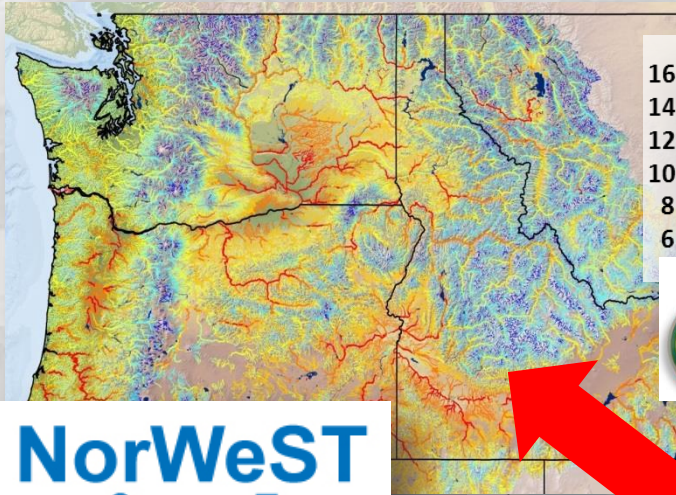
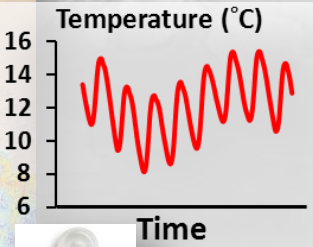


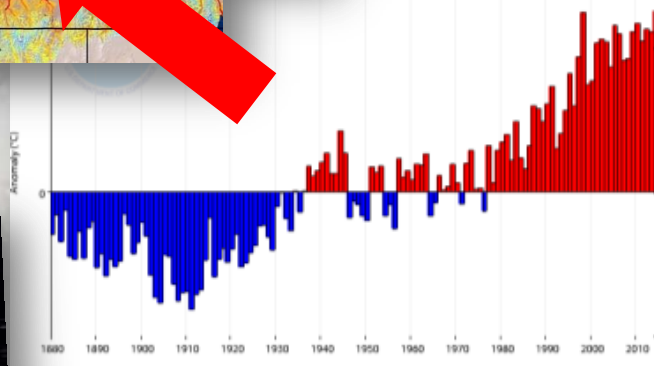
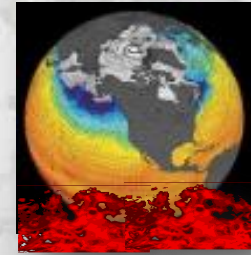
# Recent Rapid Evolution of Stream Science in the Rockies



**NorWeST**  
Stream Temp



**2014 Set New Record**



# Early Research at Missoula Lab on the genomics frontier...



Review

TRENDS in Ecology and Evolution Vol.22 No.1

Full text provided by [www.sciencedirect.com](http://www.sciencedirect.com)

ScienceDirect

## Genetic monitoring as a promising tool for conservation and management

Michael K. Schwartz<sup>1</sup>, Gordon Luikart<sup>2,3</sup> and Robin S. Waples<sup>4</sup>

<sup>1</sup> USDA Forest Service, Rocky Mountain Research Station, 800 E. Beckwith Avenue, Missoula, MT 59801, USA

<sup>2</sup> Center for Investigation of Biodiversity and Genetic Resources, University of Porto, Campus Agrário de Vairão 4485-661, Portugal

<sup>3</sup> Division of Biological Sciences, University of Montana, Missoula, MT 59812, USA

<sup>4</sup> National Marine Fisheries Service, Northwest Fisheries Science Center, 2725 Montlake Boulevard East, Seattle, WA 98112, USA



Review

TRENDS in Ecology and Evolution Vol.18 No.4 April 2003

189

## Landscape genetics: combining landscape ecology and population genetics

Stéphanie Manel<sup>1</sup>, Michael K. Schwartz<sup>2</sup>, Gordon Luikart<sup>1</sup> and Pierre Taberlet<sup>1</sup>

<sup>1</sup>Laboratoire d'Ecologie Alpine, Equipe Génomique des Populations et Biodiversité, UMR CNRS 5553, BP 53, Université Joseph Fourier, 38041 Grenoble Cedex 9, France

<sup>2</sup>Rocky Mountain Research Station, US Forest Service, 800 E. Beckwith, Missoula, MT 59801, USA

# eDNA Revolution: Reliable biodiversity assessments



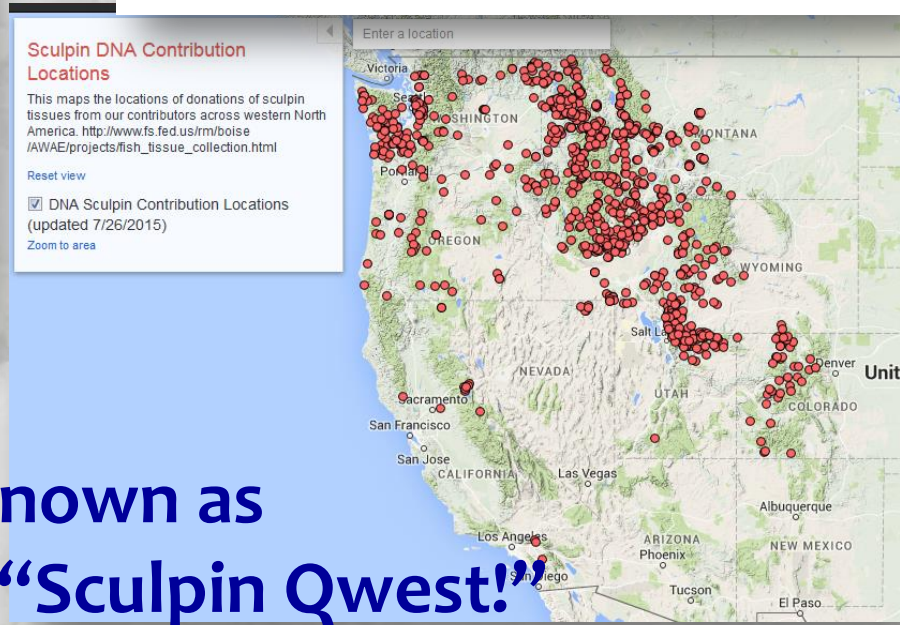
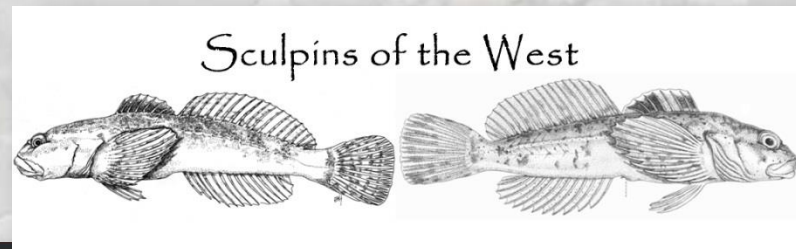
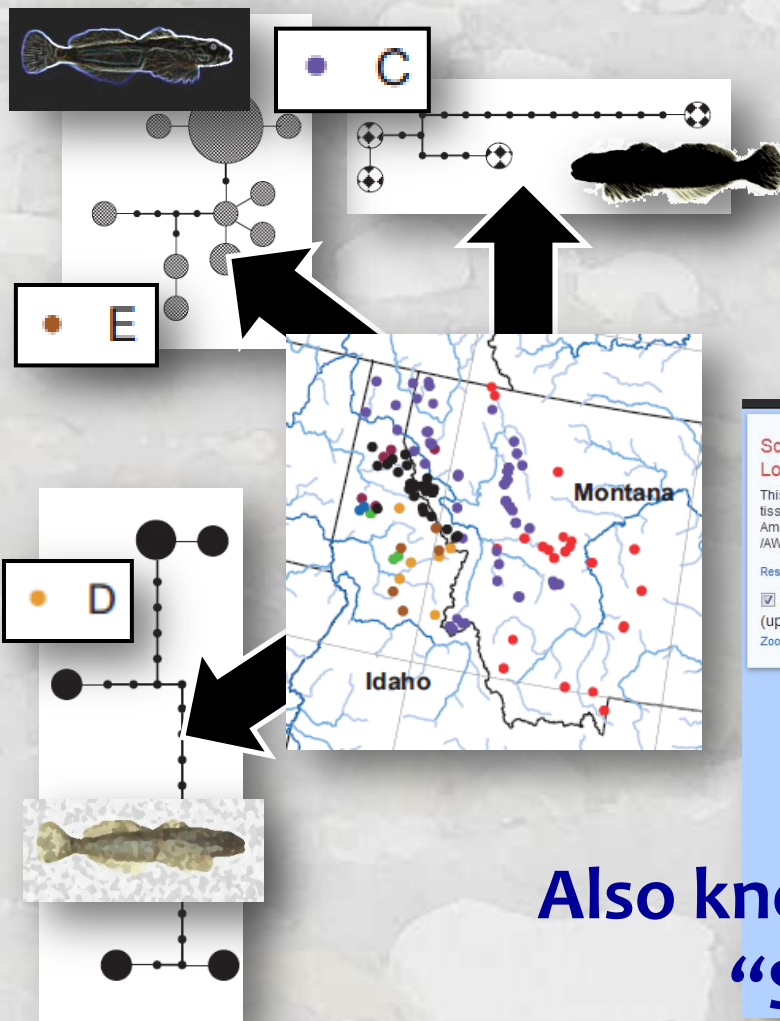
## USFS National Genomics Center for Wildlife & Fish Conservation

- Pioneered the technique for salmonids
- Species specific, highly reliable (1 trout / 100 m = 85% detection)
- Field-proven protocol
- Cost: \$70 sample



