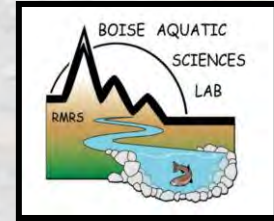


Building a Stream InterNet for Enhanced Conservation & Management of Aquatic Resources

Dave Nagel, Dona Horan, Sharon Parkes,
Gwynne Chandler, Sherry Wollrab

Erin Peterson, Jay Ver Hoef

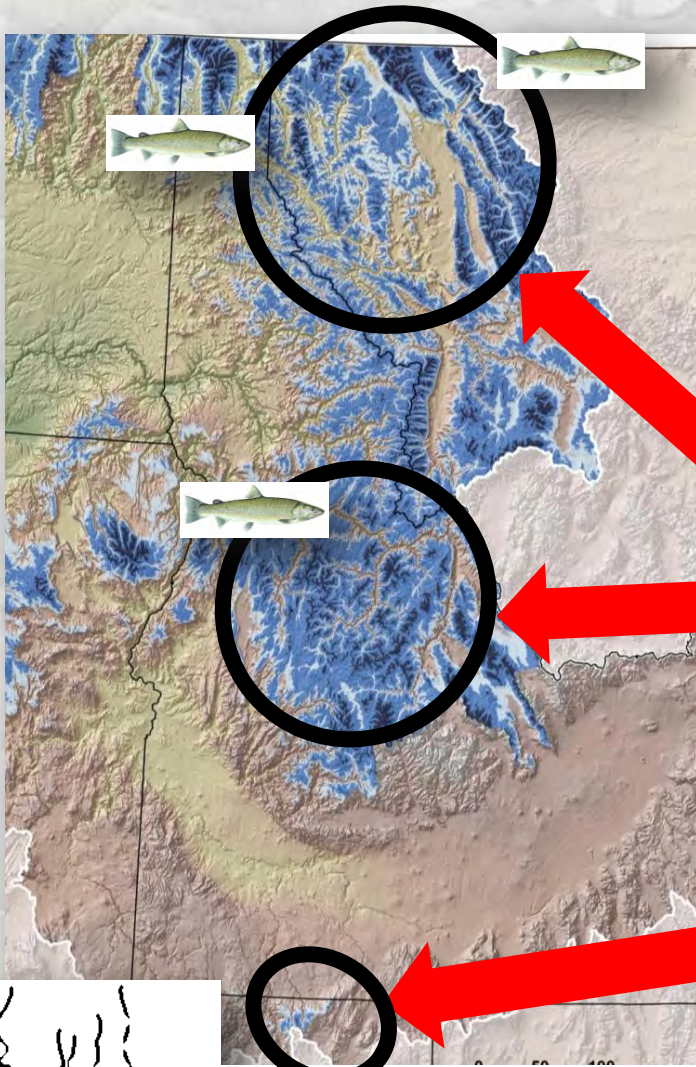


100's of partner –ologists



10's of agencies

Better Information Enables Better Decisions, Efficiency, & Resource Stewardship

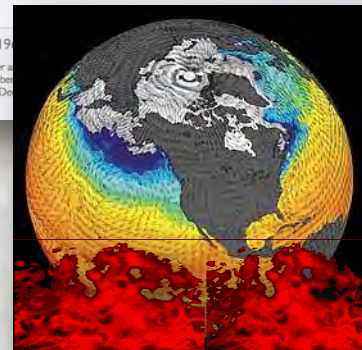


2012: HOTTEST YEAR ON RECORD

Average Annual Temperature in Contiguous U.S.



* Source: Climate Central, compiled from NOAA's National Climatic Data Center as part of the Climate Information System. Based on observed temperatures through December 31, 2012. An estimate of the Normal distribution of temperatures for the last 21 days of December is based on data from the previous 117 years. (See methodology)



