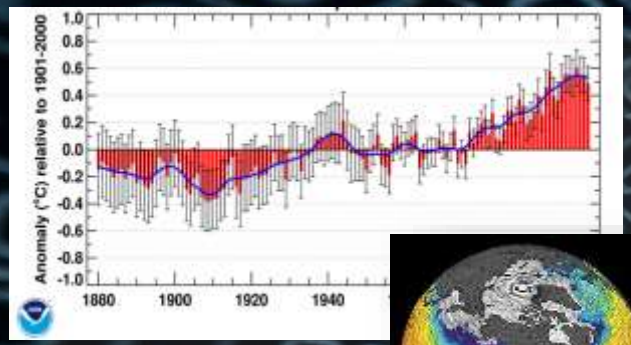
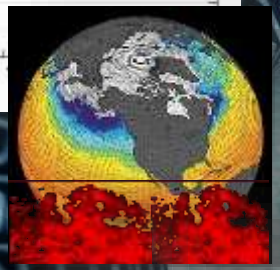
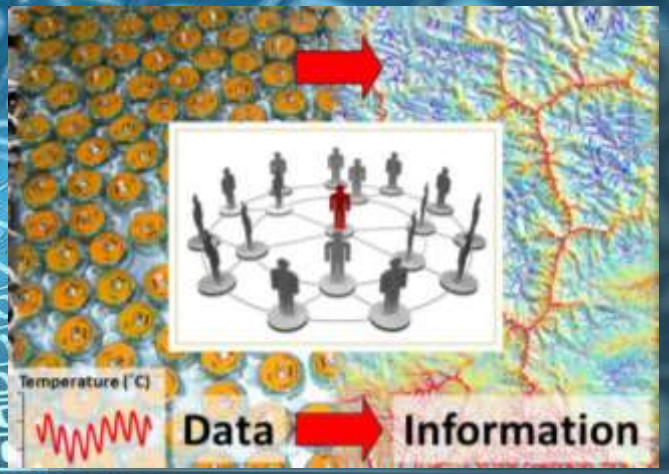
Big Data Compilations to Engage Conservation Communities and Assess Climate Change Effects On Aquatic Environments

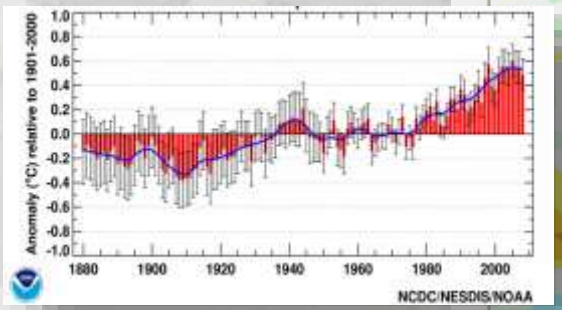
Dan Isaak, US Forest Service

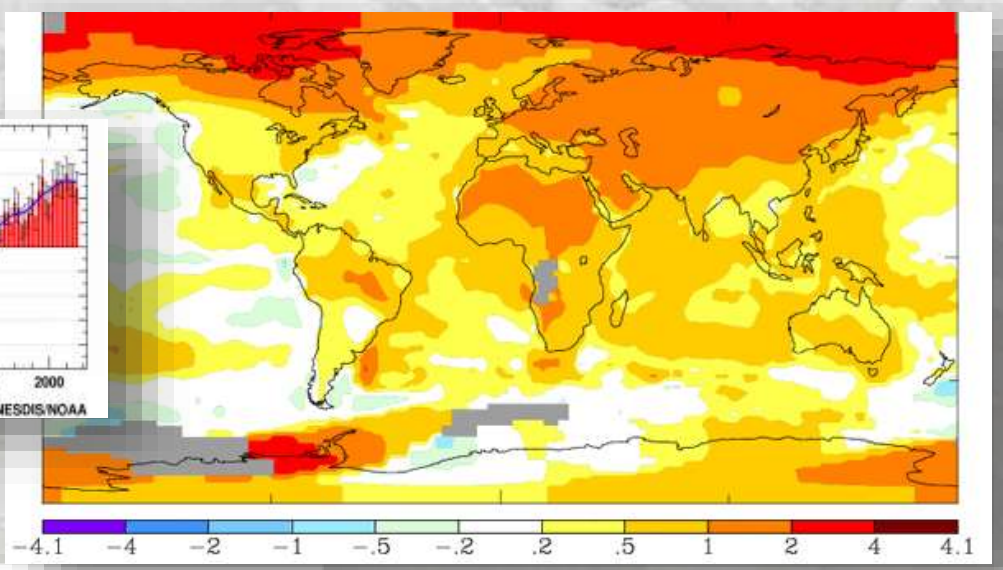




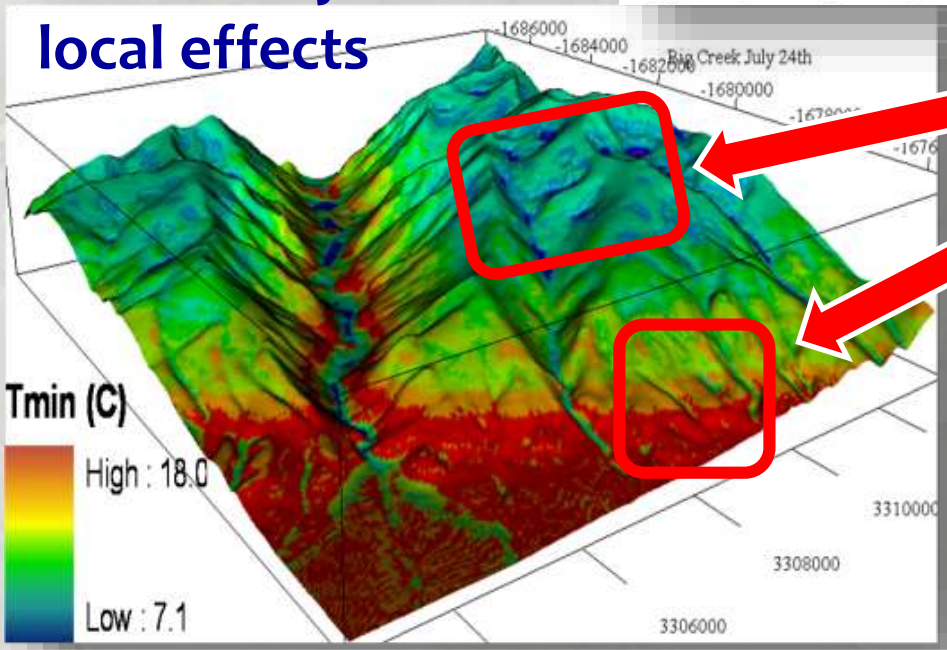


Global Phenomenon…





With idiosyncratic local effects



I'm going to invest here…

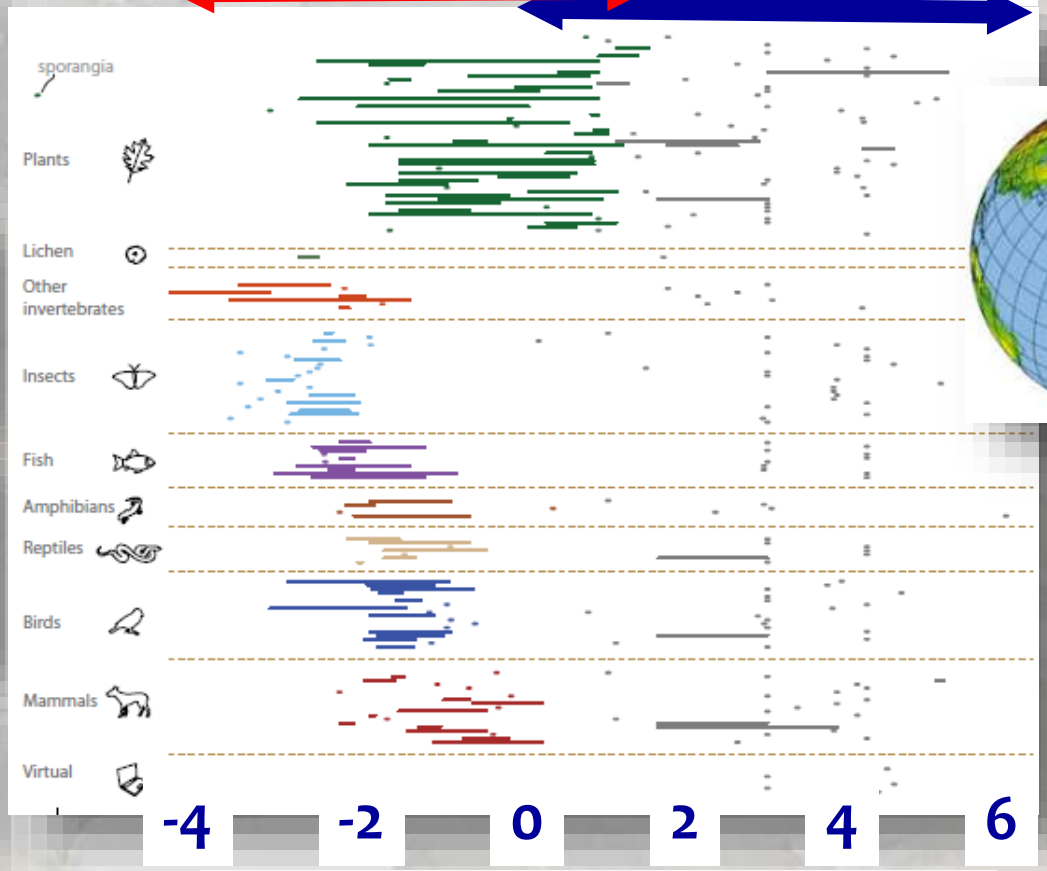
… instead of here

Adaptation requires understanding local nuance

Precise & Consistent Information Needed Across Broad Areas & Multiple Jurisdictions

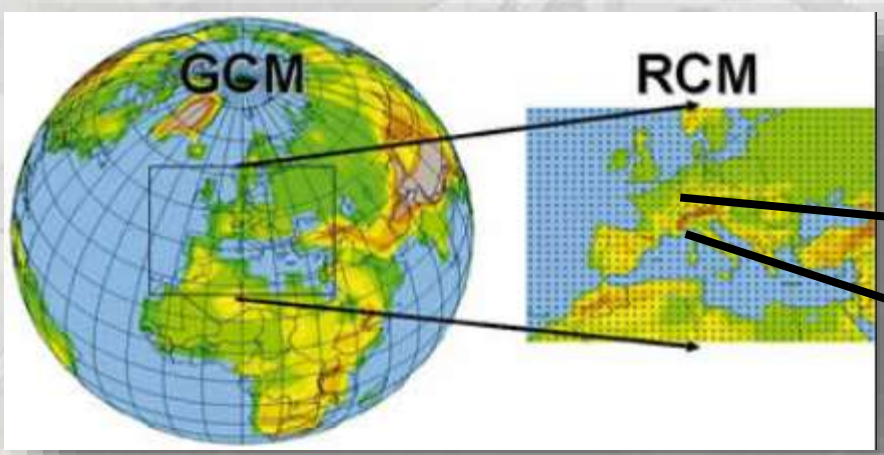
~3,500,000 km²

What's Needed vs. What's Available

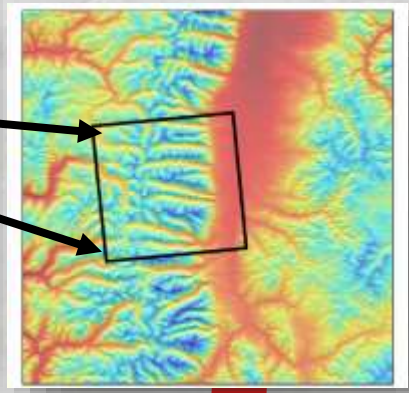


Potter et al. 2013. Microclimatic challenges in global change biology. *Global Change Biology* **19**:2932–2939.