**Mike Schwartz**  
**Mike Young**  
**Kevin McKelvey**

# DNA Barcoding: A few fin clips from a few fish in many places reveals evolutionary legacy & units of conservation



Also known as  
**“Sculpin Qwest!”**

Young et al. 2013. DNA barcoding at riverscape scales: assessing biodiversity among fishes of the genus *Cottus* in northern Rocky Mountain streams. *Molecular Ecology* doi: 10.1111/1755-0998.12091

# Early Climate Change Research at Boise Aquatics Sciences Lab...

Climate Change, Aquatic Ecosystems, and Fishes in the Rocky Mountain West: Implications and Alternatives for Management

## Literature review & science status assessment...

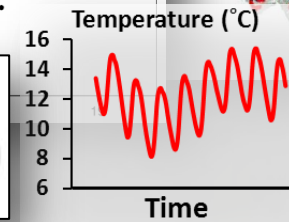
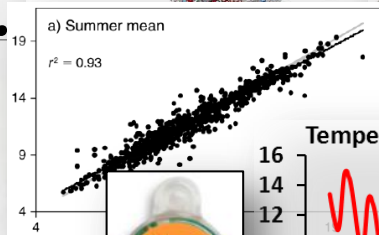
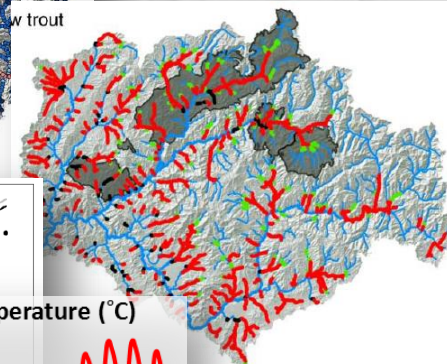
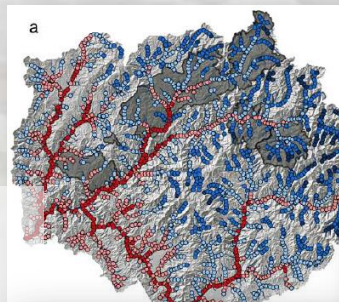
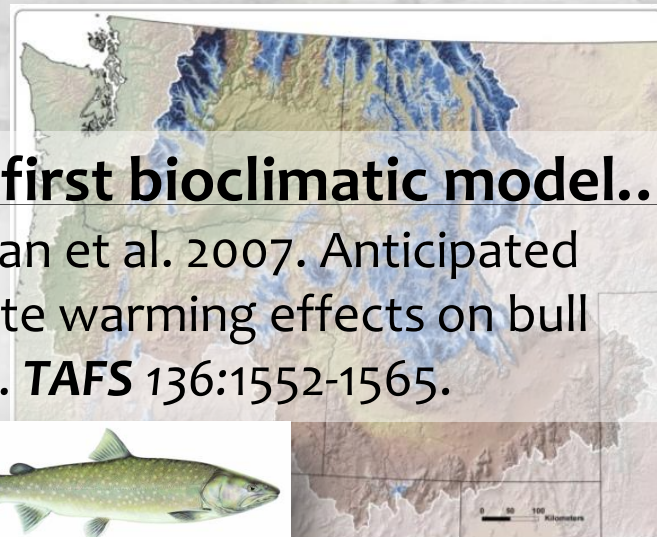
Rieman & Isaak. 2010. Climate Change, Aquatic Ecosystems, and Fishes in the Rocky Mountain West. RMRS General Technical Report 224.

## Protocol for “downscaling” climate to stream networks...

Isaak et al. 2010. Effects of climate change and wildfire on stream temperatures in a mountain river network. *Ecol. Apps.* 20:1350-1371.

## Our first bioclimatic model...

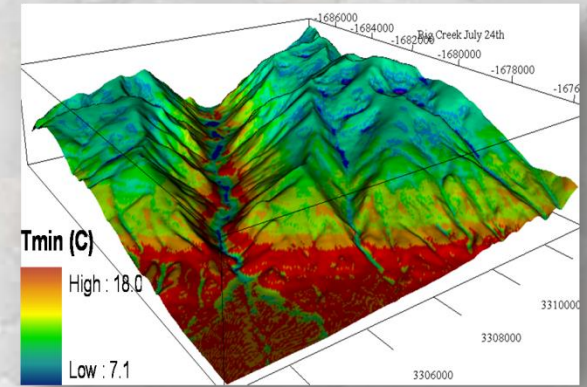
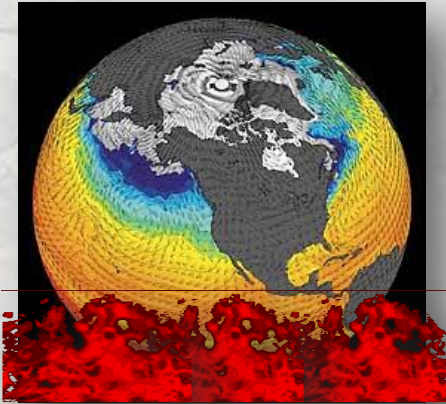
Rieman et al. 2007. Anticipated climate warming effects on bull trout. *TAFS* 136:1552-1565.



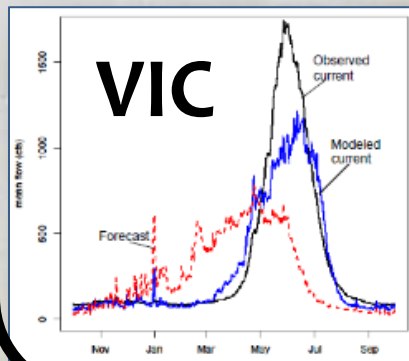
# Need: High Resolution Stream Scenarios to Provide Management-Relevant Information

Global climate models  
Resolution: 10000s of meters

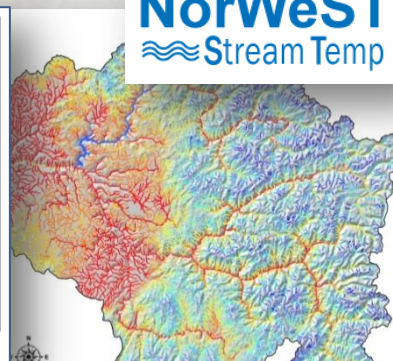
Landscape climate models  
Resolution: 1000s meters



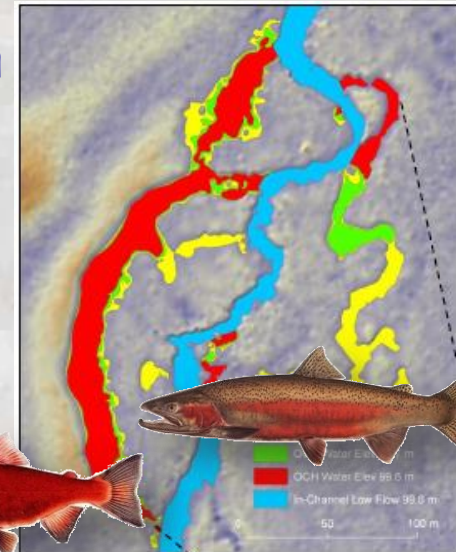
River network  
temperature & flow



NorWeST  
Stream Temp



Stream  
reach

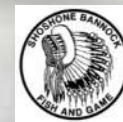
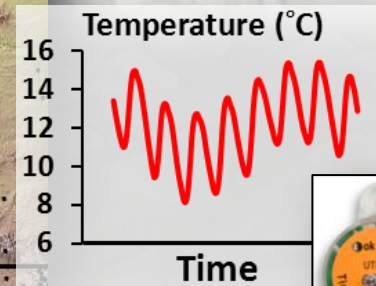
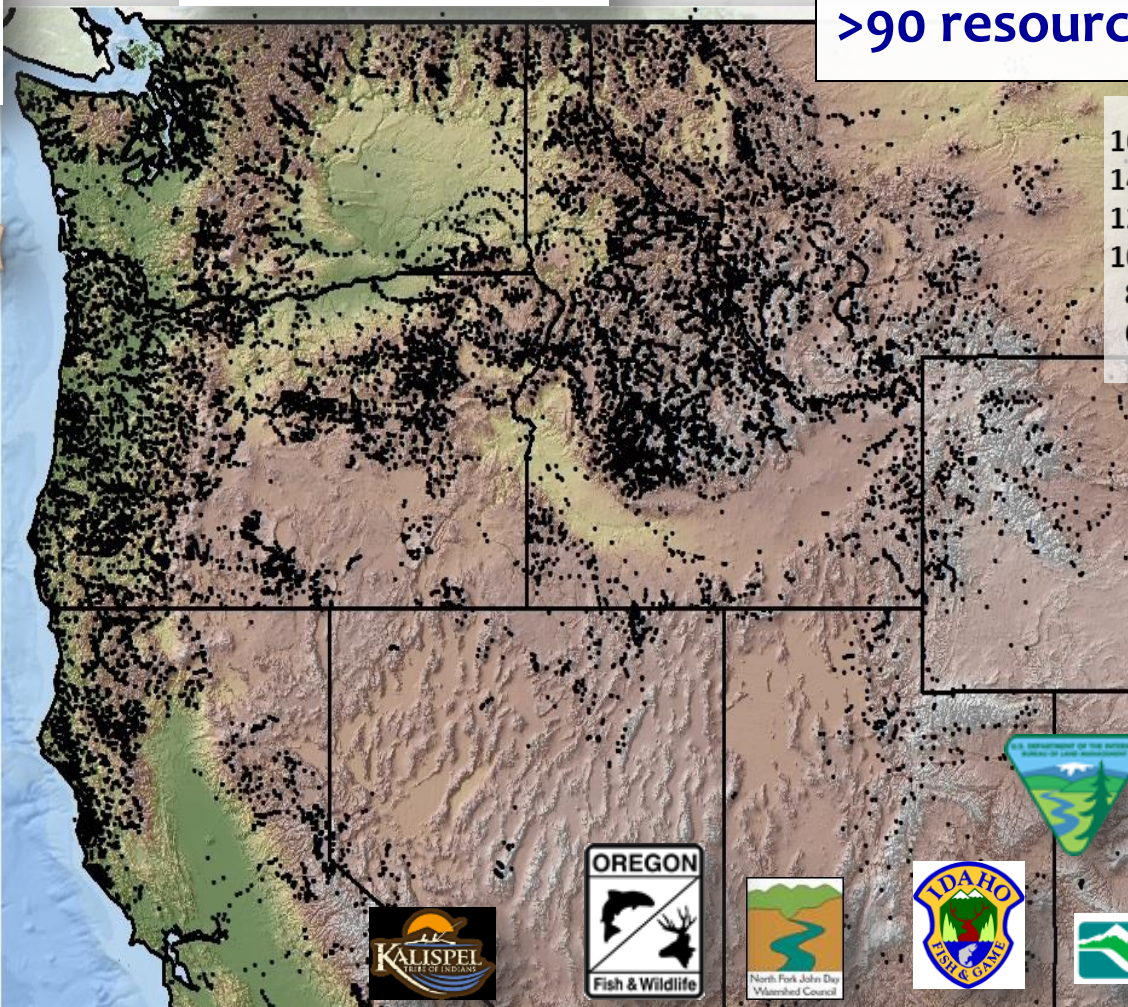