Invest Here

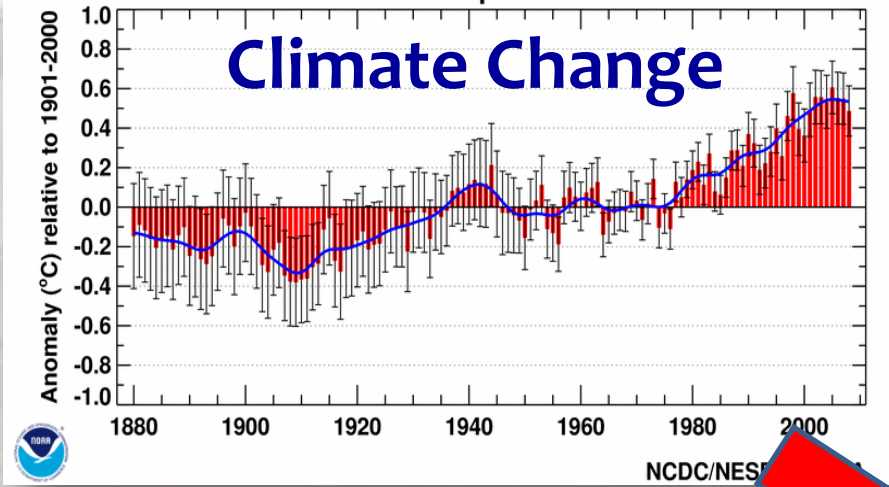
Not here



Sorry Charlie



More Pressure, Fewer Resources



Urbanization & Population Growth



Shrinking Budgets

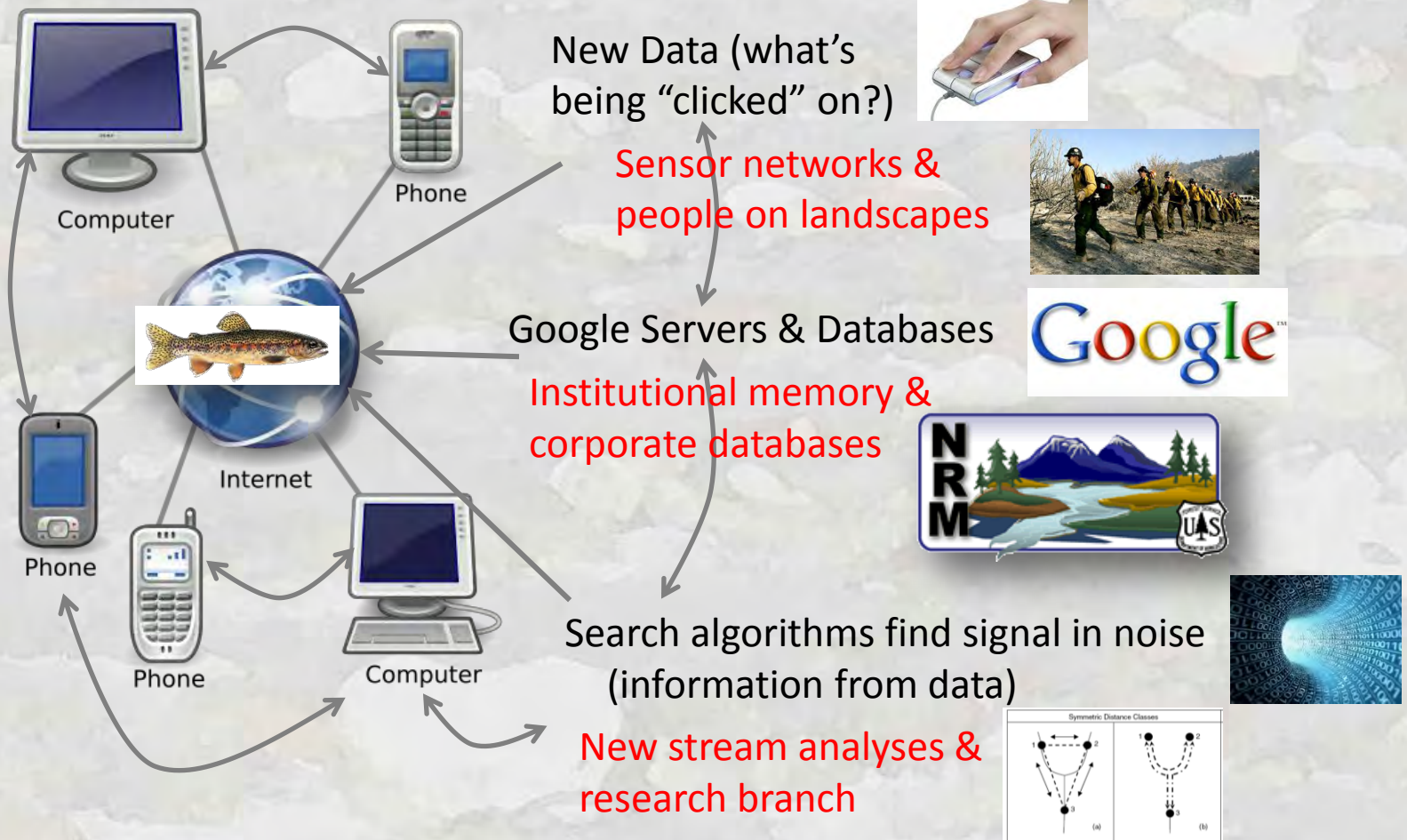


Need to do more with less



Development of (& Open Access to) Good Information is Critical

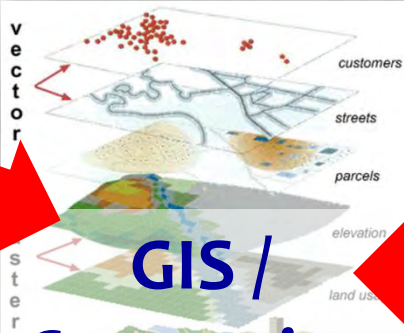
“Internet”: A networked system capable of transferring massive amounts of information among many participants simultaneously



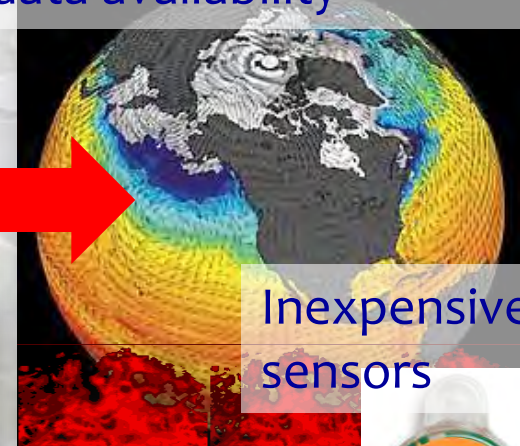
Key feature: information flows in many directions

Key Ingredient #1: Geospatial Tools for Accurate Regional Scale Stream

Remote Sensing



Climate, weather, GCM data availability



Inexpensive sensors



Visualization Tools

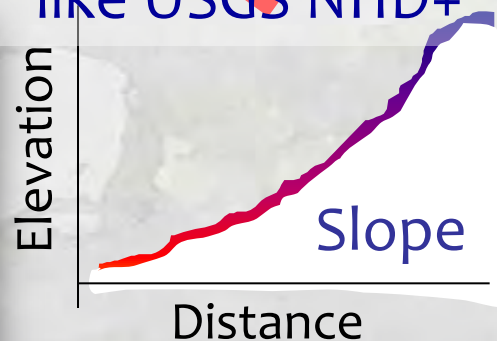


GIS / Computing Capacity

Nationally Consistent Hydrocoverages like USGS NHD+



Elevation



Drainage Area



Key Ingredient #2: Spatial Statistical Models for Stream Networks

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

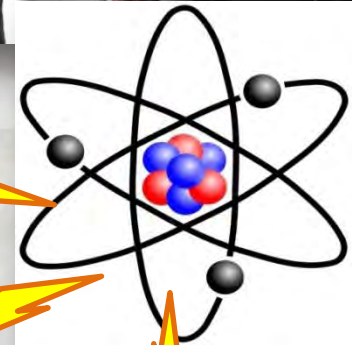


Freshwater Biology (2007) 52, 267–279

doi:10.1111/j.1365-

Geostatistical modelling on stream networks: developing valid covariance matrices based on hydrologic distance and stream flow

ERIN E. PETERSON,* DAVID M. THEOBALD† AND JAY M. VER HOEF‡



Functional Linkage of Water basins and Streams (FLoWS) v1 User's Guide:

ArcGIS tools for Network-based Analysis
Contact info:

Authors:
David M. Theobald
John B. Norman
Erin Peterson
S. Ferraz
A. Wade
M.R. Sherburne

Spatial modelling and prediction on river networks: up model, down model or hybrid?