Downscaling is Improving but Precision is Lacking

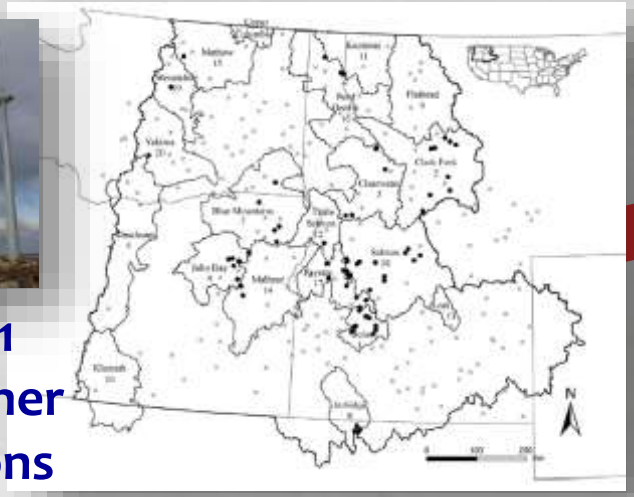


Topoclimate models (e.g., WorldClim, PRISM, DayMet)

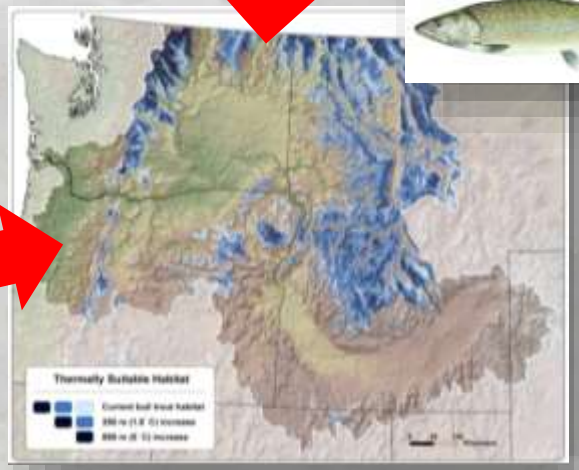


Covariates
Elevation
Slope
Aspect
Etc...

Sparse empirical support



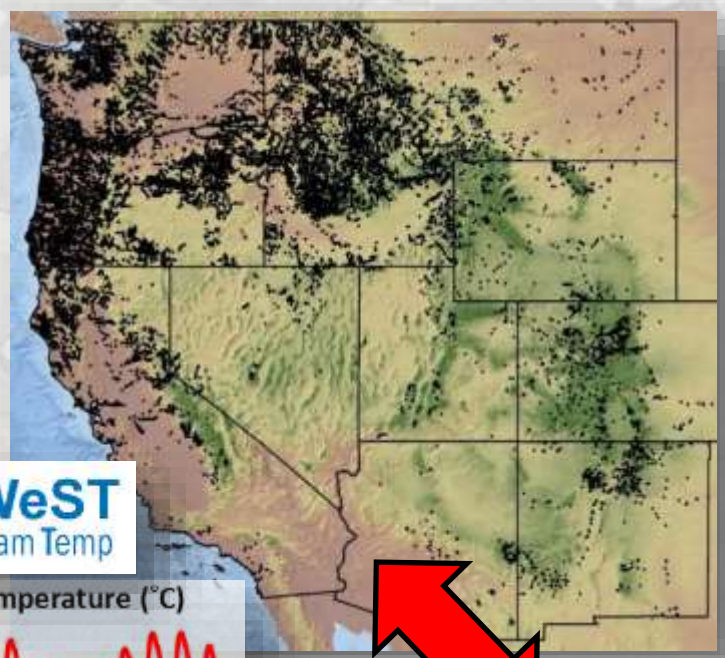
n = 191 weather stations

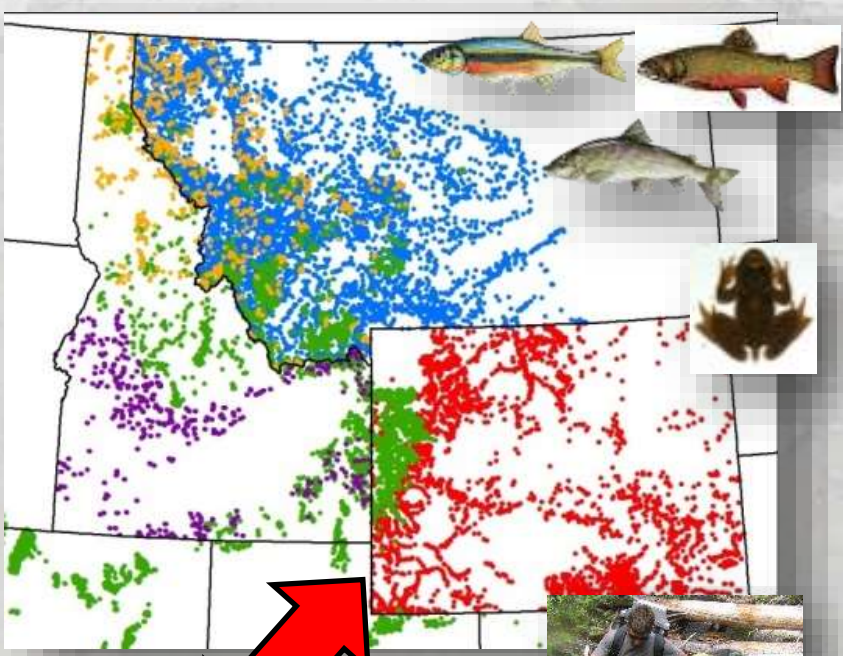


Rieman et al. 2007. Climate Warming Effects on Bull Trout Habitats and Populations Across the Interior Columbia River Basin. *TAFS* **136**:1552-1565.

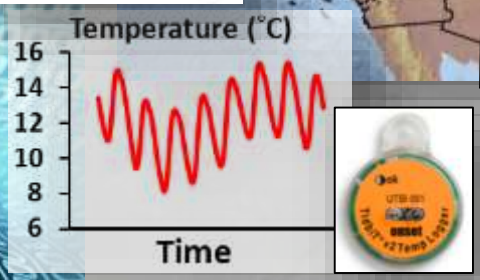
Dense Datasets Exist If Viewed Collectively

>23,000 stream temperature sites **>20,000 fish sample sites**



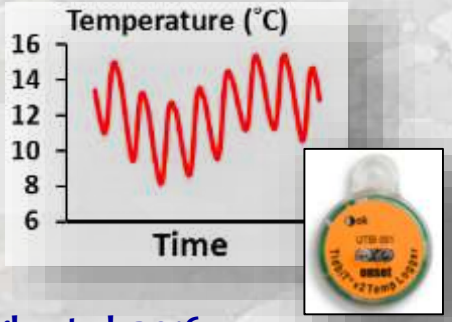


NorWeST Stream Temp



>100 agencies

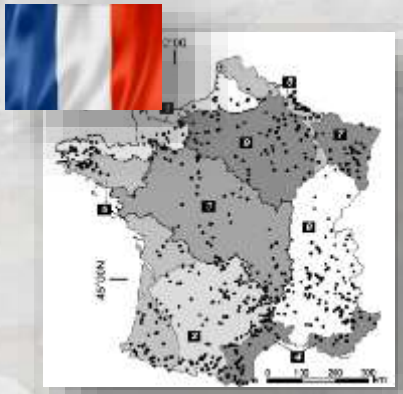
Dense Datasets Exist If Viewed Collectively



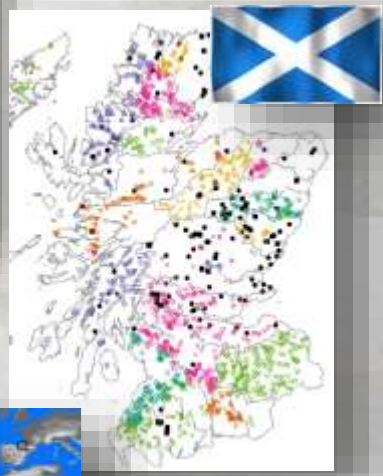
Daigle et al. 2016

Arora et al. 2016

Buisson et al. 2008

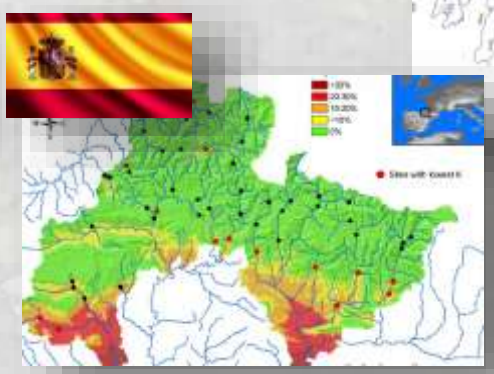


Millar et al. 2016



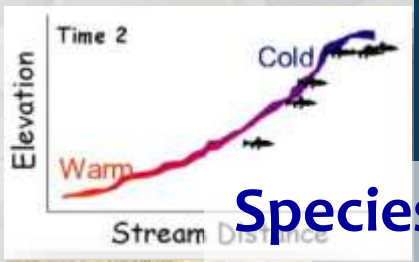
Molinero et al. 2015

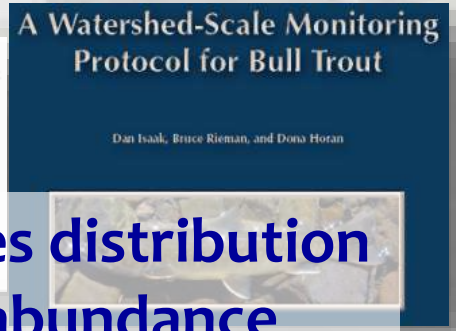
Hannah & Garner 2015



Ayllon et al. 2013

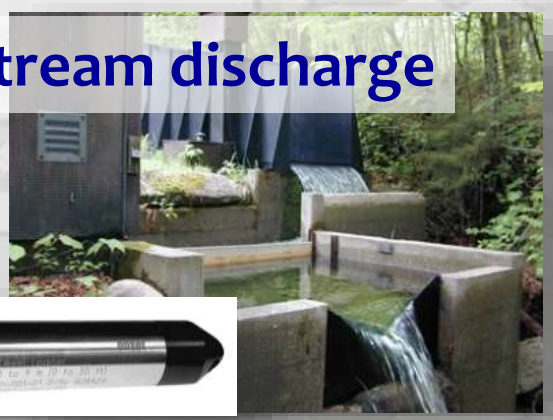
Many Groups Collect Similar Types of Data with Standard Protocols & Sensors…