# Step 1: Forge Disparate Data Into a Functional Database

Funded by:

**NorWeST**  
Stream Temp

>50,000,000 hourly records  
>18,000 unique stream sites  
>90 resource agencies



# Data Pulled/Uploaded From/To Aquatic Surveys Module in NRM

Work closely with Callie McConnell's database team



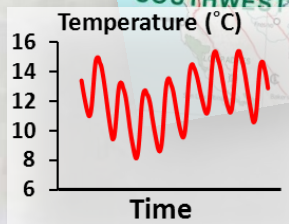
The screenshot displays the NRM software interface. The 'Feature Inspector' window lists various survey locations such as Bear Creek\_LTW, Beaver Creek on 214\_LTW, Big Bend Creek at the Mouth\_LTW, Black Rock Fork at the Mouth\_LTW, Boulder Creek Wilderness\_LTW, Boulder Creek at the Mouth\_LTW, Rice Creek below Adams Creek\_LTW, Buckeye Creek at the Mouth\_LTW, Call Creek base Station\_LTW, Carlton Creek at the mouth\_LTW, Carlton Rock Fork at the Mouth\_LTW, Cedar Creek at the Mouth\_LTW, City Creek at the mouth\_LTW, Clearwater River above Piacorect\_LTW, Clover Creek at the mouth\_LTW, Copeland Creek at the mouth\_LTW, Cow Creek above dinal Creek\_LTW, Coyote Creek -Wahsawed #1\_LTW, Culbus Creek at the mouth\_LTW, Daniel Creek at the Mouth\_LTW, Elk Creek at Lake\_LTW, Jackson Creek near the Mouth\_LTW, Lake Creek below Diamond Lake\_LTW, Leary Creek above Phather Creek\_LTW, Little River above Claver Creek\_LTW, Little River below White Creek\_LTW, Little Rock Creek at the Mouth\_LTW, Panther Creek at the mouth\_LTW, Quartz Creek at the Mouth\_LTW, South Unquapa River above South Unquapa Fa, South Unquapa at Tiler Ranger Station\_LTW, Squaw Creek at the Mouth\_LTW, Shearboat above Carlton\_LTW, Shearhead Creek at the Mouth\_LTW, Upper Shearboat below Little Rock\_LTW, and Surveys.

The 'SURVEYS' table shows the following data:

Survey Type	Name	Start Date	End Date	Protocol
Temperature	Daily Min Max Temp	6/14/1978	6/20/1978	ec11684-466d-4c4b-af6d-9c30a
Temperature	Daily Min Max Temp	6/9/1979	10/21/1979	ec11684-466d-4c4b-af6d-9c30a
Temperature	Daily Min Max Temp	6/17/1982	9/21/1982	ec11684-466d-4c4b-af6d-9c30a
Temperature	Daily Min Max Temp	6/19/1984	9/30/1984	ec11684-466d-4c4b-af6d-9c30a
Temperature	Daily Min Max Temp	6/14/1985	9/30/1985	ec11684-466d-4c4b-af6d-9c30a
Temperature	Daily Min Max Temp	6/20/1986	9/23/1986	ec11684-466d-4c4b-af6d-9c30a
Temperature	Daily Min Max Temp	6/16/1987	7/27/1987	ec11684-466d-4c4b-af6d-9c30a
Temperature	Daily Min Max Temp	7/6/1988	9/22/1988	ec11684-466d-4c4b-af6d-9c30a
Temperature	Daily Min Max Temp	6/29/1989	10/11/1989	ec11684-466d-4c4b-af6d-9c30a
Temperature	Daily Min Max Temp	6/15/1990	9/3/1990	ec11684-466d-4c4b-af6d-9c30a
Temperature	Daily Min Max Temp	6/8/1991	9/22/1991	ec11684-466d-4c4b-af6d-9c30a
Temperature	Daily Min Max Temp	6/19/1993	9/7/1993	ec11684-466d-4c4b-af6d-9c30a
Temperature	Daily Min Max Temp	6/4/1997	9/17/1997	ec11684-466d-4c4b-af6d-9c30a

The 'Attachments' window shows two image files:

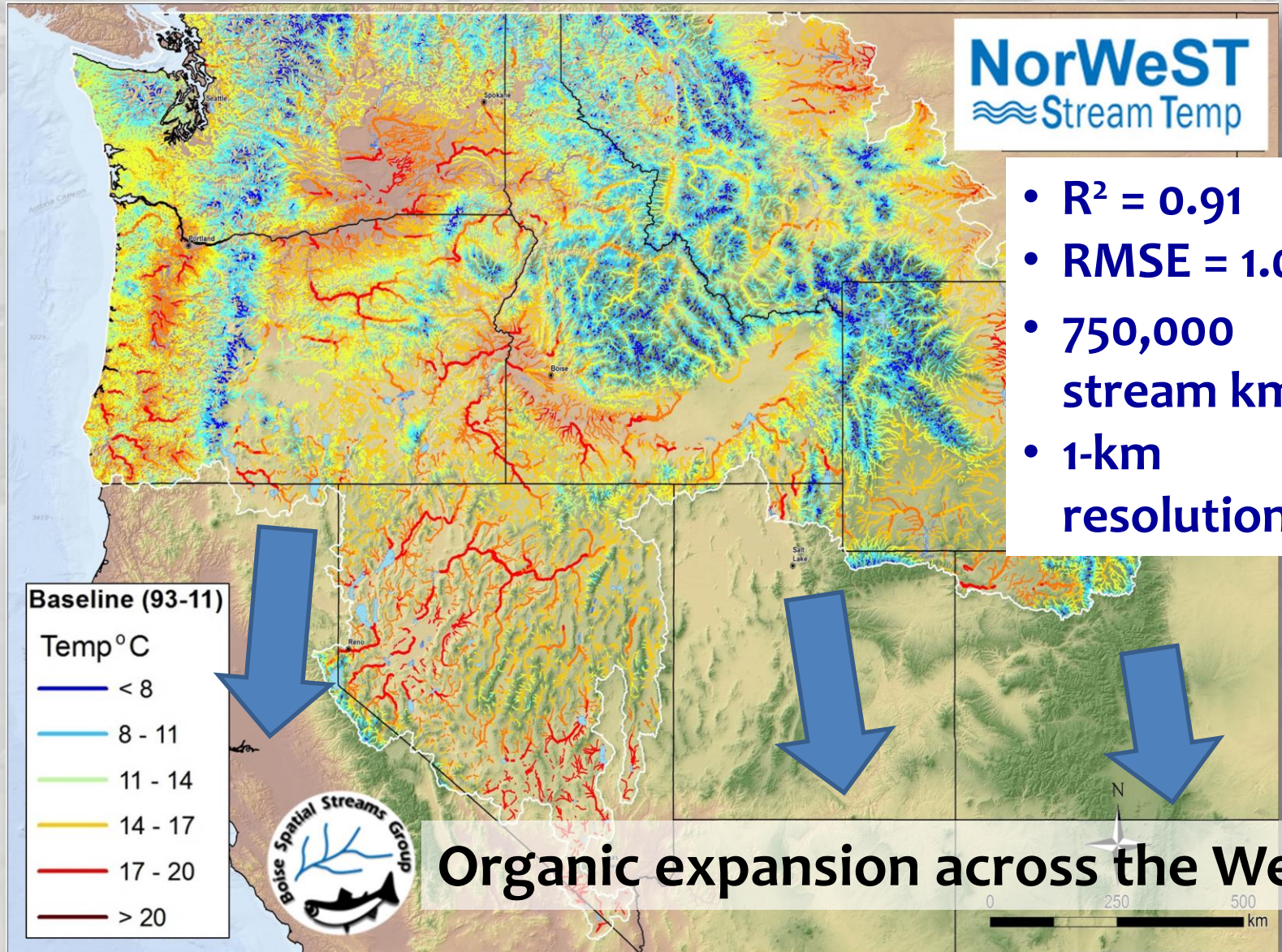
Attachment	File Type	Attachment Date	Attachment Time	Name
	JPEG	6/25/2012	11:39	LakeCR US E004 6-25-2012
	JPEG	6/25/2012	11:39	LakeCR US E004 6-25-2012