Vincent Garreta^{1,*†}, Pascal Monestiez² and Jay M. Ver Hoef³

¹CEREGE, UMR 6635, CNRS, Université Aix-Marseille, Europôle de l'Arbois, 13545 Aix-en-Provence, France

²INRA, Unité de Biostatistique et Processus spatiaux, Domaine St Paul, Site Agroparc, 84914 Avignon Cedex 9, France

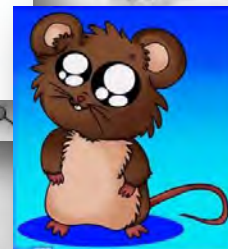
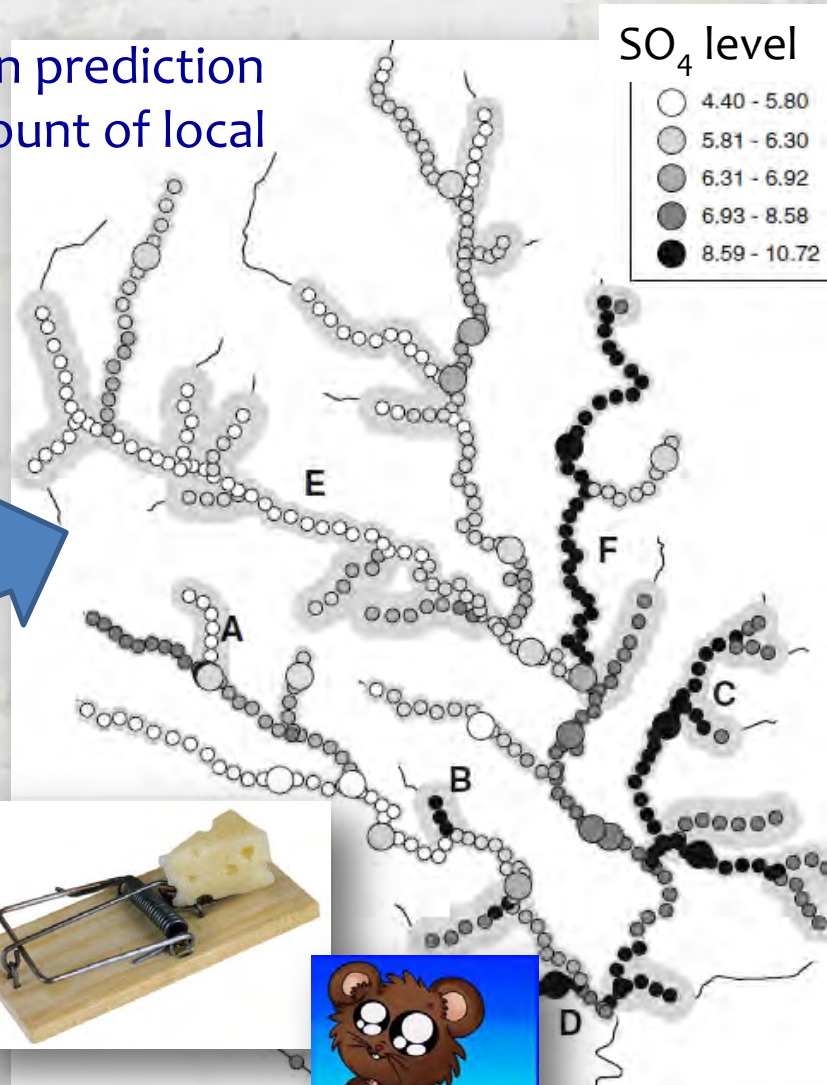
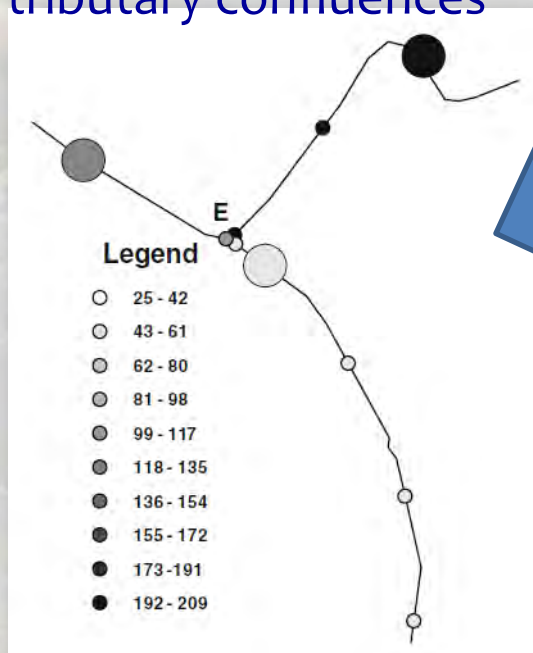
³NOAA National Marine Mammal Lab, Alaska Fisheries Science Center, 7600 Sand Point Way NE, Seattle, WA 98115, USA

Spatial Statistical Network Models

Work the Way that Streams Do...

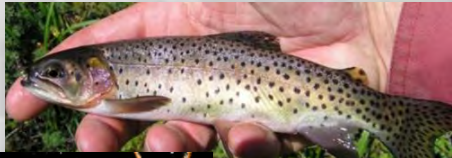
Portray spatial differences in prediction precision related to the amount of local empirical support...

... & represent changes in attributes that occur at tributary confluences



... & are significantly better mousetraps

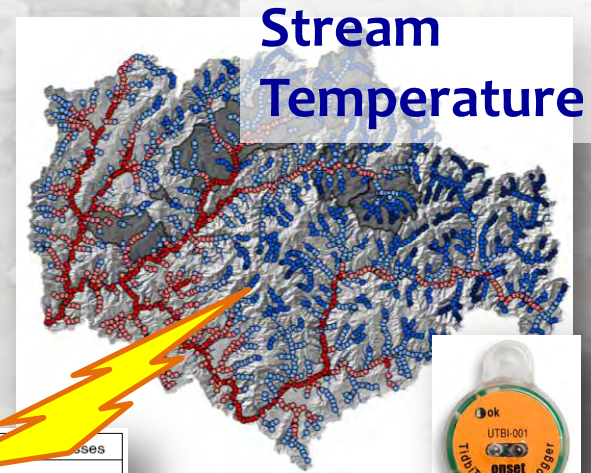
Stream Models are Generalizable...