Species distribution & abundance

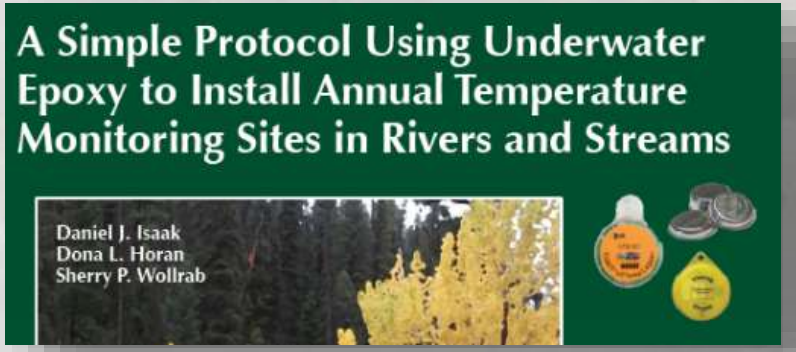
Stream discharge



Tissue Samples & DNA barcoding

Water Chemistry

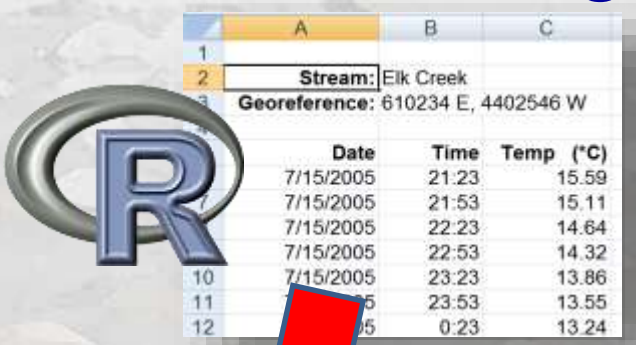
Water Temperature



Data ≠ Database

Data Aggregation

QA/QC Data Cleaning



	A	B	C
1			
2	**Stream:**	Elk Creek	
3	**Georeference:**	610234 E, 4402546 W	
	Date	**Time**	**Temp (°C)**
	7/15/2005	21:23	15.59
	7/15/2005	21:53	15.11
	7/15/2005	22:23	14.64
	7/15/2005	22:53	14.32
10	7/15/2005	23:23	13.86
11		23:53	13.55
12		0:23	13.24

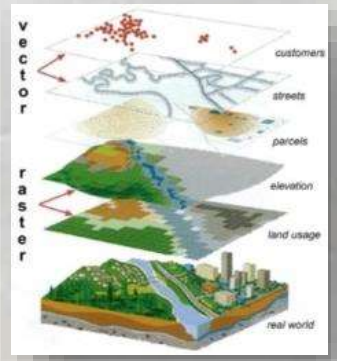
Data Summaries & Georeferencing

Mean

Minimum

Maximum

Metadata & Digitally Archiving



Creating & Maintaining Big Databases is a Full-Time Job for Technical Experts

Geospatial databases

Relational databases

Statistical analysis & summaries

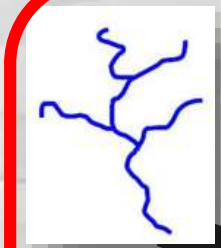
Microsoft Access

ORACLE DATABASE

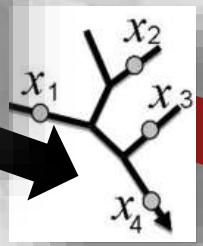
R

sas

Big Data Requires Expanding the Traditional Aquatic Science Model

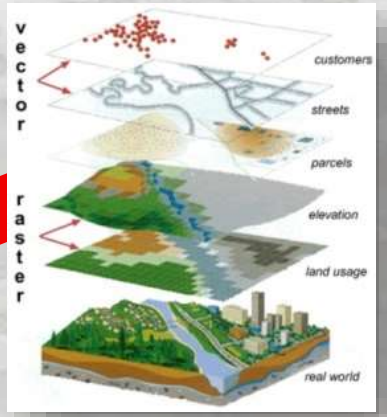


Modelers



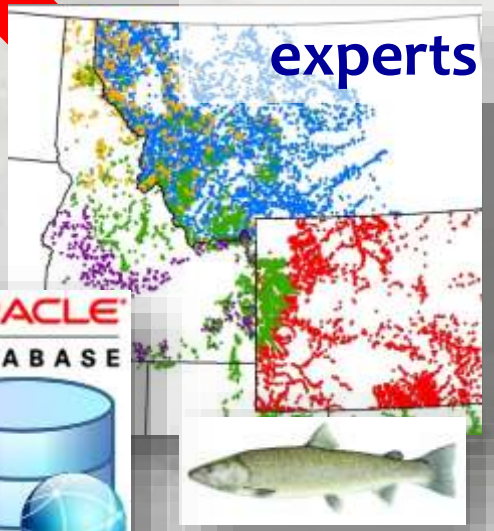
Scientists

GIS analysts



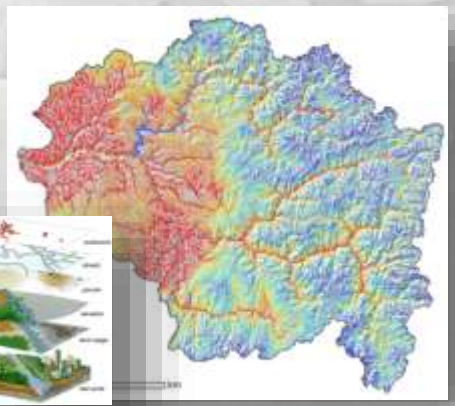
Webdesigner

Database experts

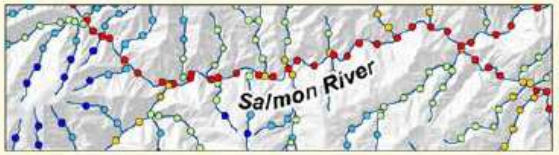


Custom Websites Make Data Available to User-Communities & Engages Them

GIS shapefiles of stream temperature scenarios



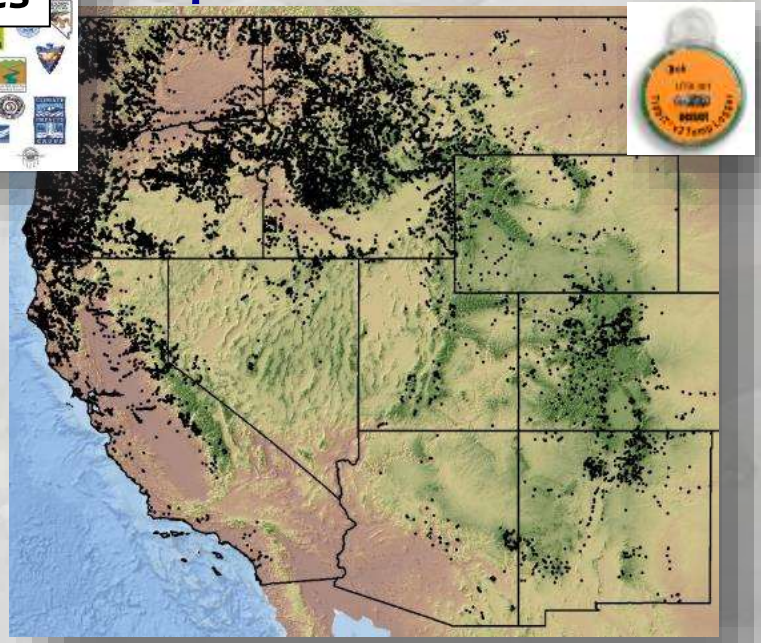
NorWeST Stream Temp



Regional Database and Modeled Stream Temperatures

>100 agencies

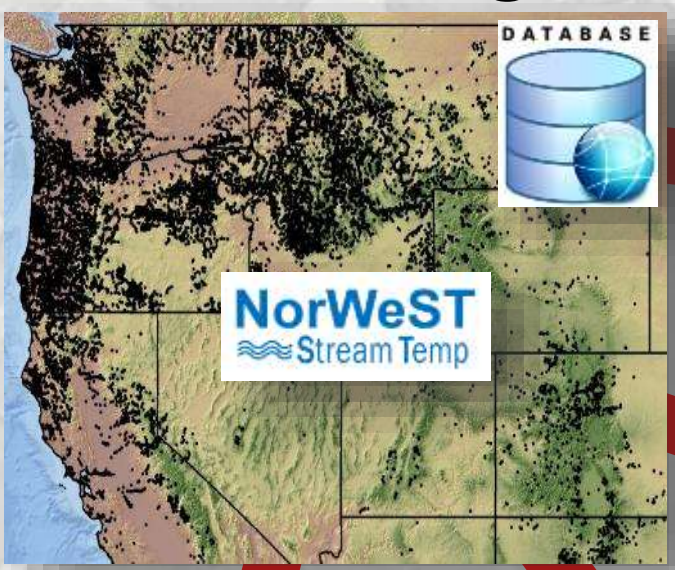
Temperature data summaries



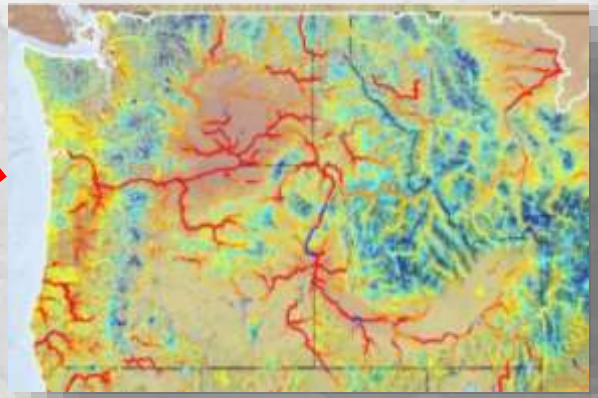
40-50 visits/day

12,000 visits/year

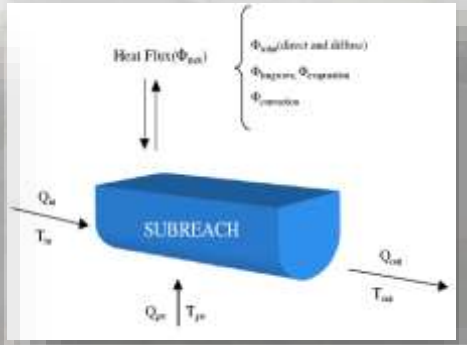
Comprehensive, Open-Access Databases Create Synergies