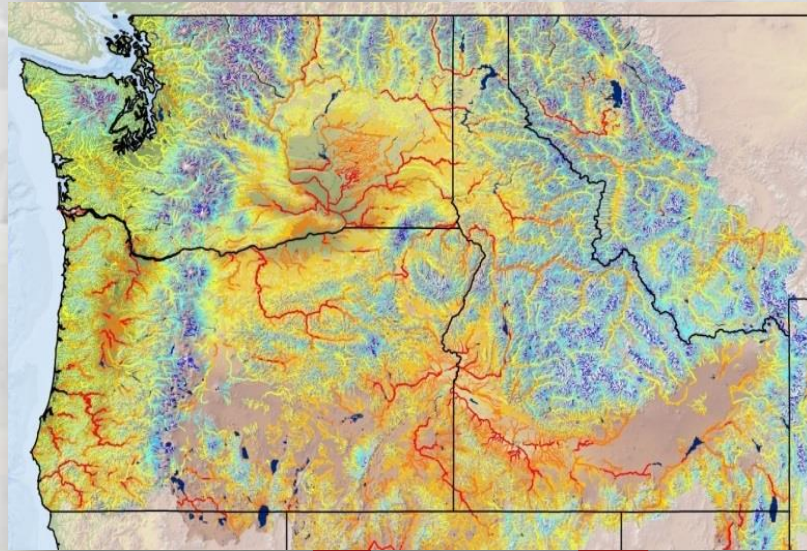
Forest's legacy datasets migrated into corporate database



# Step 2: Model Accurate Stream Scenarios



# Temperature Applications



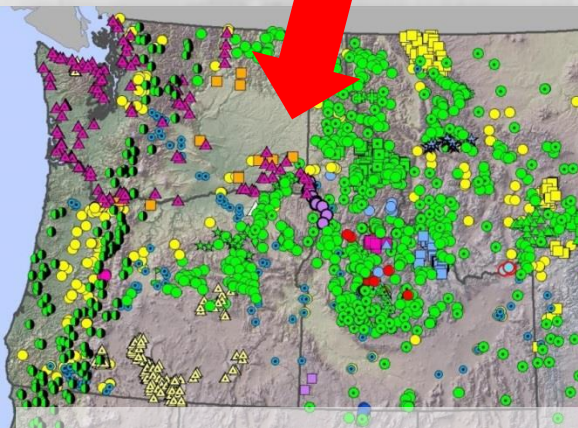
Regulatory temperature standards



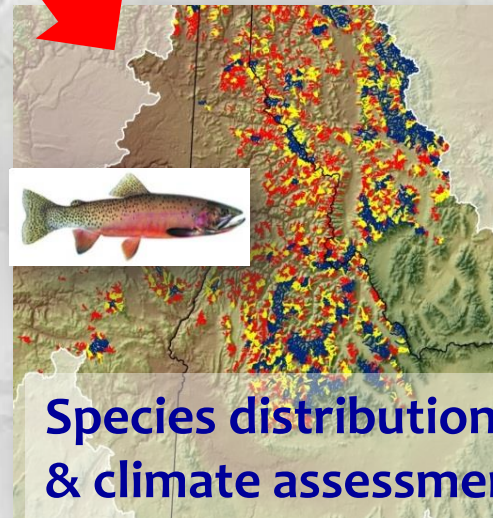
Too Hot!

Too cold!

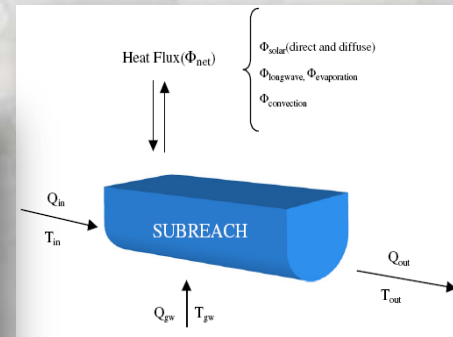
Data access accelerates temperature research



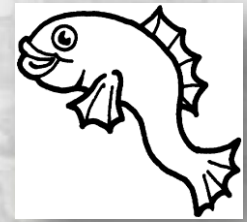
Coordinated Interagency monitoring



Species distribution models & climate assessments

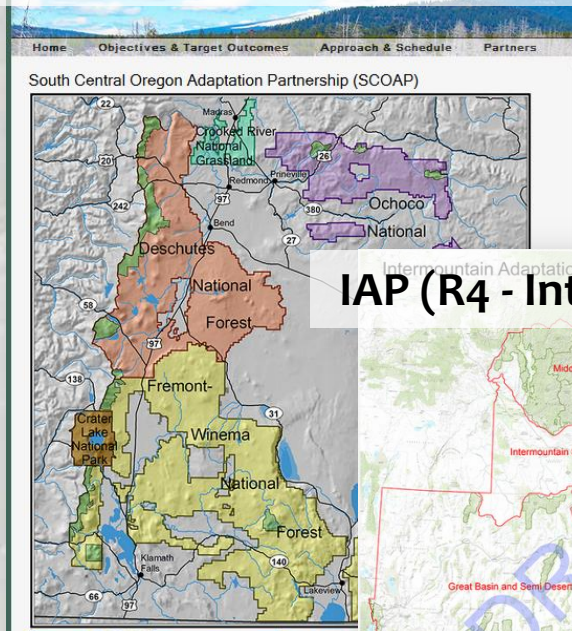


# Climate Adaptation Partnerships (Dave Peterson – PNW Research)



- All Forests in Region 1, 4, & 6
- Stream climate scenarios & fish vulnerability assessments for ~40 NFs by end 2015

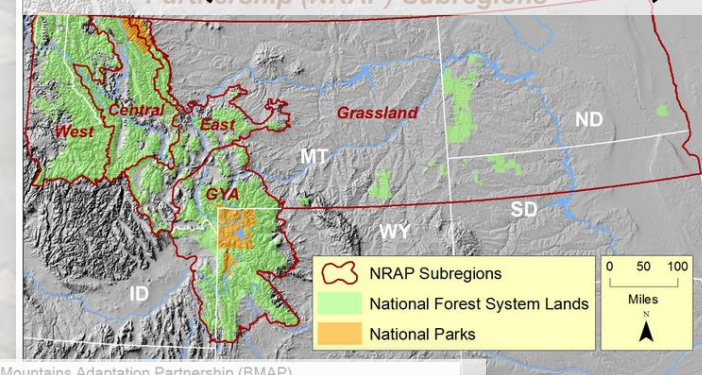
## SCOAP (South Central Oregon)



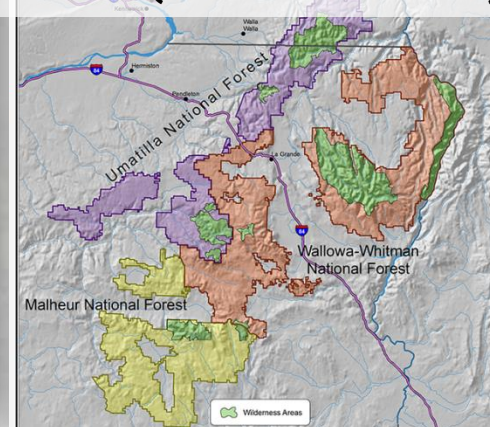
## IAP (R4 - Intermountain)



## NRAP (R1 - Northern Rockies)

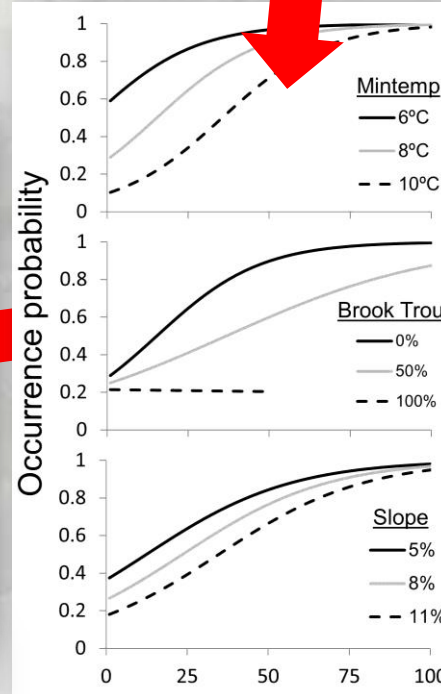
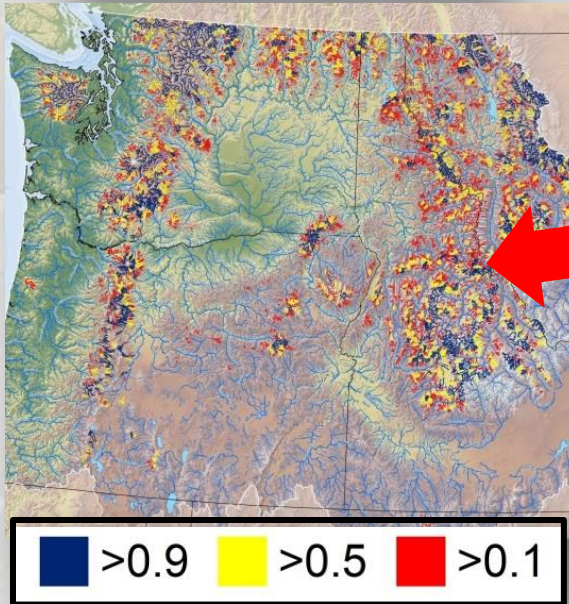
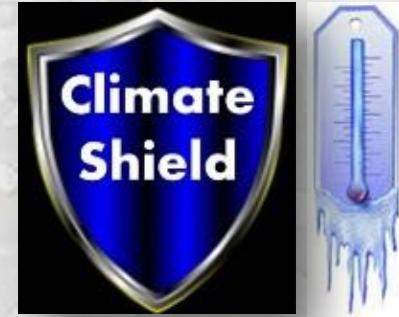
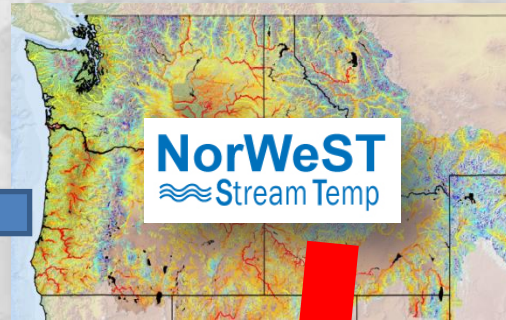
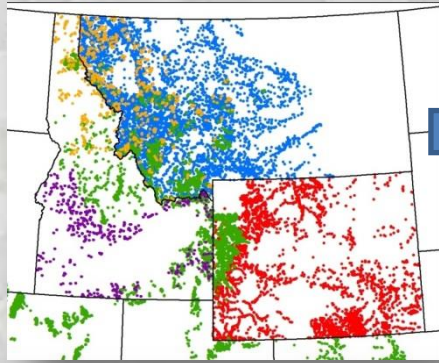