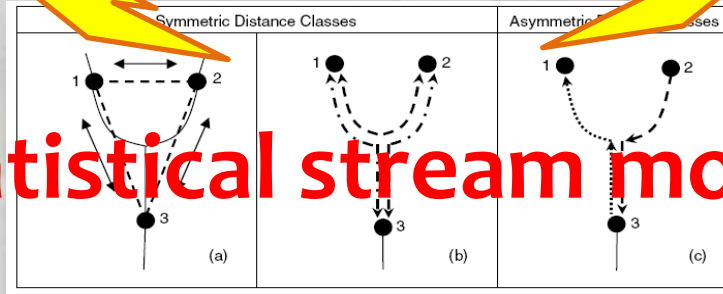
Distribution & abundance

Response Metrics

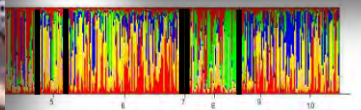
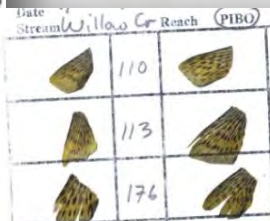
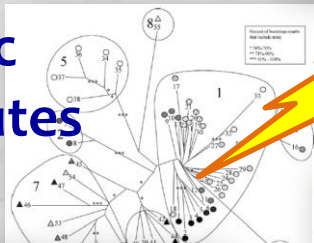
- Gaussian
- Poisson
- Binomial



Statistical stream models



Genetic Attributes

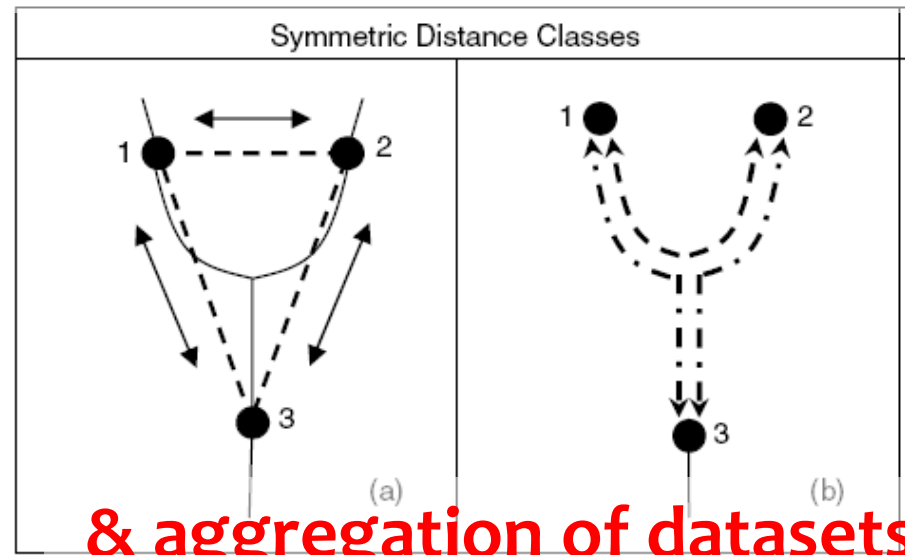
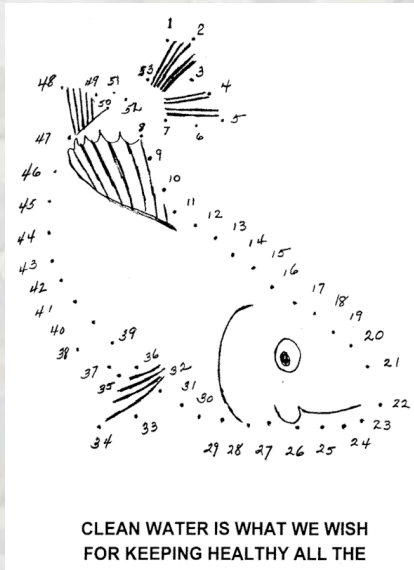