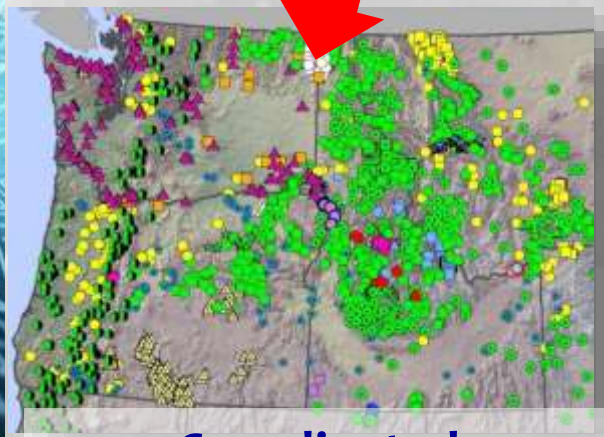


High Resolution Scenarios

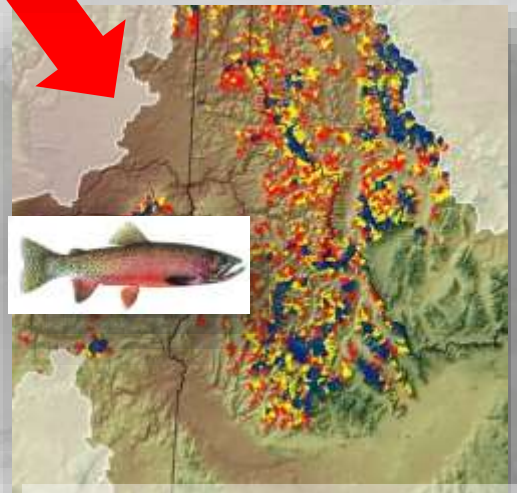


Data access accelerates temperature research



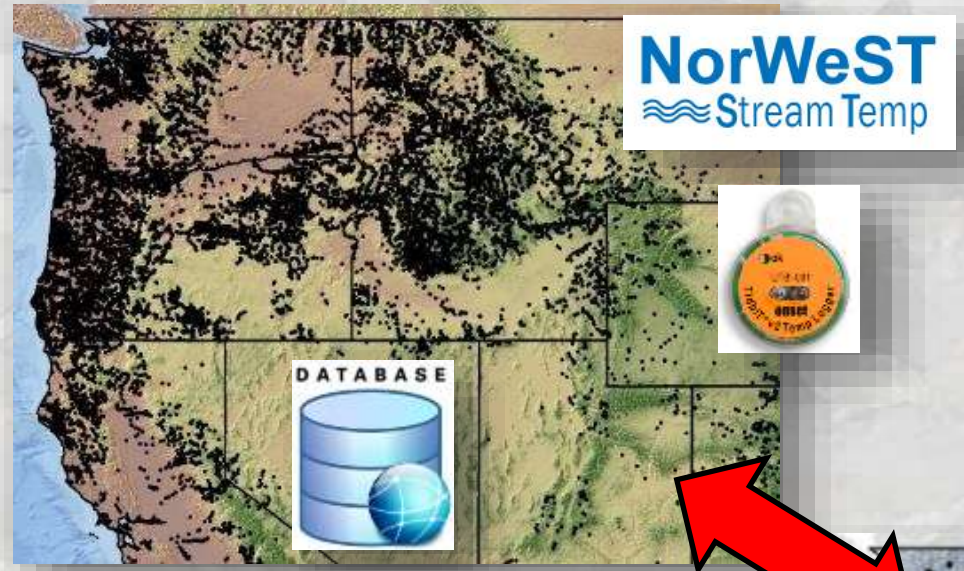


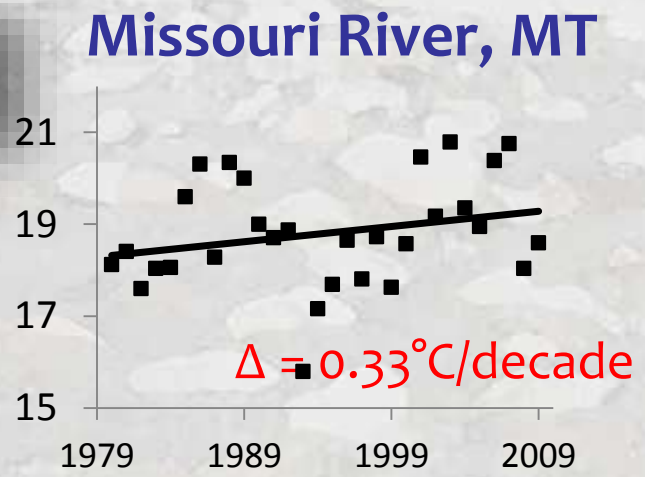
Coordinated Interagency monitoring

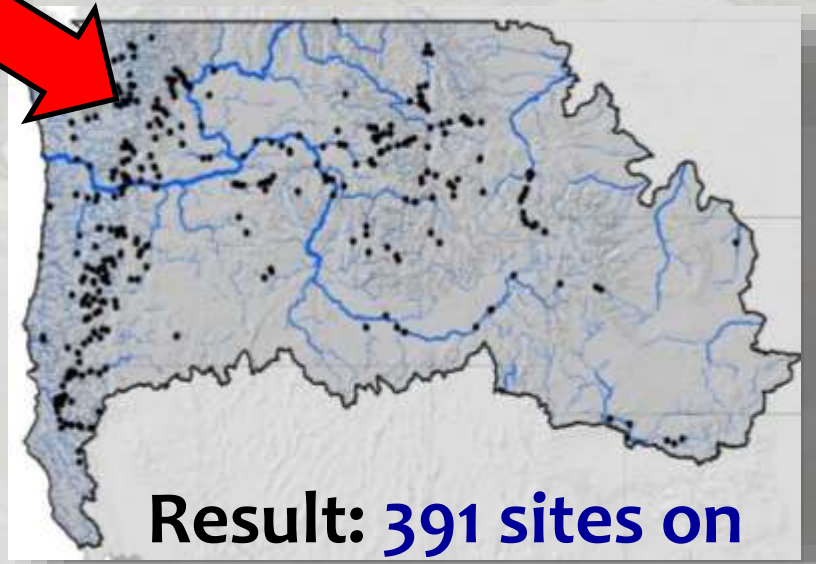


Species distribution models

Question: At What Rate is Climate Change Warming Rivers in the Western US?







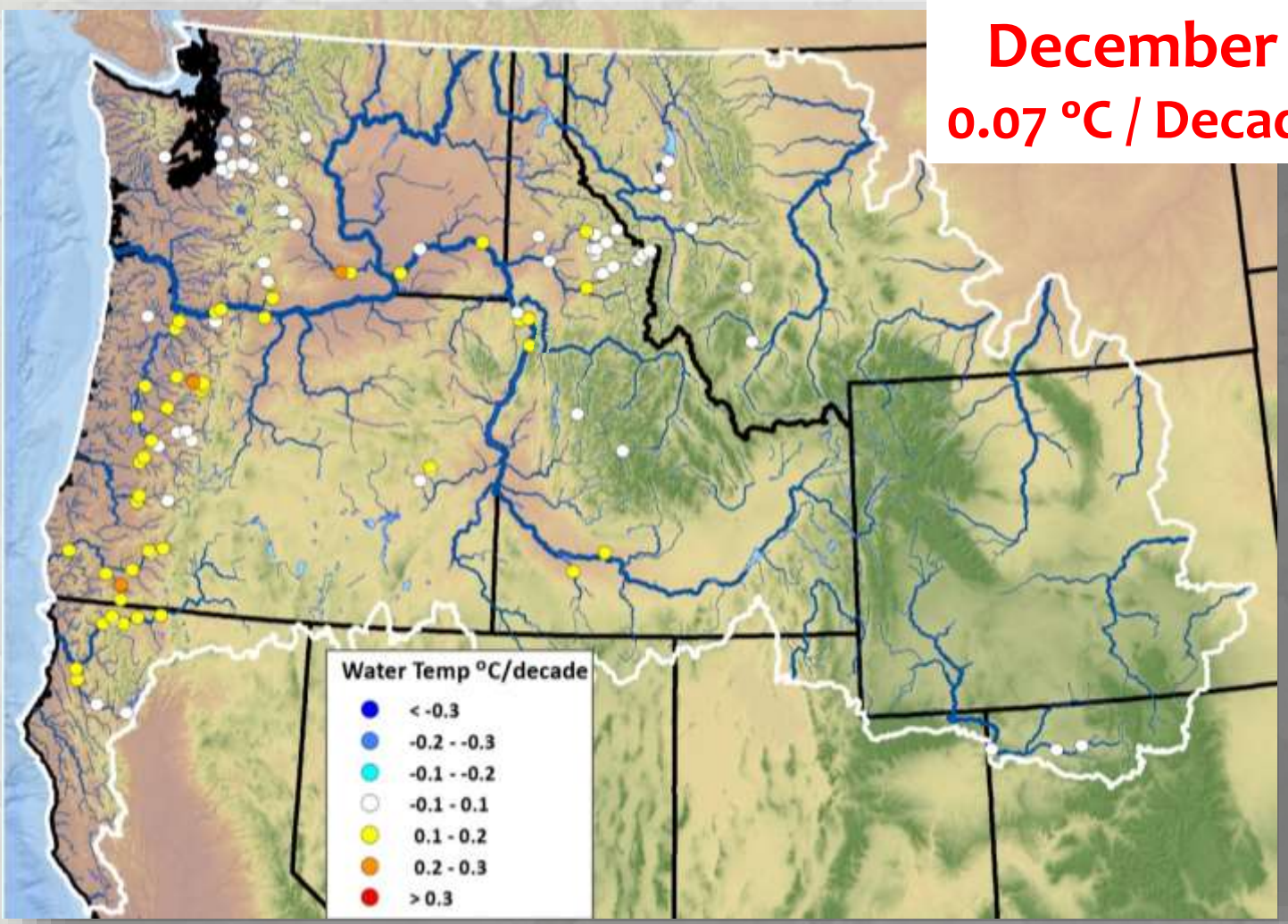
Database query:

1) Sites with >10 years of monitoring

2) Sites that occur on rivers with >100 cfs flow

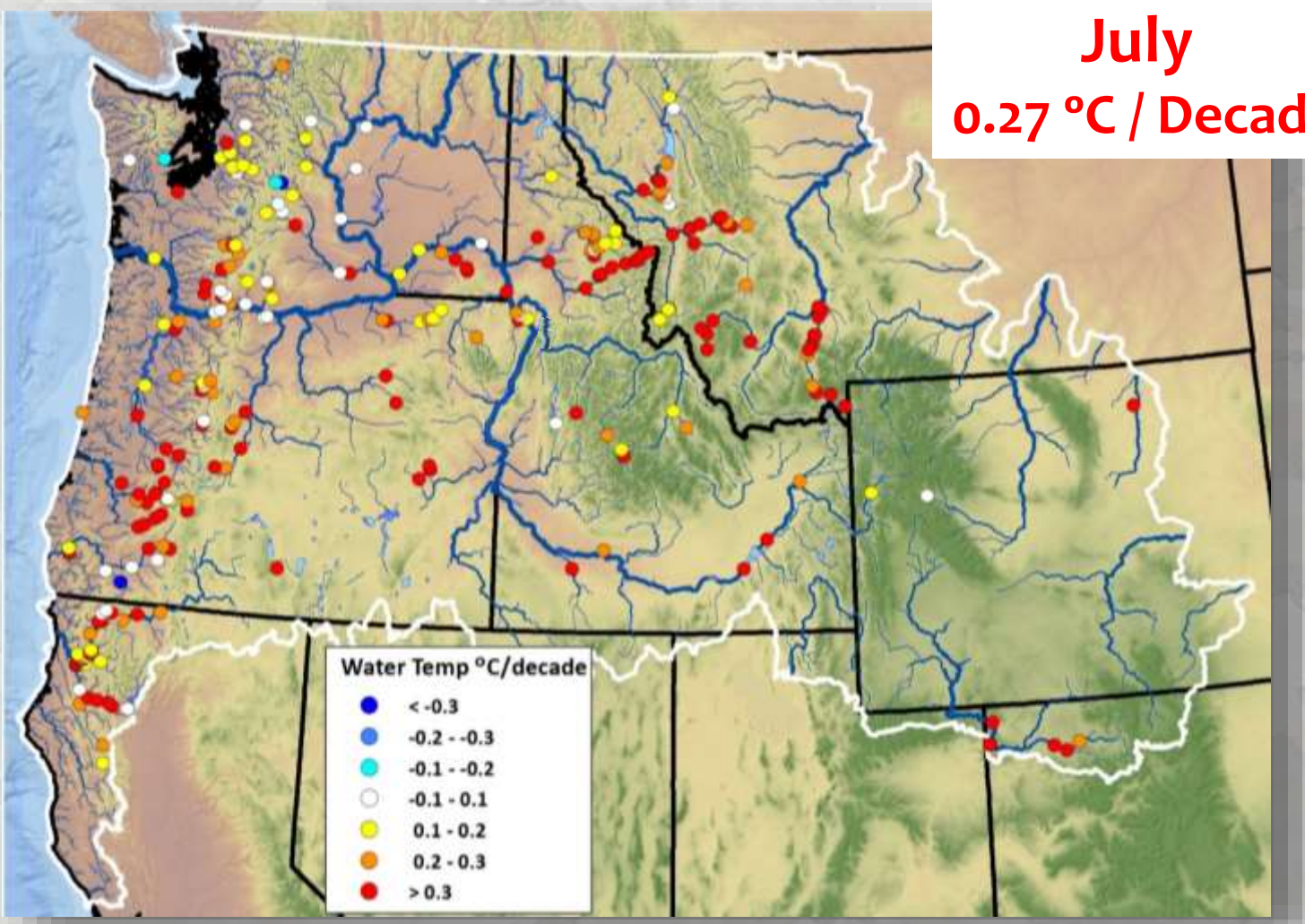
Result: 391 sites on 56,000 river km

River Temperature Trends (1976–2015)



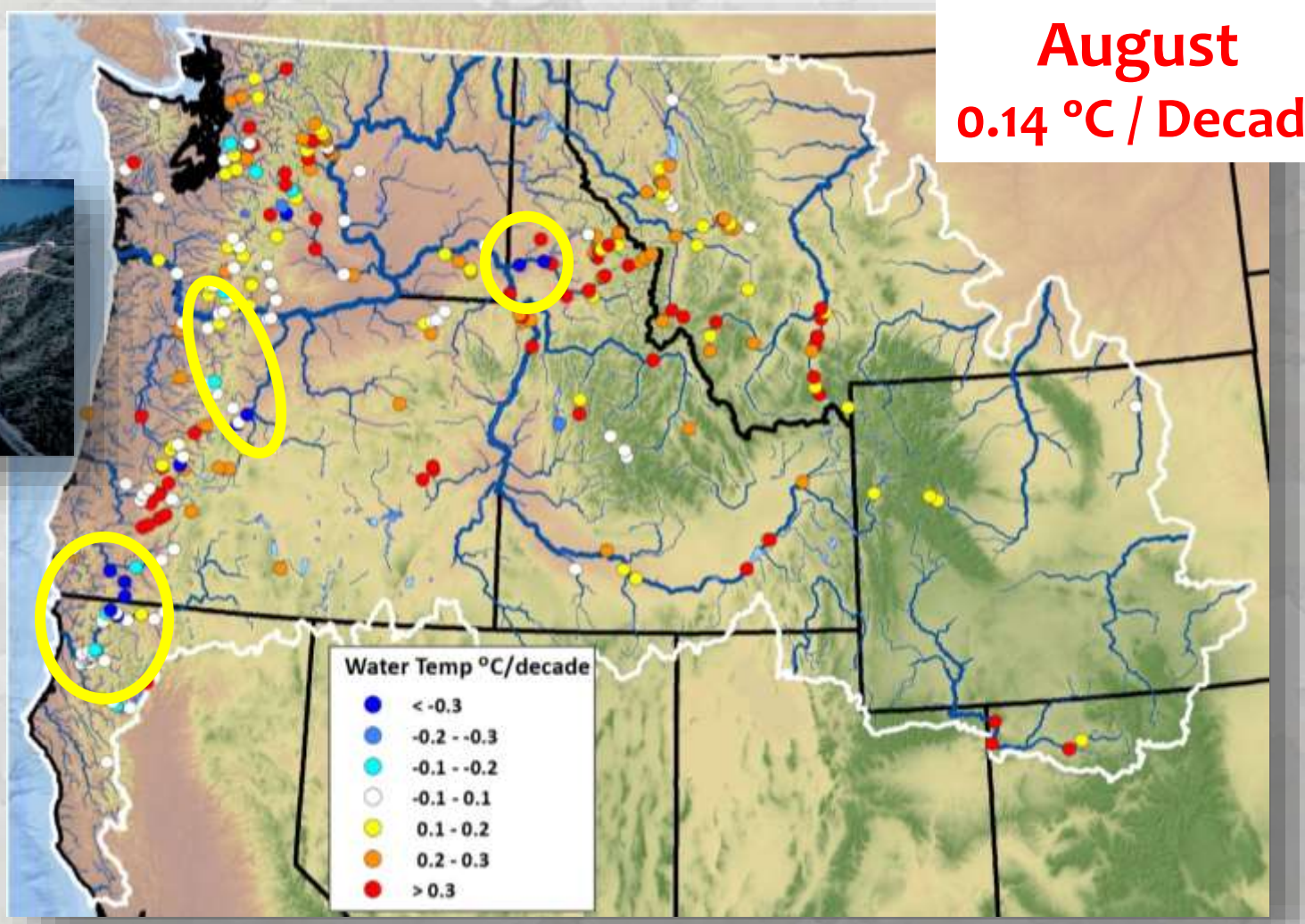
Isaak et al. In Review. Global warming of salmon and trout rivers: Road to ruin or path through purgatory? *Transactions of the American Fisheries Society.*

River Temperature Trends (1976–2015)



Isaak et al. In Review. Global warming of salmon and trout rivers: Road to ruin or path through purgatory? *Transactions of the American Fisheries Society.*

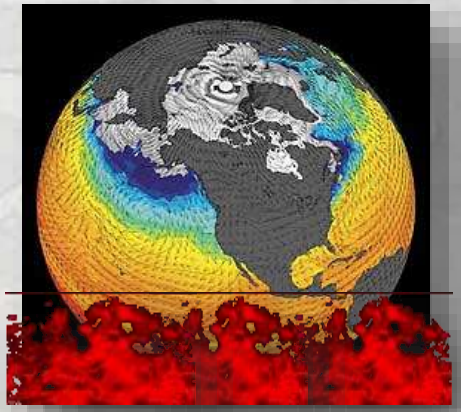
River Temperature Trends (1976–2015)



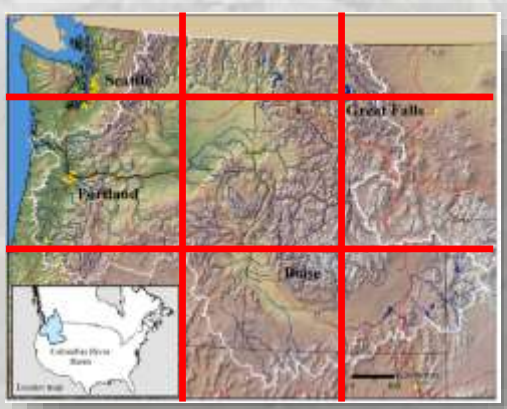
Isaak et al. In Review. Global warming of salmon and trout rivers: Road to ruin or path through purgatory? *Transactions of the American Fisheries Society.*

Need: High-Resolution Climate Scenarios

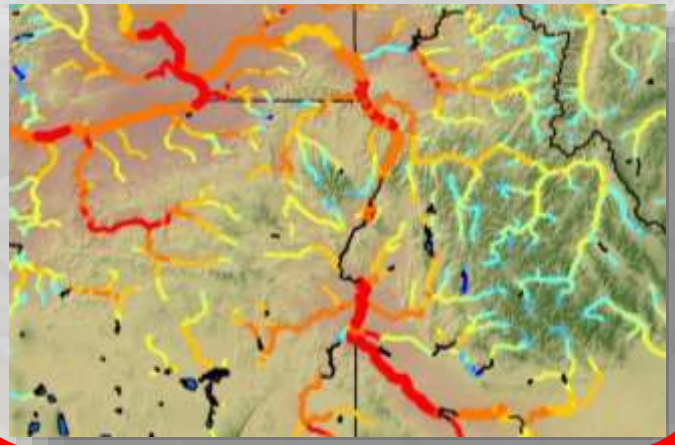
Global climate model
Resolution: 1000's of kilometers



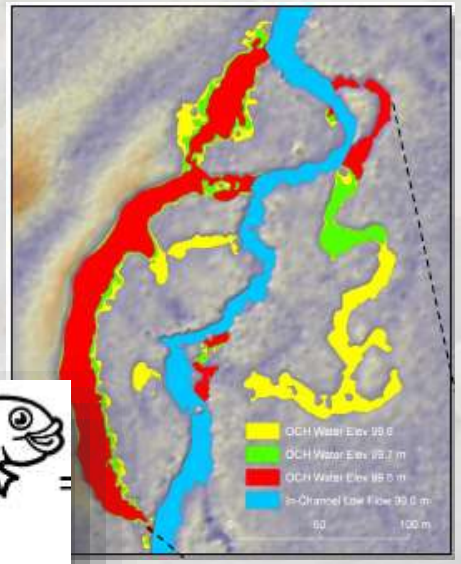
Regional climate model
Resolution: 100's of km