## BMAP (Blue Mountains)



# Cold-Water Climate Shield Project (NRAP)

## BIG FISH DATA



**78% - 85% predictive accuracy in 500+ validation streams**

Isaak et al. 2015. The cold-water climate shield: Delineating refugia for preserving salmonids through the 21<sup>st</sup> Century. *Global Change Biology* 21 doi:10.1111/gcb.12879

# Ongoing Collaboration with Stream Statisticians: Models for Data on Stream Networks... FINALLY!

Environ Ecol Stat (2006) 13:449–464  
DOI 10.1007/s10651-006-0022-8

ORIGINAL ARTICLE

## Spatial statistical models that use flow and stream distance

Jay M. Ver Hoef · Erin Peterson · David Theobald



Freeware



## Journal of Statistical Software

January 2014, Volume 56, Issue 3.

<http://www.jstatsoft.org/>

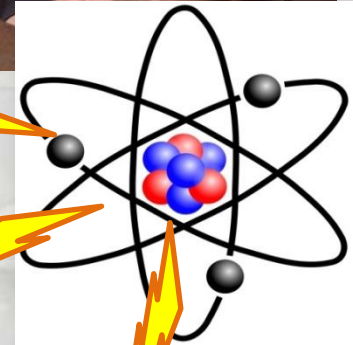
## SSN: An R Package for Spatial Statistical Modeling on Stream Networks

Jay M. Ver Hoef  
NOAA National  
Marine Mammal Laboratory

Erin E. Peterson  
CSIRO, Brisbane

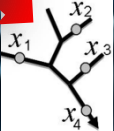
David Clifford  
CSIRO, Brisbane

Rohan Shah  
CSIRO, Brisbane



## Functional Linkage of Watersheds and Streams (FLoWS)

- ArcGIS Geoprocessing Toolbox written in Python v2.5 for ArcGIS v
- Developed by Dr. Dave Theobald and John Norman at Colorado St

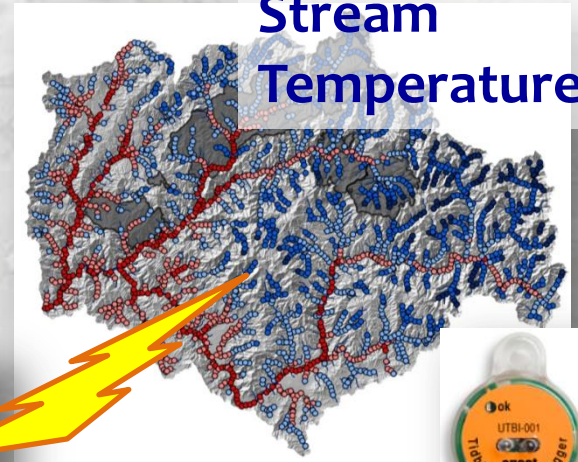


# Stream Models are Generalizable...

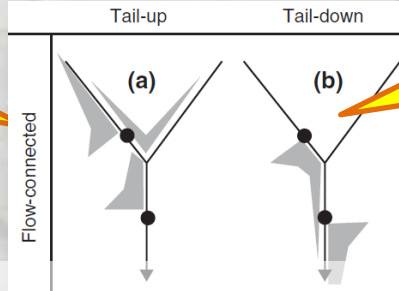
## Response Metrics

- Gaussian
- Poisson
- Binomial

## Stream Temperature

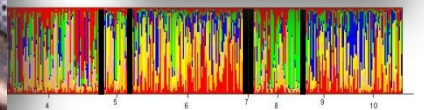
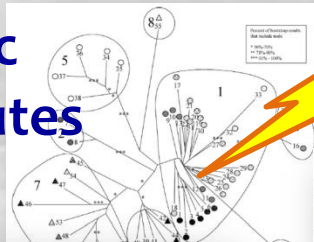


## Distribution & abundance

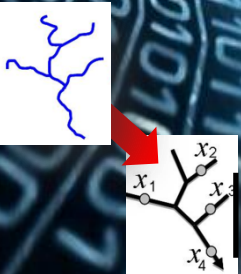


# Statistical stream models

## Genetic Attributes



## Water Quality Parameters



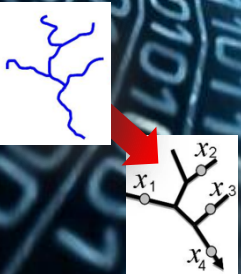
# Annual Stream Statistics Training Workshops in Boise (4th in Spring 2016)

100 participants  
~5 year waiting list...

## 3 day workshop

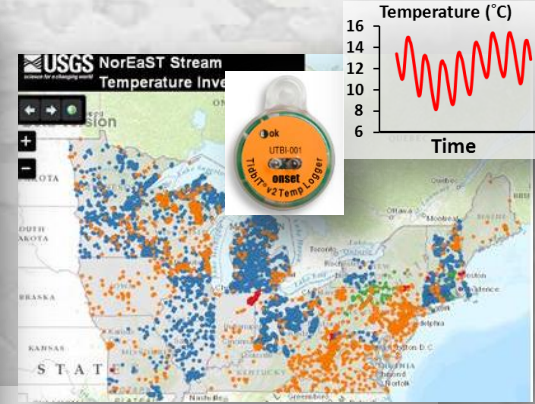
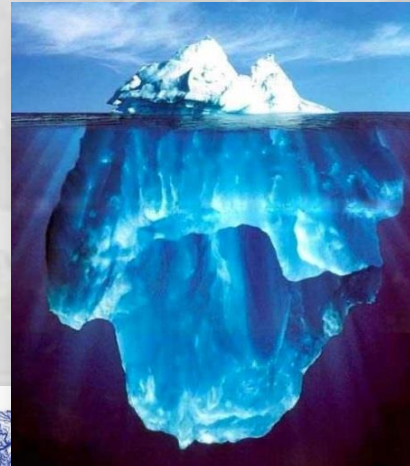
1<sup>st</sup> day: overview of spatial stream models (webinar)

2<sup>nd</sup>/3<sup>rd</sup> days: work 1-on-1 with Jay/Erin to model your data

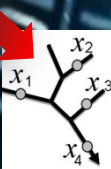
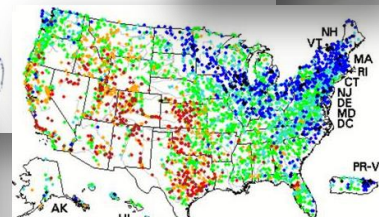
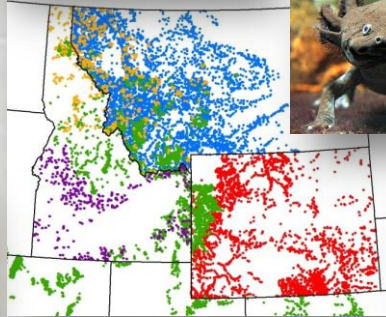