Water Quality Parameters



Spatial Statistical Models are Dot Connectors

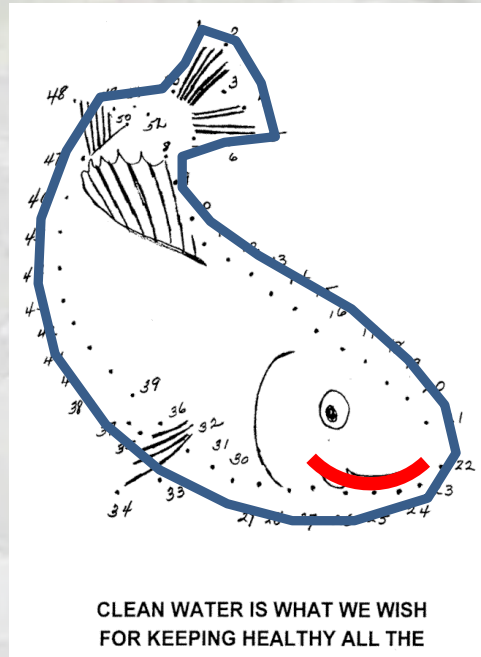
Valid interpolation on networks



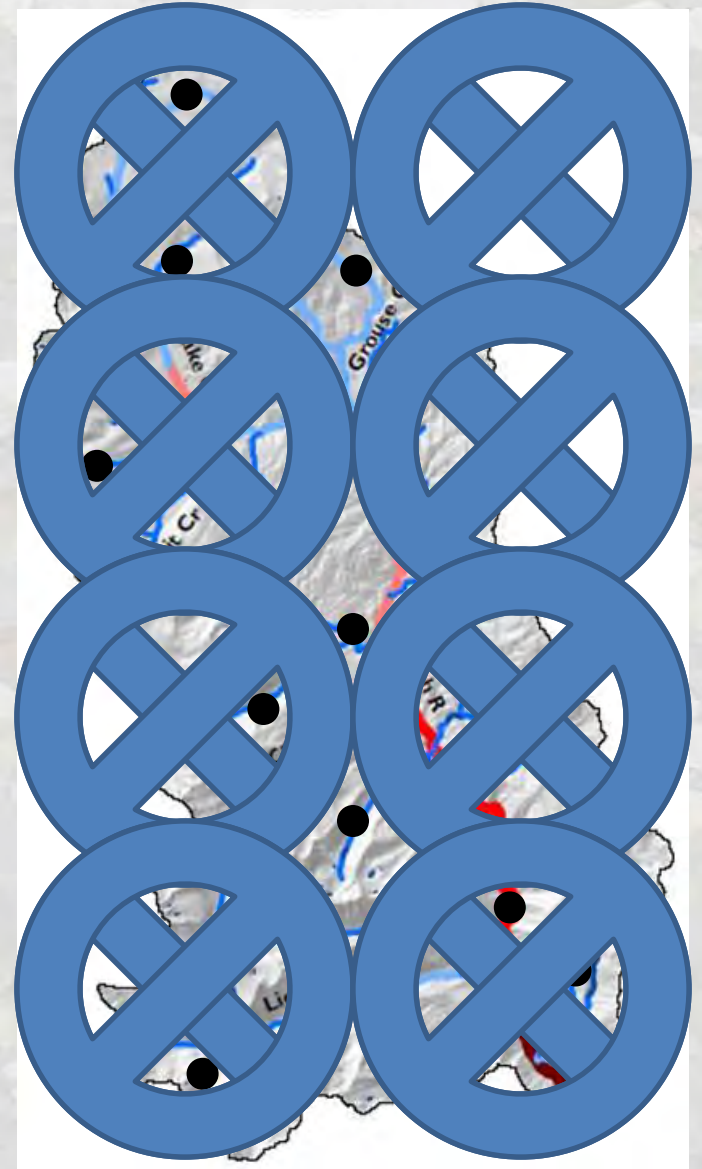
Advantages:

- flexible & valid covariance structures
by accommodating network topology
- weighting by stream size
- improved predictive ability & parameter
estimates relative to non spatial models