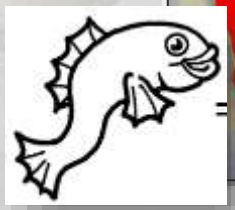


River network: 10's of km



Stream reaches: 1's of km

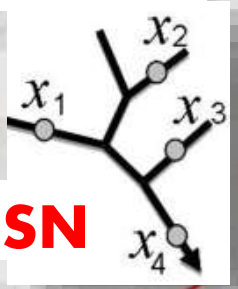




Database Query: Dataset for Modeling

n = 63,461 August Temperature Observations

$$y = X\beta + L\gamma + R\eta + z_{TU} + z_{TD} + z_{EUC} + \varepsilon,$$



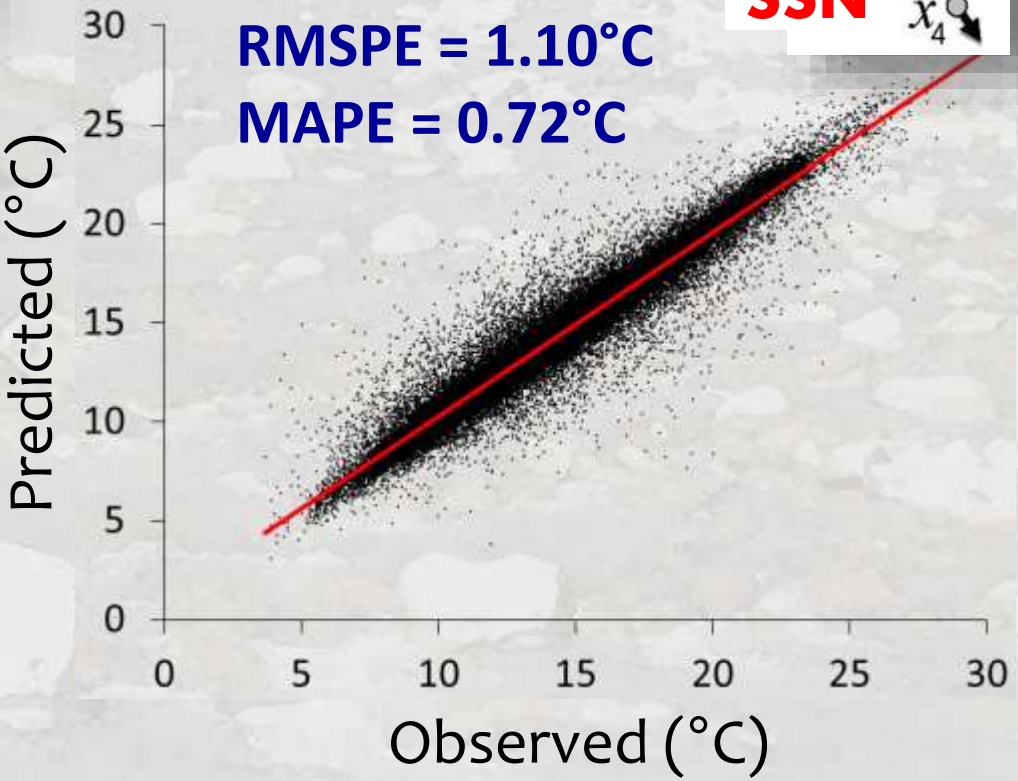
Covariate Predictors

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 (km²)
10. Discharge (m³/s)
11. Air Temperature (˚C)

$r^2 = 0.91$

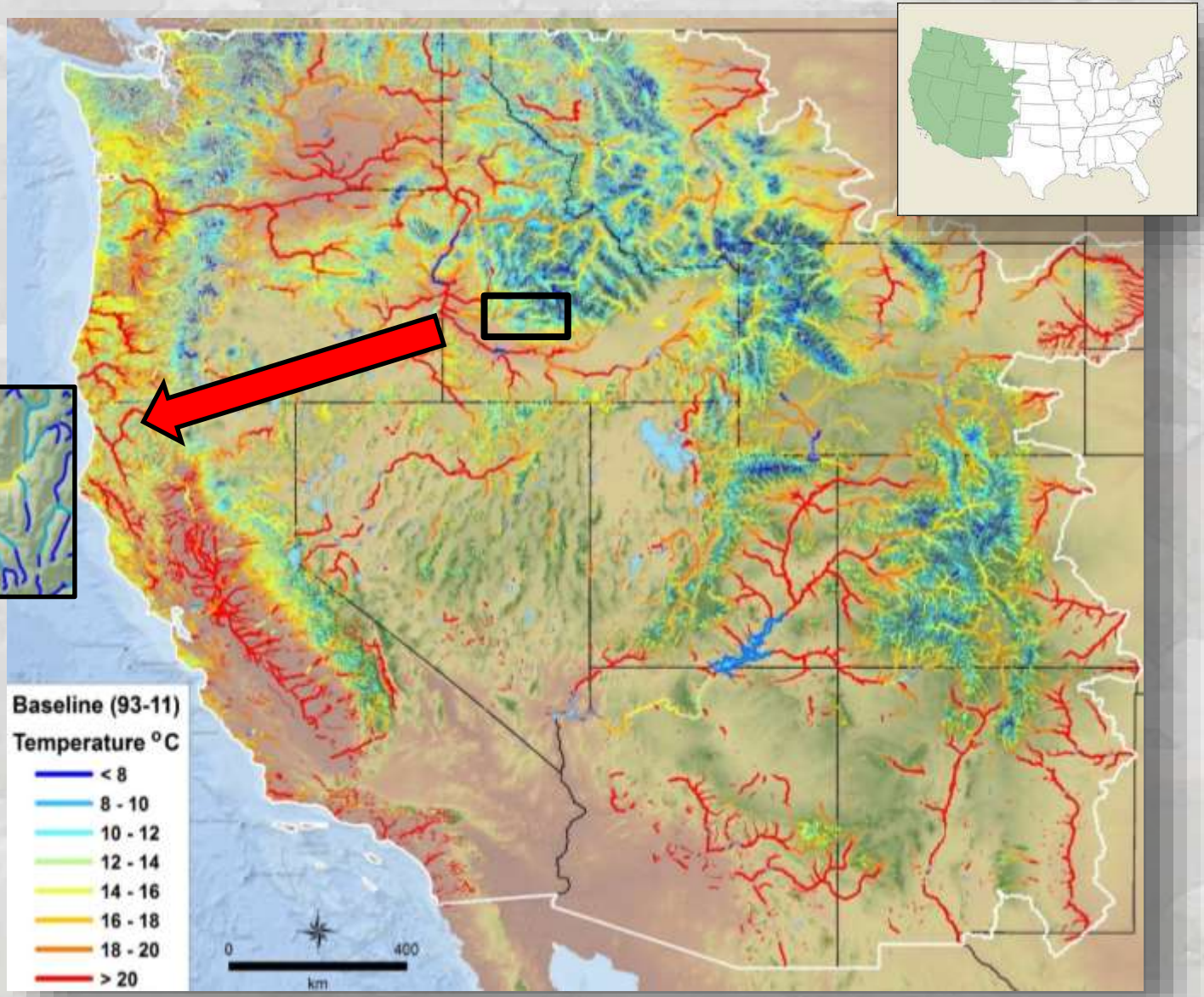
RMSPE = 1.10°C

MAPE = 0.72°C



High-Resolution Stream Climate Scenarios

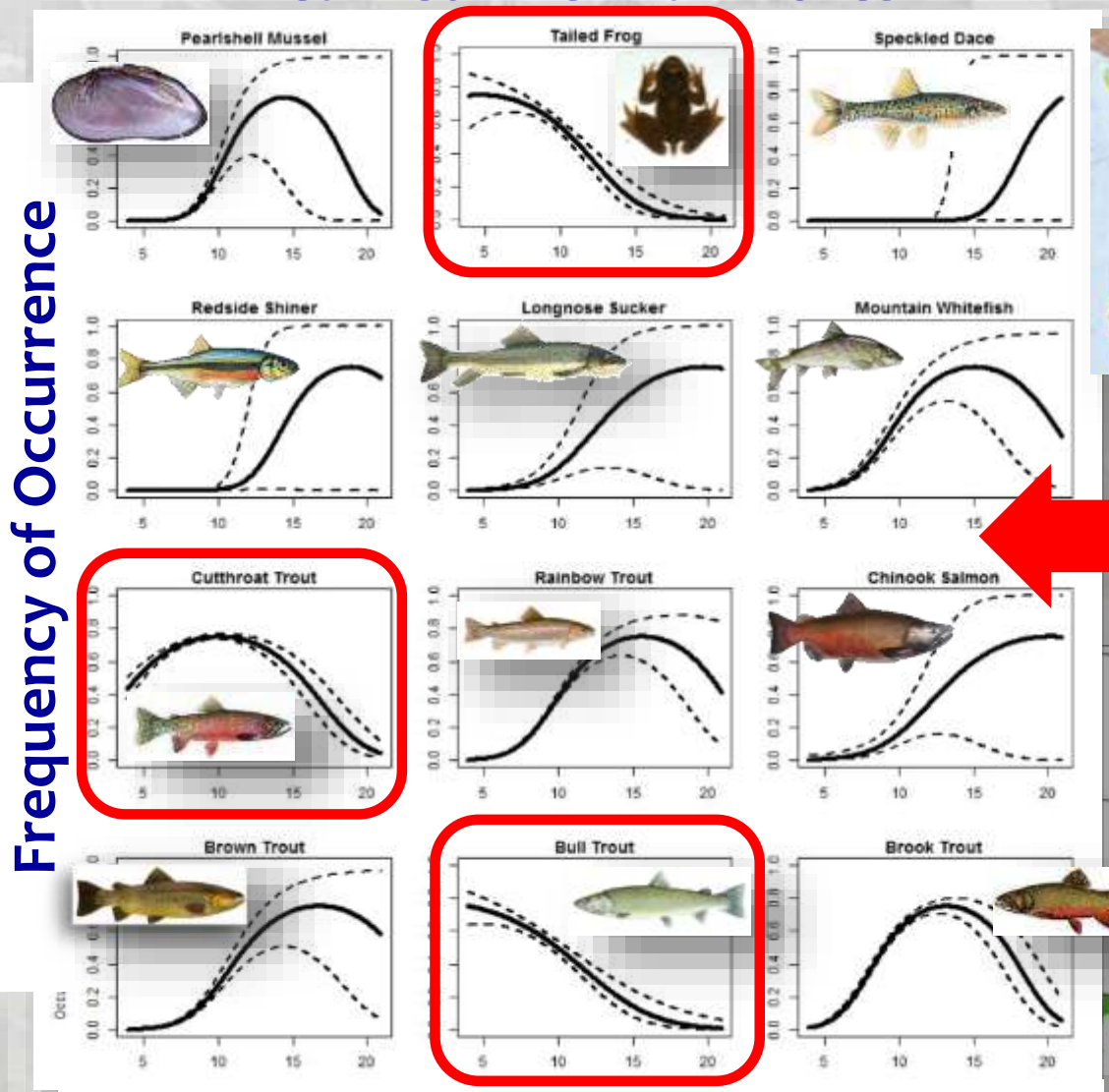
1-km resolution
400,000 km of rivers & streams