# The National Stream Internet Project

## BIG DATA = BIG POSSIBILITIES



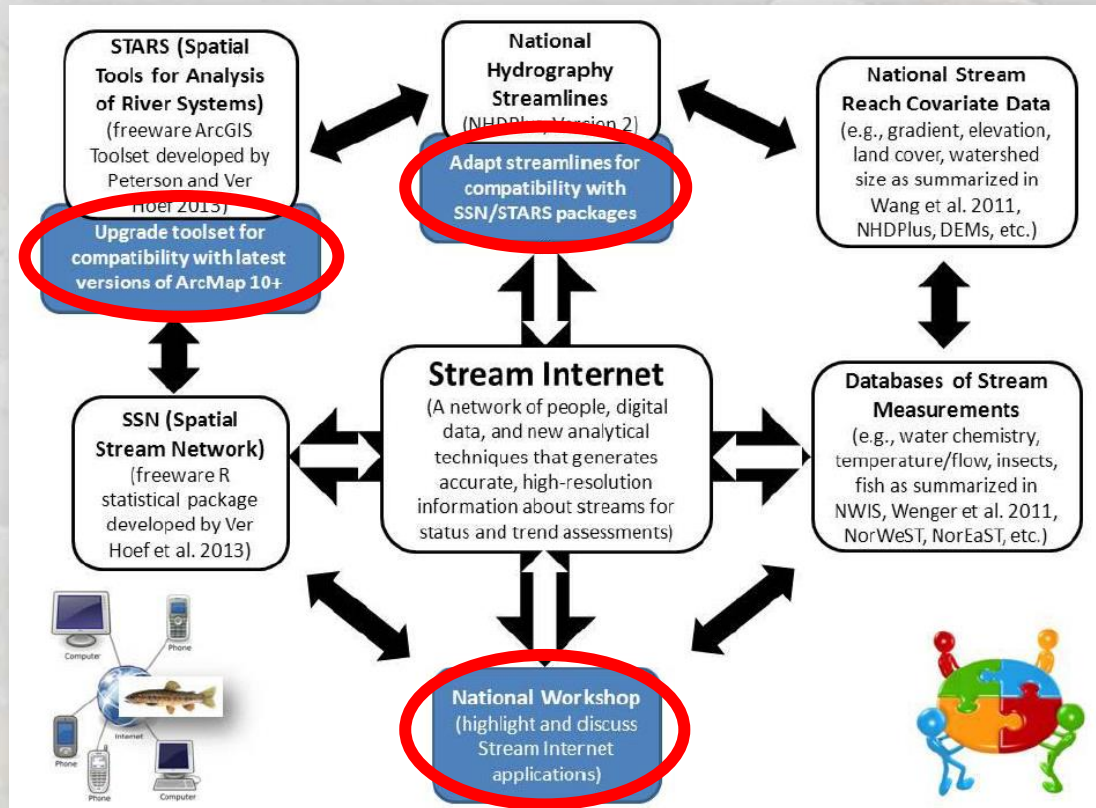
There are only 4,000,000 stream kilometers





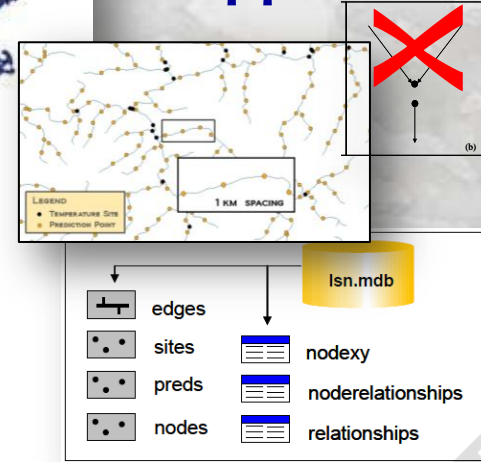
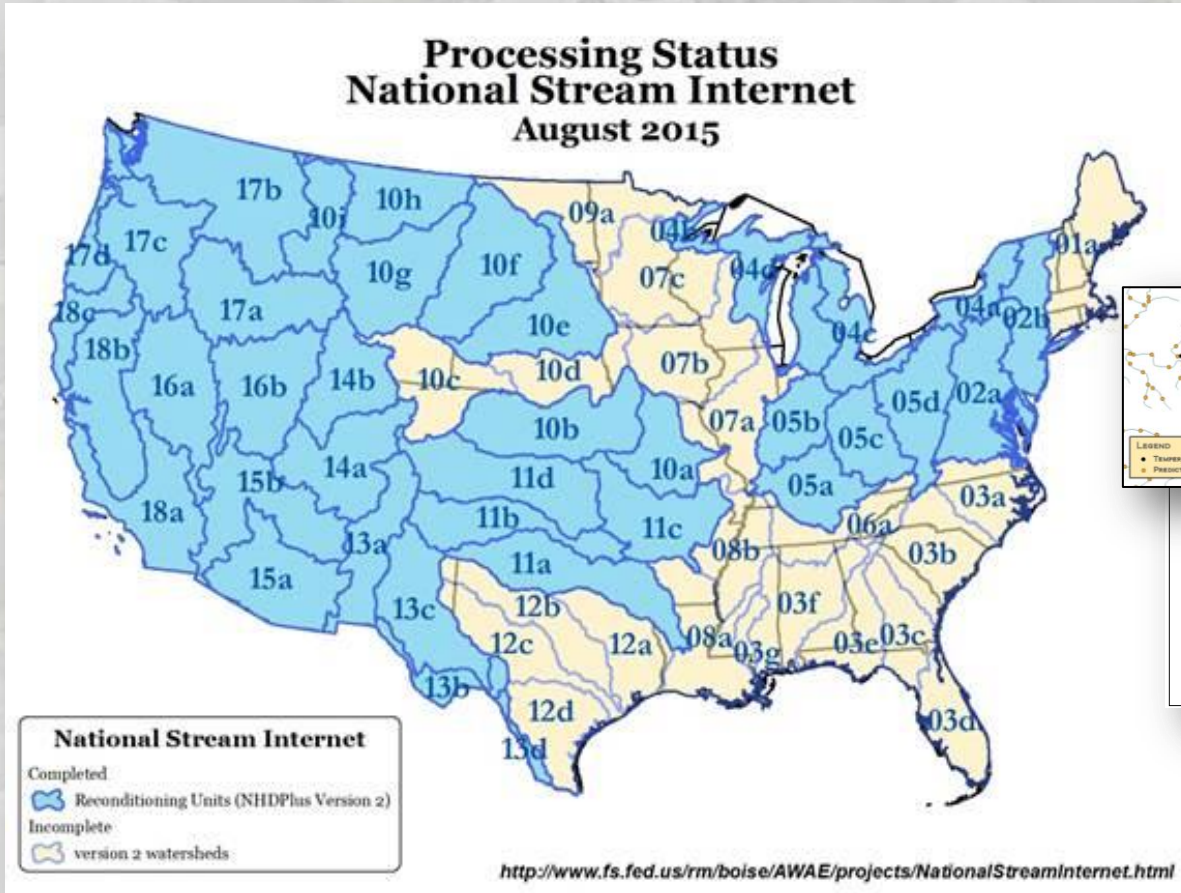
# Stream Internet Project Tasks

- 1) Develop compatibility between spatial stream analysis tools and NHDPlus national hydrology database
- 2) Update STARS stream analysis tools to ArcMap 10.2
- 3) Host a workshop to brainstorm about possibilities that new analyses & databases provide to address key questions & information needs

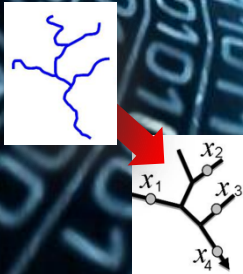


# Stream Internet Processing Status

Geotechnical protocols applied



Coordinated with:



# The rapid, range-wide inventory of bull trout: a crowd-sourced, eDNA-based approach with application to many aquatic species

Michael Young, Kevin McKelvey, Michael Schwartz, Dan Isaak, Kellie Carim, Taylor Wilcox, Katie Zarn, Kristy Pilgrim, Dona Horan, Sherry Wollrab



## Collaborators



Bureau of Reclamation  
Clark Fork Coalition  
Clearwater Resource Council  
Coeur d'Alene Tribes  
Idaho Department of Fish and Game  
Idaho Power Company  
Montana Department of Natural Resources Conservation  
Montana Fish, Wildlife & Parks  
National Fish and Wildlife Foundation  
The Nature Conservancy  
Nez Perce Tribes  
Oregon Department of Fish and Wildlife

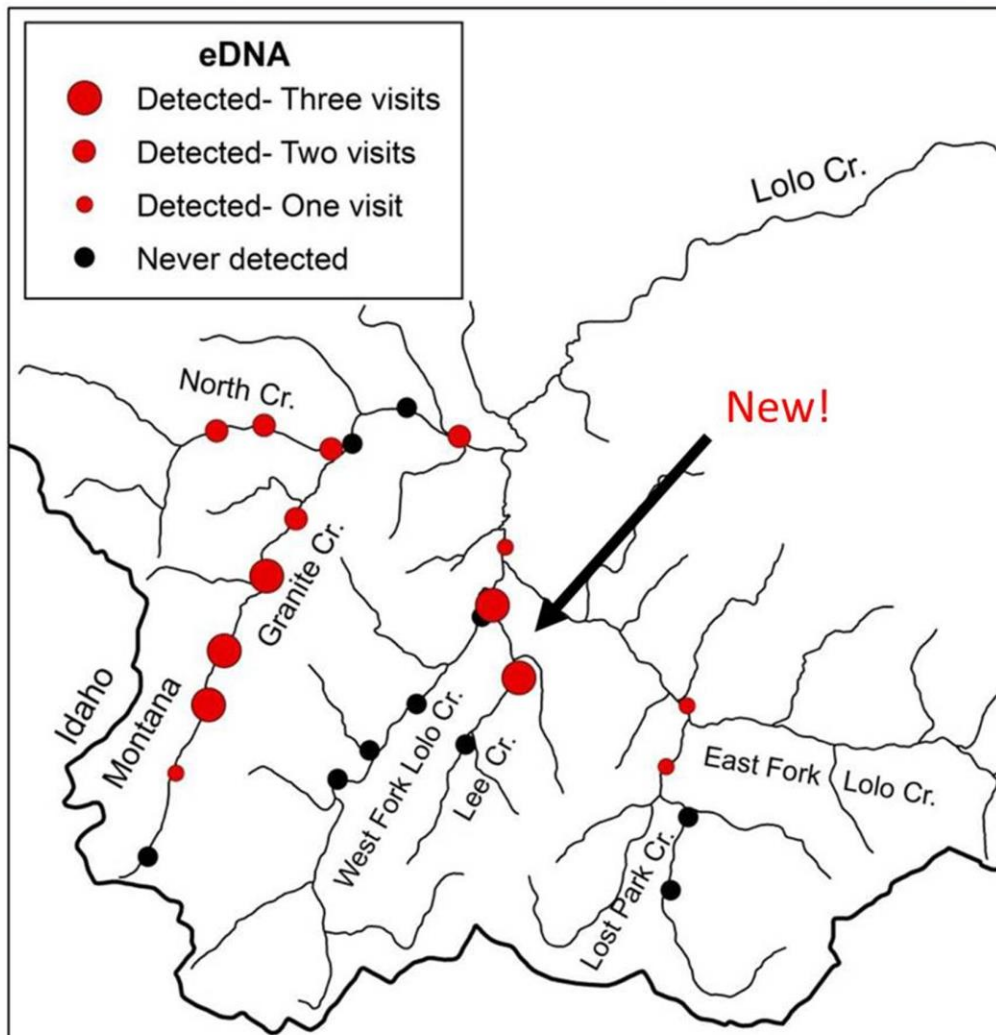


Trout Unlimited  
U.S. Fish and Wildlife Service  
USFS Beaverhead-Deer Lodge NF  
USFS Boise NF  
USFS Helena NF  
USFS Idaho Panhandle NF  
USFS Lolo NF  
USFS Region 1  
USFS Region 4  
USFS Region 6  
USFS Sawtooth NF  
Washington Department of Fish and Wildlife  
Yakima Nation