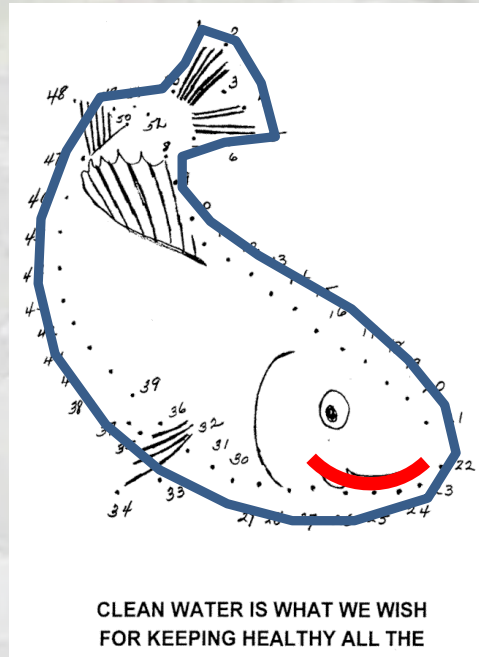
Stop Viewing Streams as Dots



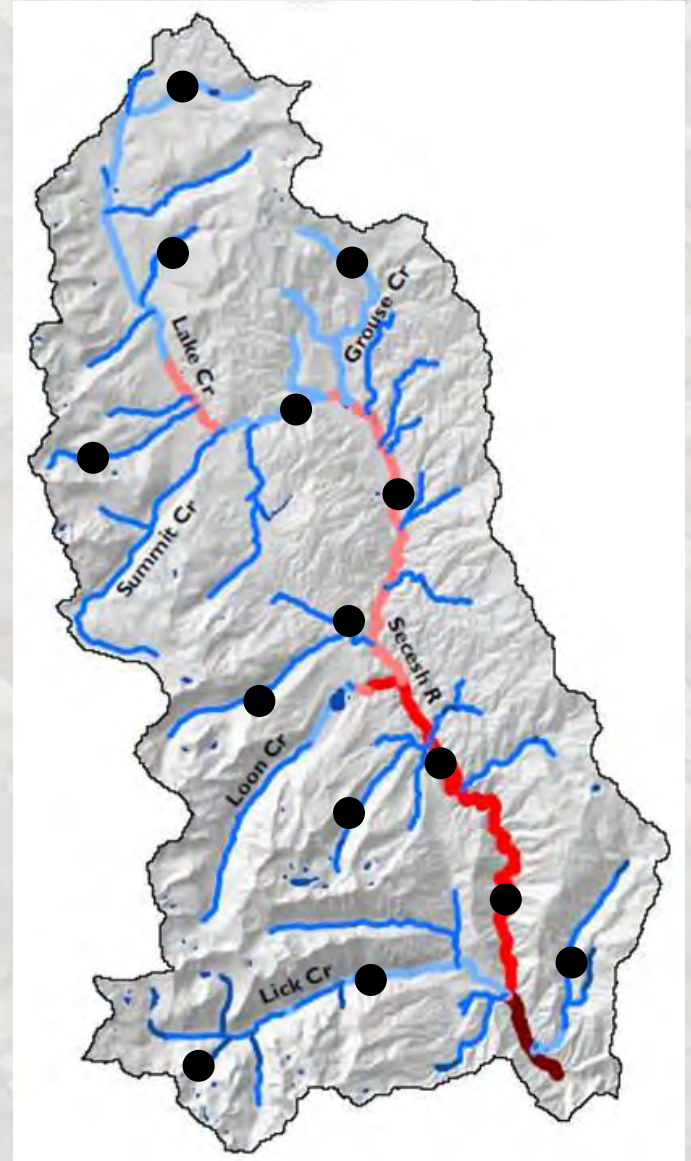
CLEAN WATER IS WHAT WE WISH
FOR KEEPING HEALTHY ALL THE



Stop Viewing Streams as Dots



CLEAN WATER IS WHAT WE WISH
FOR KEEPING HEALTHY ALL THE



“Smart” Maps Developed from Data

Good Maps Significantly
Reduce Uncertainty

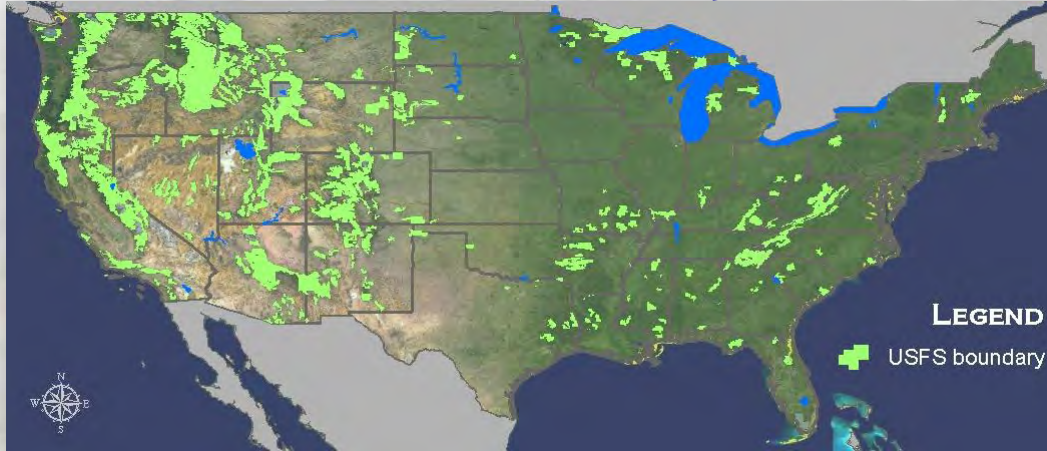


We need to make this generation's maps showing
aquatic resource status



Consistent, Accurate Information Needed Across Broad Areas

Lands Administered by USFS

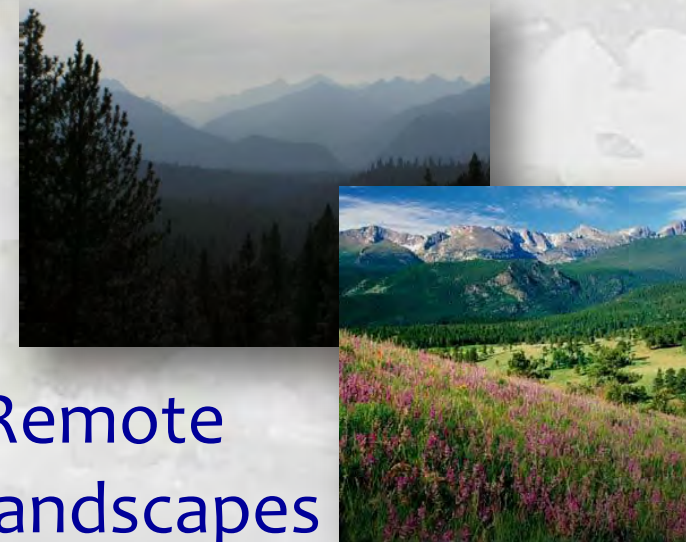


- 193 Million Acres (10% of US)
- 155 National Forests
- 500,000 stream kilometers