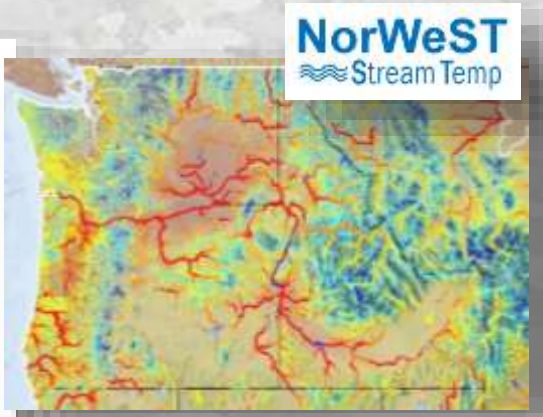


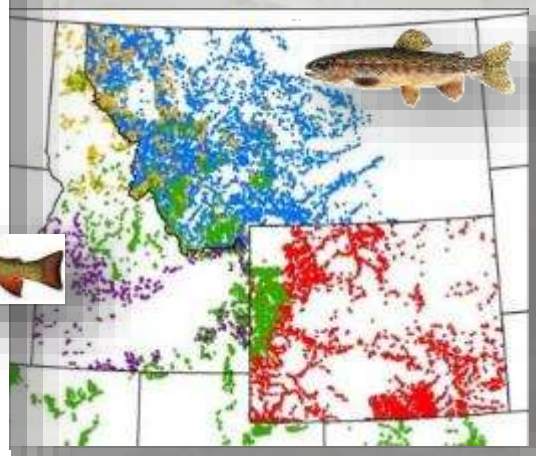
Isaak et al. 2017. The NorWeST summer stream temperature model & scenarios for the western U.S. *Water Resources Research* **53**: 9182-9205.

Combining Big Databases Creates Synergy

Realized Thermal Niches



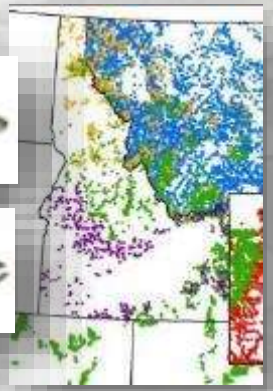




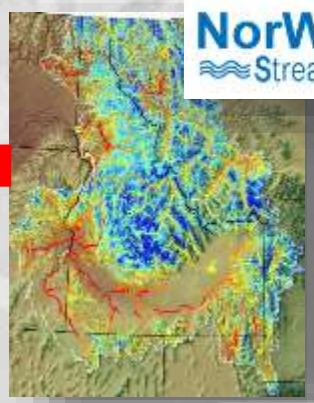
NorWeST Stream Temperature

Isaak et al. 2017. Big biology meets microclimatology. *Ecol. Apps.* **27**:977-990.

Precise Species Distribution Models to Highlight Climate Refugia



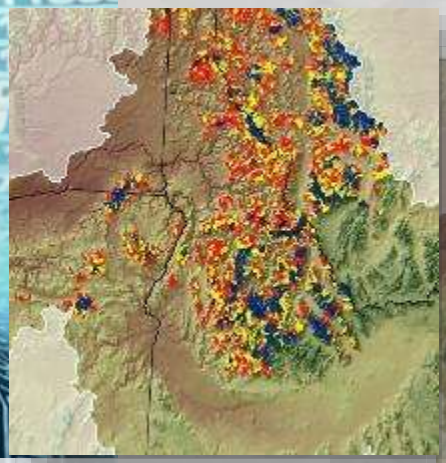
NorWeST Stream Temp



Additional Covariates

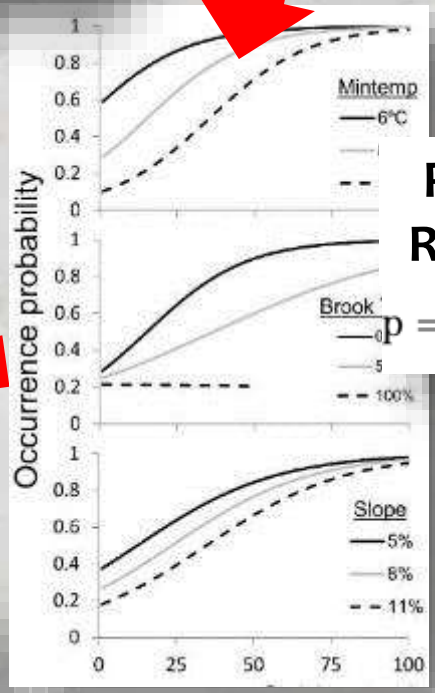
1. Elevation (m)
2. Stream slope (%)
3. Lakes upstream (%)
4. Baseflow Index
5. Watershed size (km²)

Climate Shield



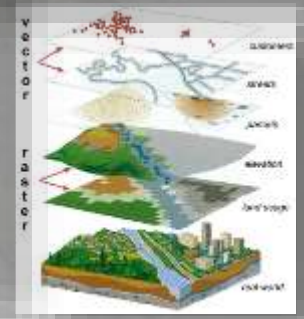
Occurrence probability maps

>0.9 >0.5 >0.1



Predictive Logistic Regression Models

$$p = \frac{\exp(a + bx \ldots ny)}{(1 + \exp[a + bx \ldots ny])}$$



Isaak et al. 2015. The cold-water climate shield: Delineating refugia for preserving native trout through the 21st Century. *Global Change Biology* **21:** 2540-2553

Bull Trout Probability Map

2000s

Stream population scale predictions

>0.9 >0.5 >0.1

5,332 >0.1 habitats
1,325 >0.5 habitats
348 >0.9 habitats

Bull Trout Probability Map

2040s

>0.9 >0.5 >0.1

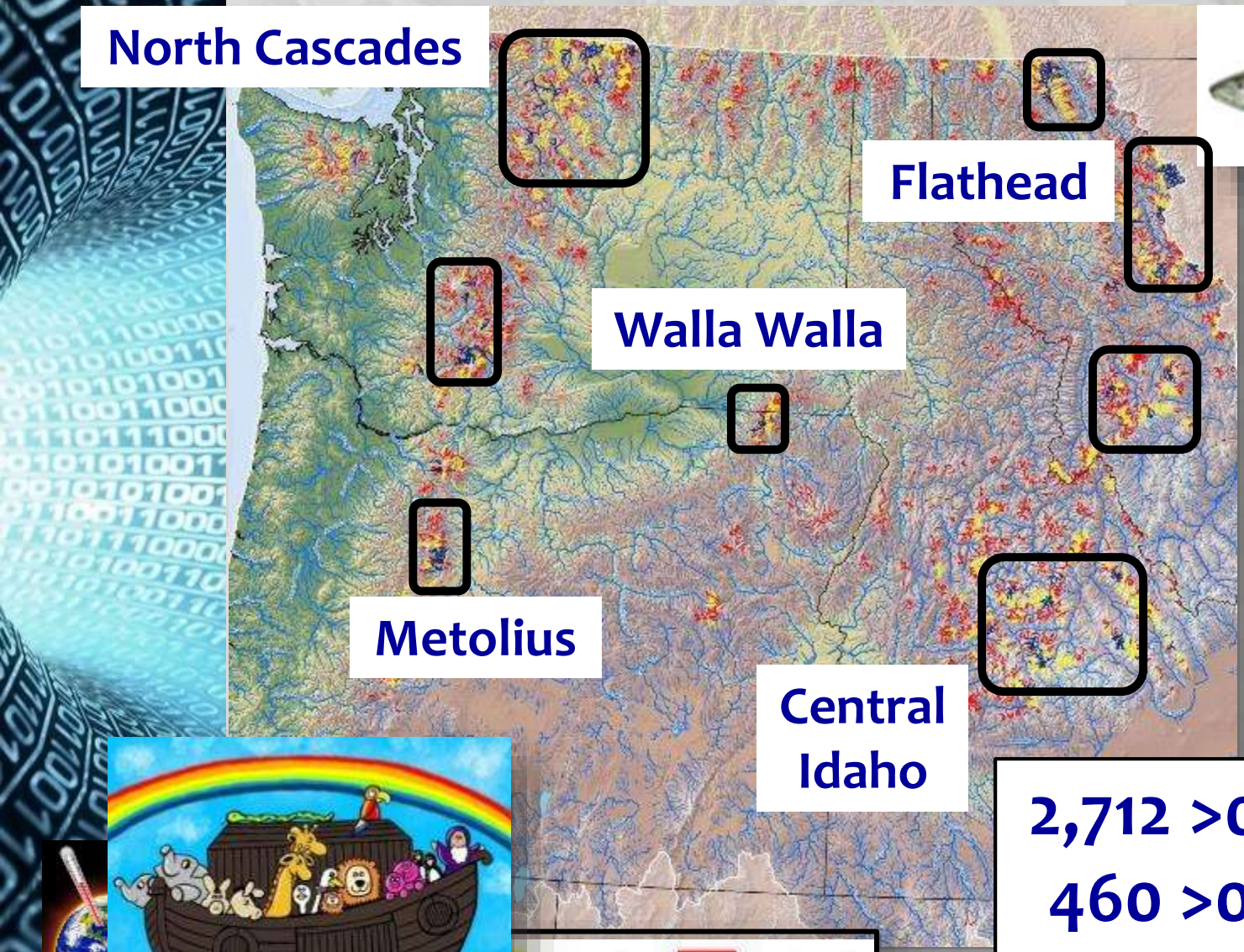
3,304 >0.1 habitats

641 >0.5 habitats

130 >0.9 habitats

Bull Trout Probability Map

2080s



Extreme scenario!
+5°C

Extinction not Likely

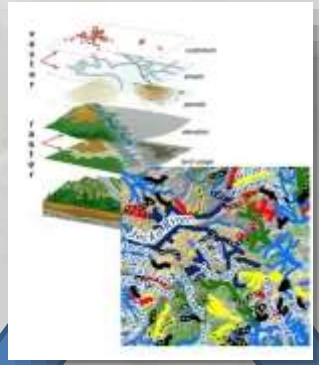
2,712 >0.1 habitats
460 >0.5 habitats
62 >0.9 habitats

Website Provides Information in User-Friendly Digital Formats

Just Google "Climate shield trout"

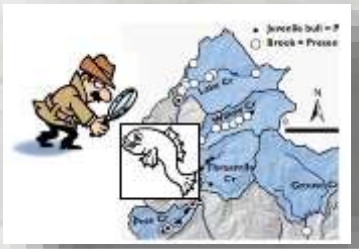
Presentations & Publications

Digital Maps & ArcGIS Shapefiles



Fish Data Sources

Distribution Monitoring



File formats:

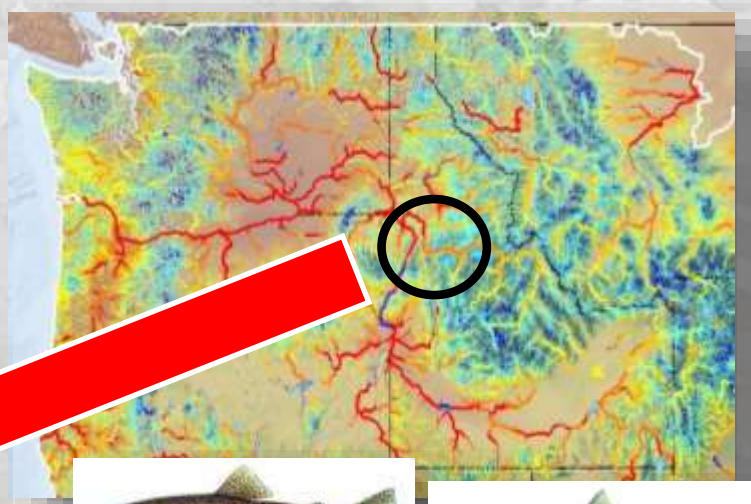
- ArcGIS files
- pdf files

15 Scenarios:

- 3 climate periods
- 5 Brook invasion levels

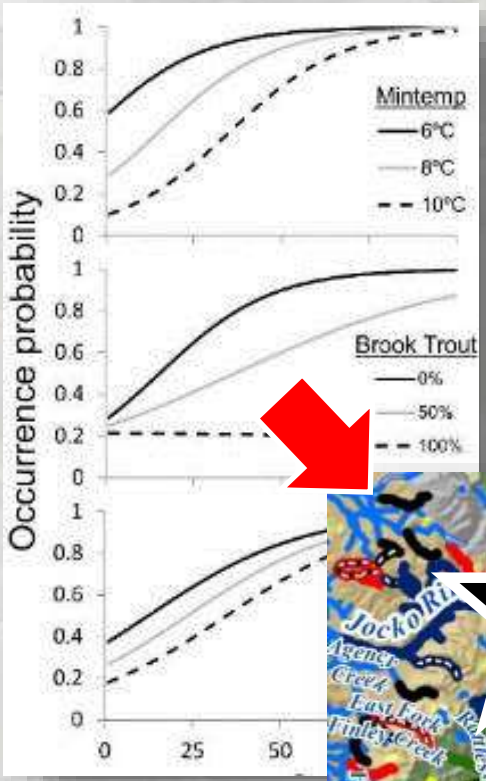
Precise Information Across Broad Scales

Empowers local decision makers & facilitates efficient coordination



Highest priority conservation investment!

Goal: Big Data & Precise Models for all Species in all Streams, Rivers, Lakes, Ponds, etc.



I'm going to invest here…

Aquatic eDNA Revolution: Water Samples Contain the DNA of All Species

Comprehensive Biodiversity Archive









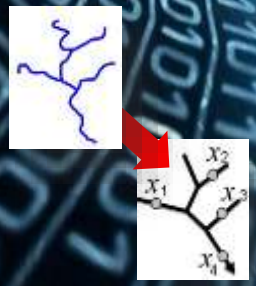



One Person Can Sample Many Sites Rapidly

- 20 minutes to collect a sample
- All sampling equipment is carried in a daypack

Bull trout eDNA survey
St. Joe River (266 sites)

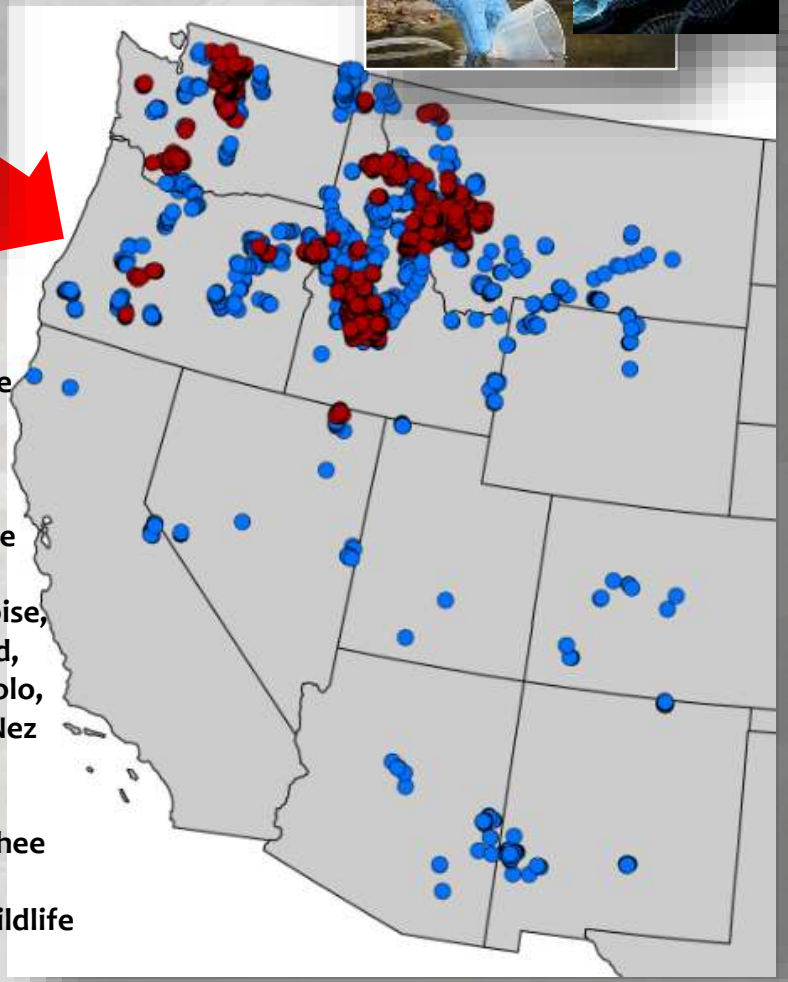
Detection
No detection



eDNAtlas Database for the Western U.S.

Online this winter with 10,000 samples

Update database with thousands of new samples annually



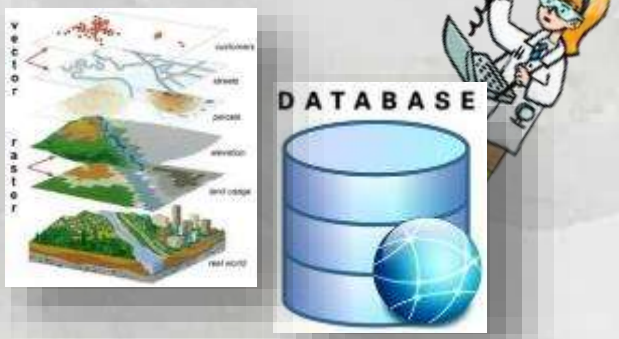
Partner Agencies

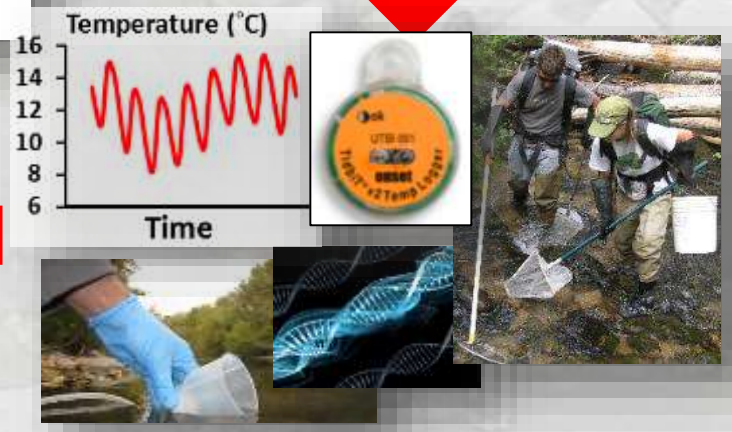
BLM
Bureau of Reclamation
Chehalis Tribe
Clark Fork Coalition
Coeur d'Alene Tribes
Great Northern LCC
Idaho Conservation League
Idaho DEQ
Idaho Fish and Game
Idaho Power Company
Kalispel Tribes
Montana Dept. Natural Resources Conservation
Montana Fish, Wildlife & Parks
National Fish & Wildlife Foundation
The Nature Conservancy
National Park Service
Oregon Dept. Fish & Wildlife
Shoshone-Bannock Tribes
Trout Unlimited
University of Washington
U.S. Fish and Wildlife Service
USFS National Forests: Beaverhead-Deer Lodge, Boise, Colville, Deschutes, Flathead, Helena, Idaho Panhandle, Lolo, Mount Baker-Snoqualmie, Nez Perce-Clearwater, Payette, Salmon-Challis, Sawtooth, Wallowa-Whitman, Wenatchee
USFS Regions 1, 4, and 6
Washington Dept. Fish & Wildlife
Yakama Nation

Open-Access Big Databases are Cost-Effective & *Engage Everyone*

Many stakeholders

"Boots-on-the-Ground"





Research develops databases & relevant information

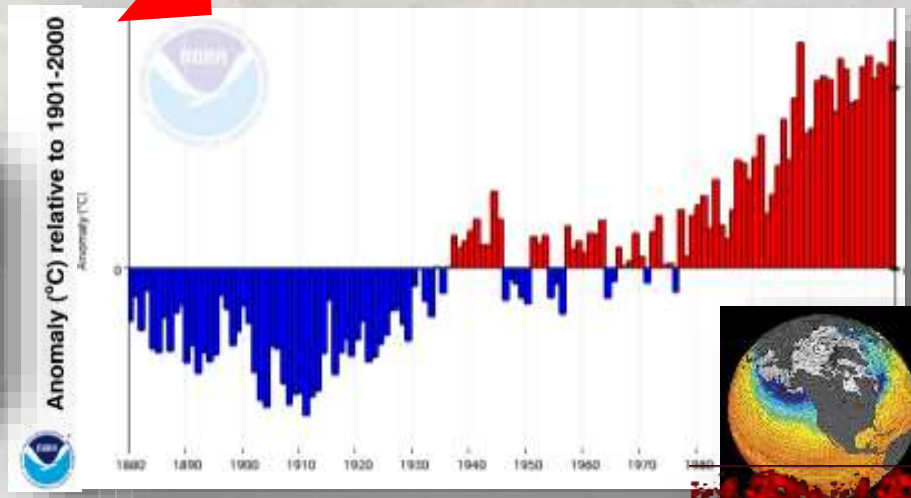
Standard data protocols

Better Information Enables Better Adaptation, Conservation & Management…

Urbanization & Population Growth

Habitat degradation

Climate Change




The End