# Using eDNA to detect bull trout

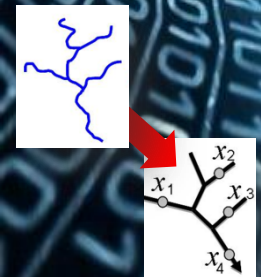
- Federally listed as threatened
- Dictates land management & planning
- Widespread, rare, & difficult to detect
- Ideal candidate for eDNA detection
- Pilot test: Montana 2014
- Confirmed known habitats
- Discovered new ones



Carim et al. 2014. Protocol for collecting eDNA samples from streams. Version 1.5. USDA Forest Service, Rocky Mountain Research Station, Missoula, MT. 12 p.







McKelvey et al. In review. Sampling large geographic areas for rare species using eDNA: a preliminary study of bull trout occupancy in western Montana.

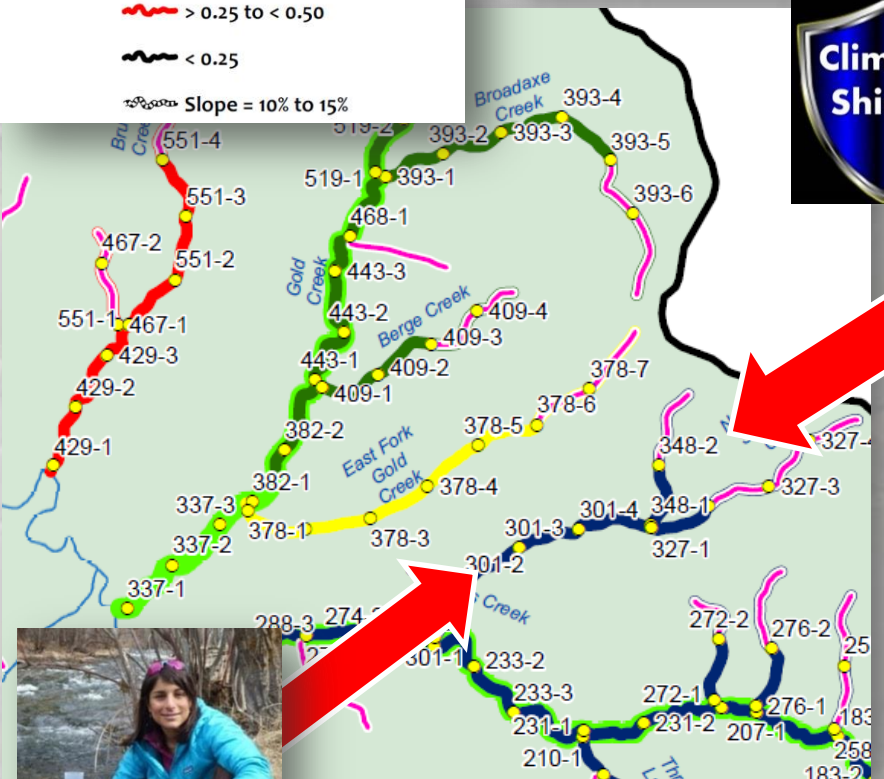
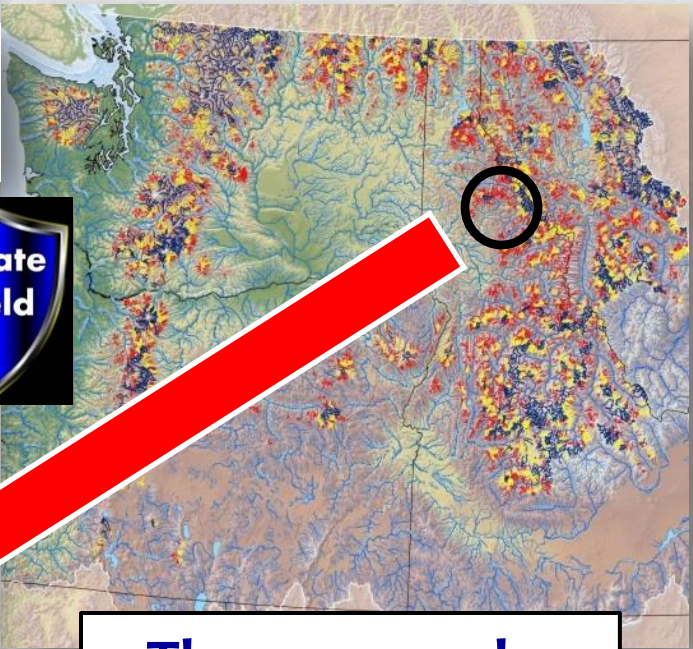
Wilcox et al. 2014. A blocking primer increases specificity in eDNA detection of bull trout. Conservation Genetics Resources, 1-2.



# Combine eDNA sampling with Precise Predictions from Climate Shield Model

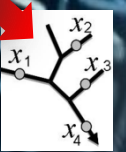
## Occupancy Probability

-  > 0.90
-  > 0.75 to < 0.90
-  > 0.50 to < 0.75
-  > 0.25 to < 0.50
-  < 0.25
-  Slope = 10% to 15%



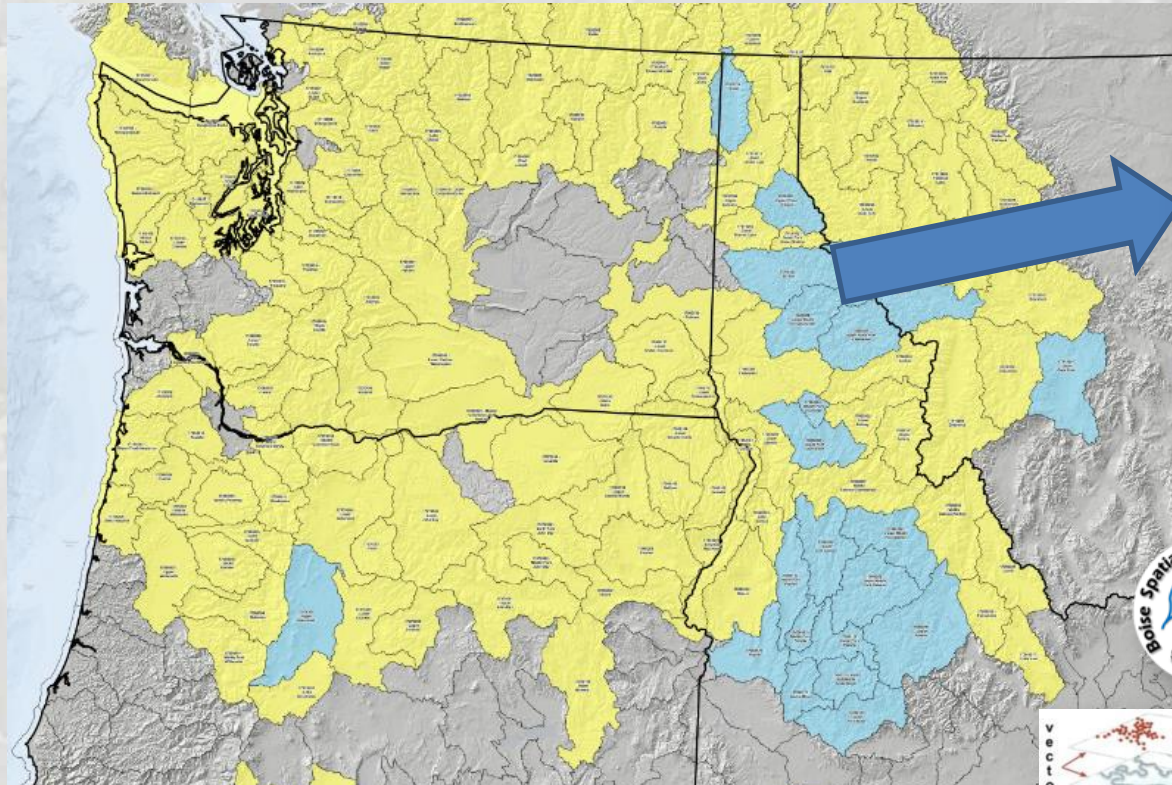
**There are only...**  
**5,332 >0.1 habitats**  
**1,325 >0.5 habitats**  
**348 >0.9 habitats**

**Target samples to resolve greatest uncertainty**



# Summers of 2015-2018: Industrial scale field sampling campaigns by FS & partner agencies

Sample sites have unique IDs & are part of digital NGC geodatabases from day 1!