Diverse streams

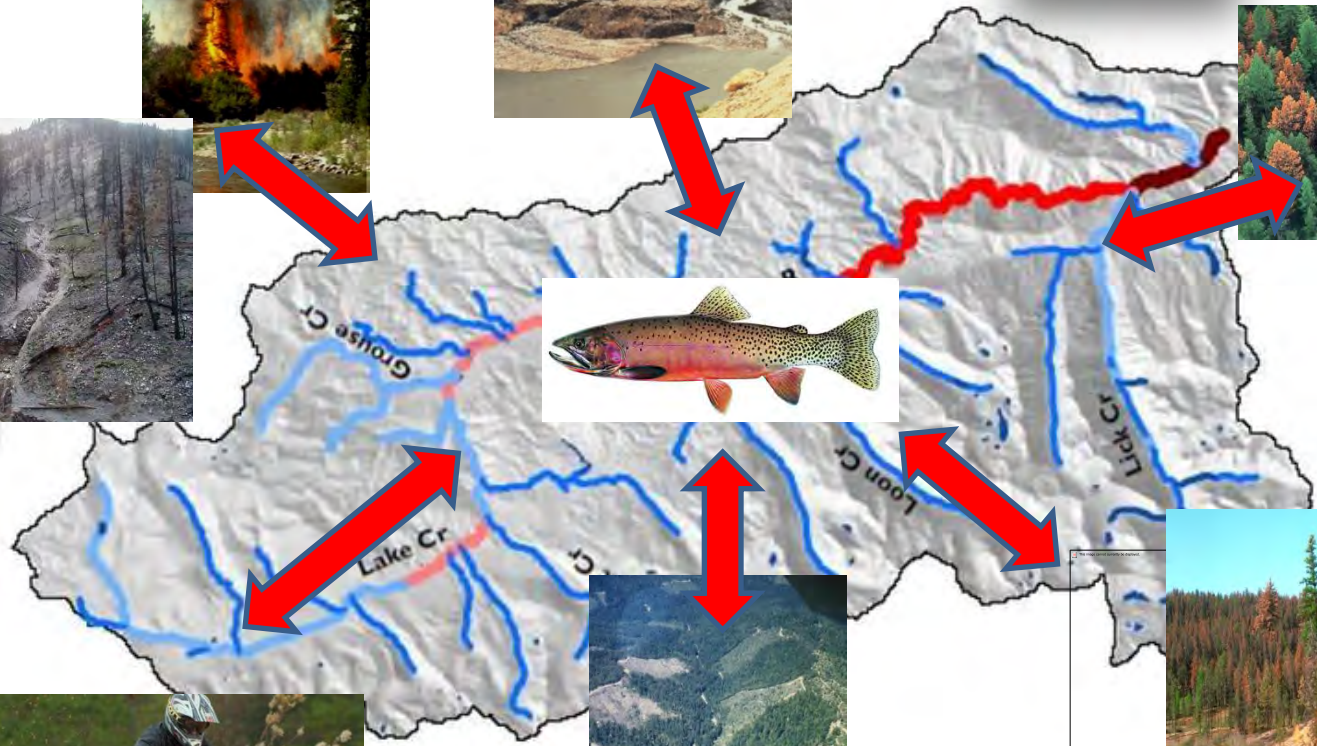


Remote landscapes



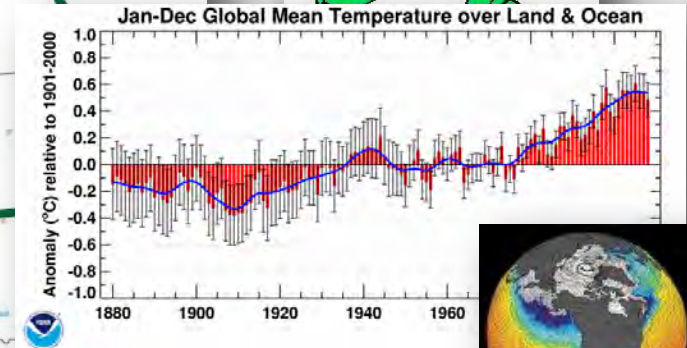
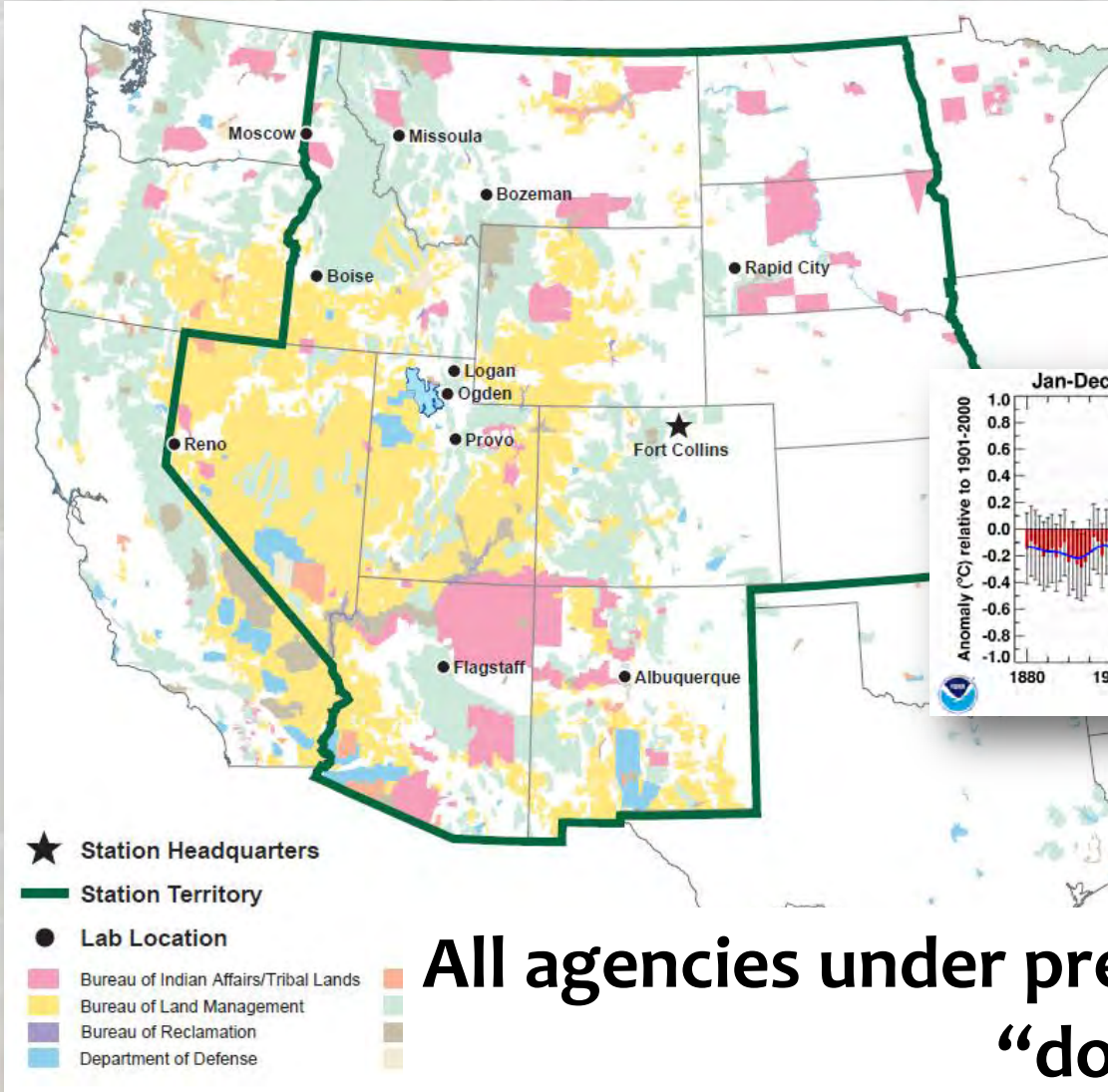
Where do Fish Fit in a Terrestrial World?

This is a Tree not a Fish



Consistent, Accurate Information Needed Across Agencies

Climate Boogeyman



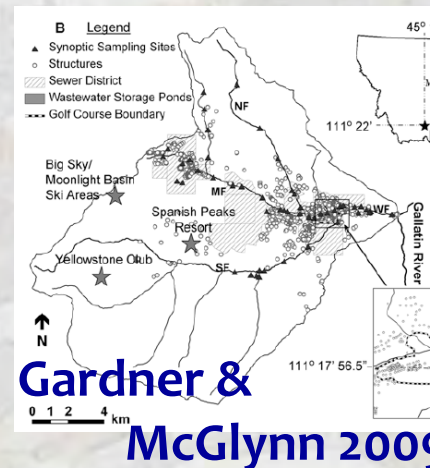
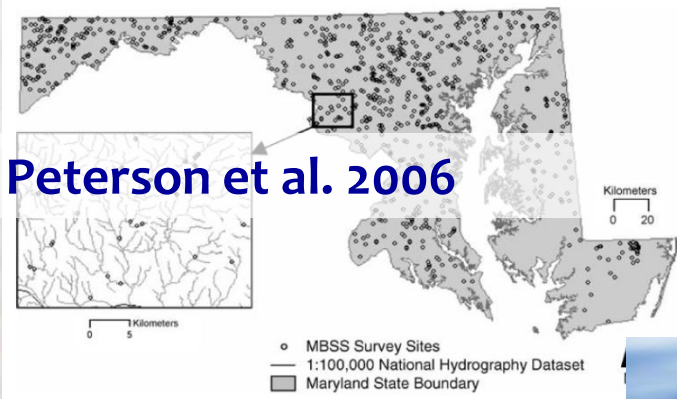
All agencies under pressure to “do something”...



