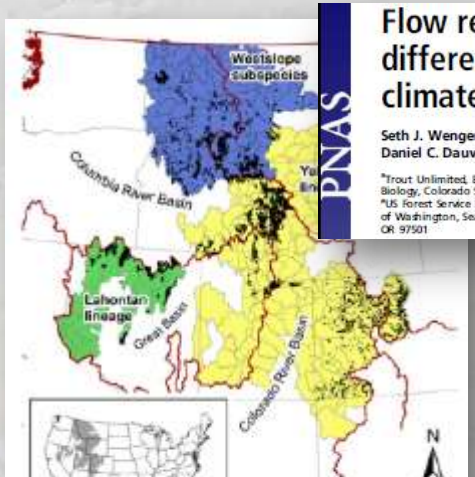
Regional Stream Temperature Trends…

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



Regional BioClimatic Assessments



PNAS

Flow regime, temperature, and biotic interactions drive differential declines of trout species under climate change

Seth J. Wenger[a,1], Daniel J. Isaak[b], Charles H. Luce[b], Helen M. Neville[a], Kurt D. Fausch[c], Jason B. Dunham[d], Daniel C. Dauwalter[a], Michael K. Young[e], Marke…

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Anticipated Climate Warming Effects on Bull Trout Habitats and Populations Across the Interior Columbia River Basin

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The End