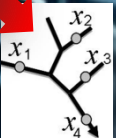
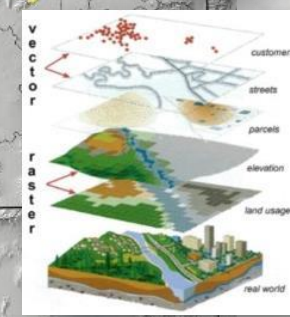
**NGC**

**ORACLE**  
DATABASE

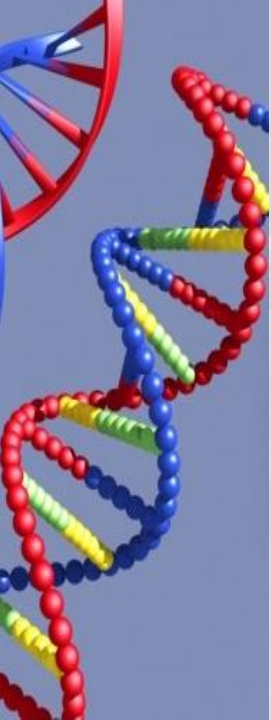


**8-digit HUCs within Historic Bull Trout Range**

- eDNA Field Sites Established (N=21)
- eDNA Field Sites Incomplete (N=119)

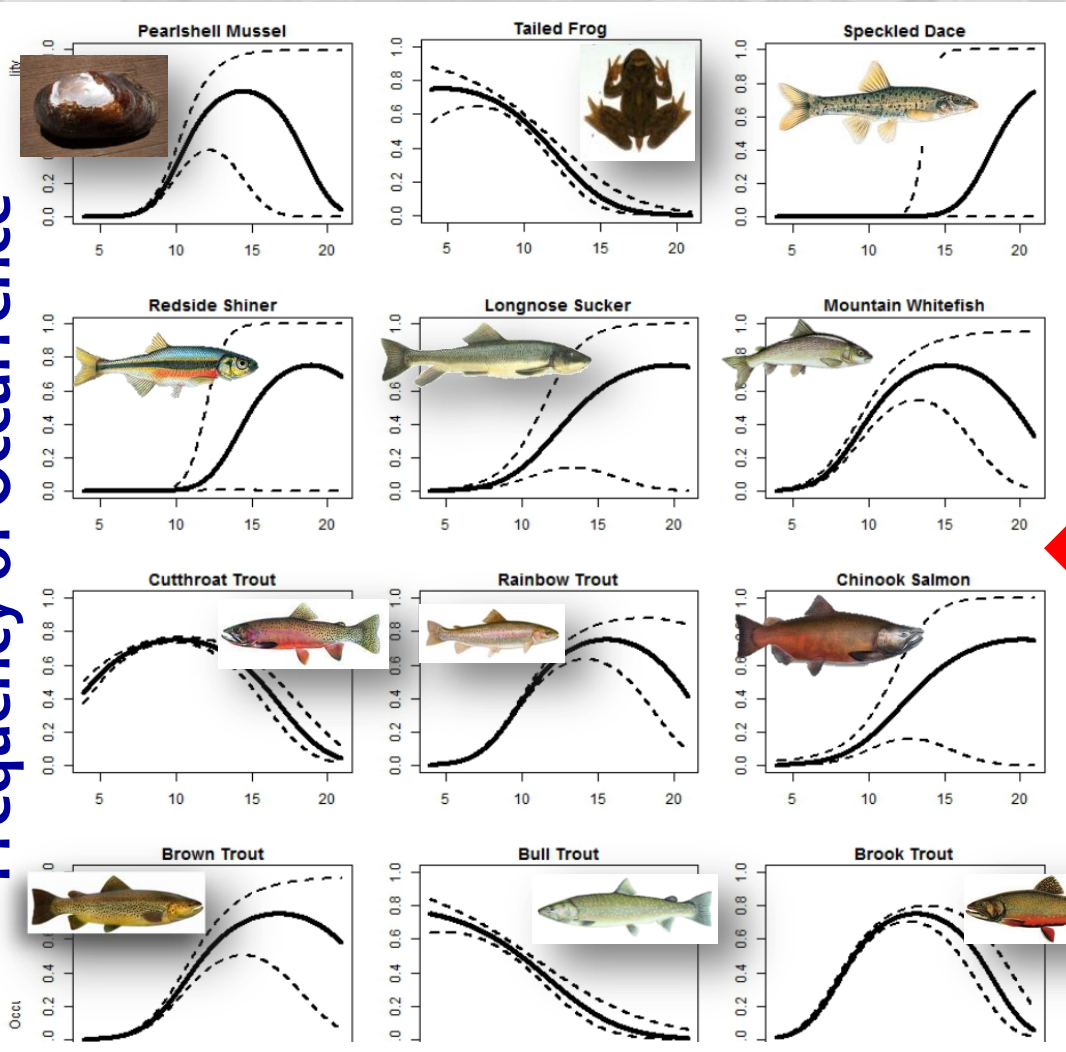


# Bull trout samples contain eDNA for other critters to provide future biodiversity archive



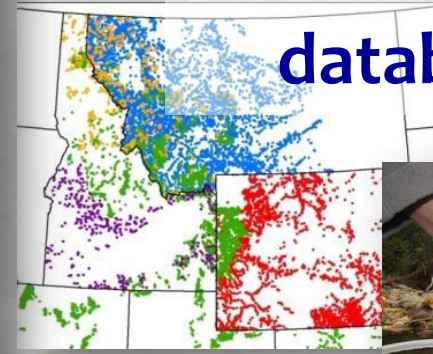
**Goal:** Empower people with tools to develop high-resolution distribution/abundance/genetic information for all aquatic life...

Frequency of Occurrence



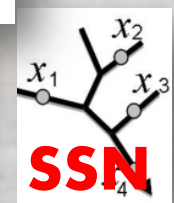
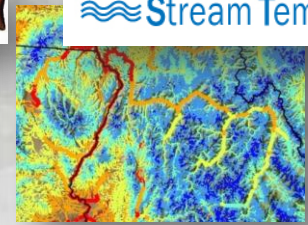
**NorWeST Stream Temperature (S1)**

**BIG biological databases**



**+**  
**Geotechnical & analytical processing**

**NorWeST**  
 Stream Temp

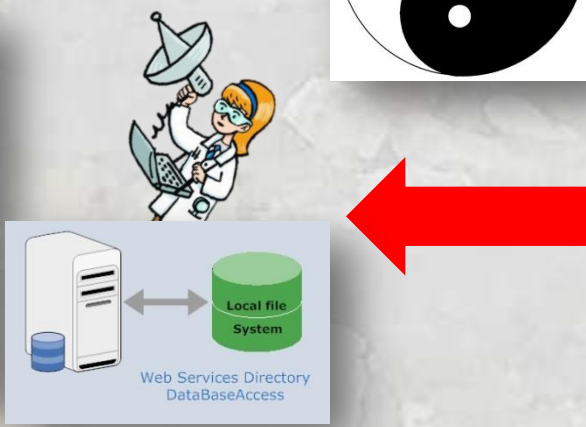
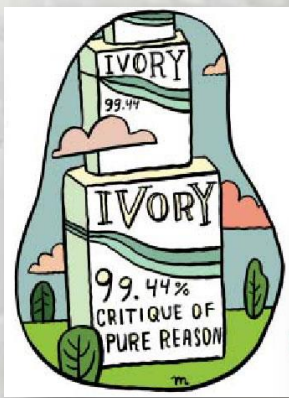
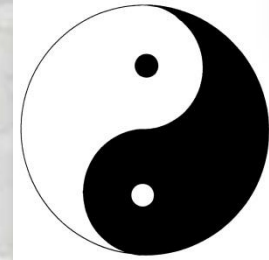




# Create a “Virtuous Cycle” of Information Creation

Many stakeholders

“Boots-on-the-Ground”



Research develops databases & relevant information

Mountains of data



# Websites & Digital Media Distribute Information in Useful, User-friendly Formats (GIS databases, software, digital maps, manuscripts, videos, etc...

>35,000 web-visits/year & rapidly growing user bases

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NOAA ACEMJS

Observations Predictions

SSN

Hourly Projections SSN & STARS

SSN & STARS: Tools for Spatial Statistical Modeling on Stream Networks

The screenshot shows a web interface for the SSN & STARS tool. It features a header with the USDA and U.S. Forest Service logos, a navigation menu, and a main content area with a map of stream networks. A diagram of a stream network with nodes labeled  $x_1, x_2, x_3, x_4$  is overlaid on the map. The text "SSN" is prominently displayed in red.

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Climate Shield

Climate Shield Cold-Water Refuge Streams for Native Trout

The screenshot shows a web page for the Climate Shield project. It features a header with the USDA and U.S. Forest Service logos, a navigation menu, and a main content area with a photograph of two trout. A blue shield icon with the text "Climate Shield" is overlaid on the image. Below the image, the text "Climate Shield Cold-Water Refuge Streams for Native Trout" is displayed.

## Locations of recent website visits



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NorWeST Stream Temp

Salmon River

Regional Database and Modeled Stream Temperatures

The screenshot shows a web page for the NorWeST Stream Temp project. It features a header with the USDA and U.S. Forest Service logos, a navigation menu, and a main content area with a photograph of a stream with yellow leaves. A diagram of a stream network with nodes labeled  $x_1, x_2, x_3, x_4$  is overlaid on the image. The text "NorWeST Stream Temp" and "Regional Database and Modeled Stream Temperatures" are prominently displayed.