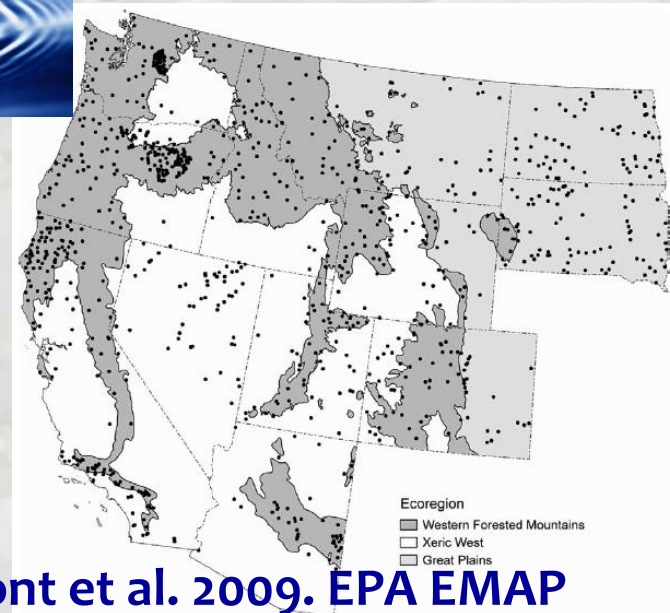
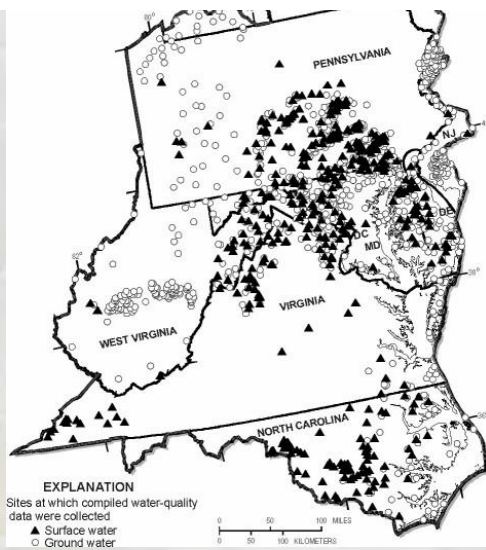
Key Ingredient #3: Existing Databases

Water Quality/Chemistry Information

(Nitrates, alkalinity, ph, DOC, conductivity, etc.)



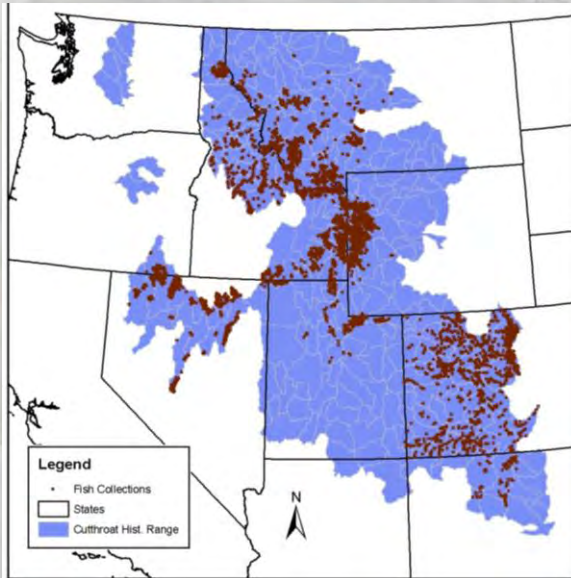
USGS, unpublished



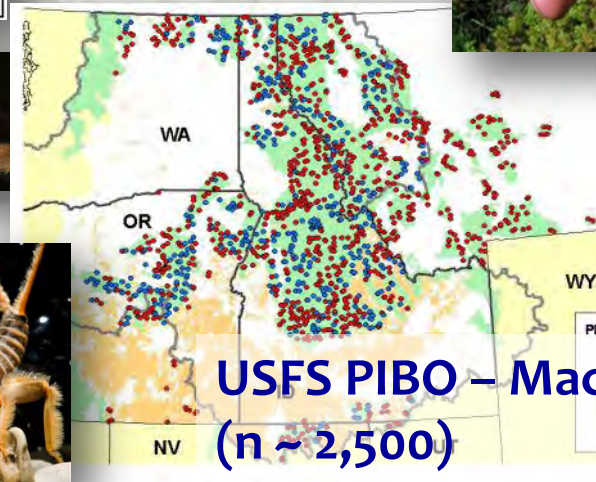
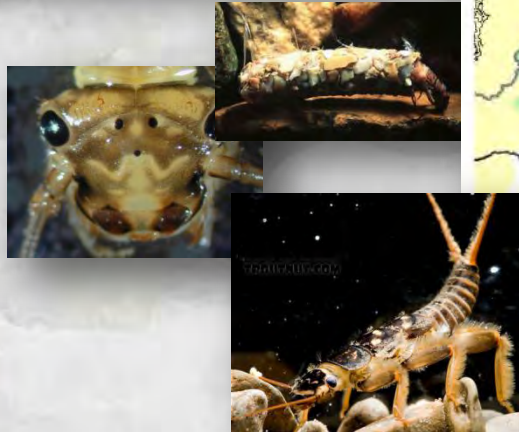
Harnessing Existing Databases

Distribution & abundance of critters

Rocky Mountain
Trout database (n ~ 10,000)

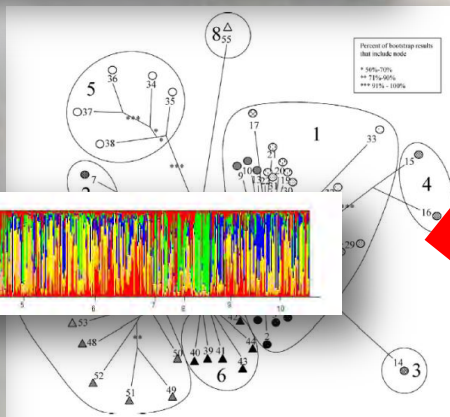
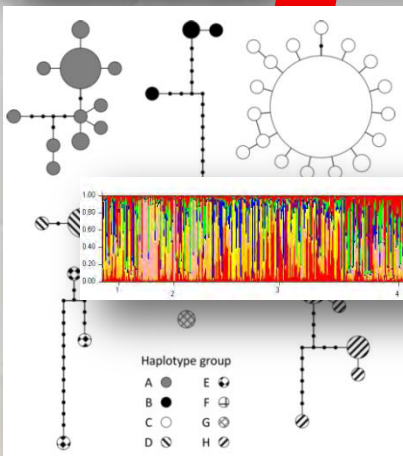
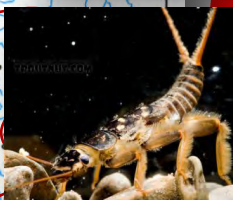
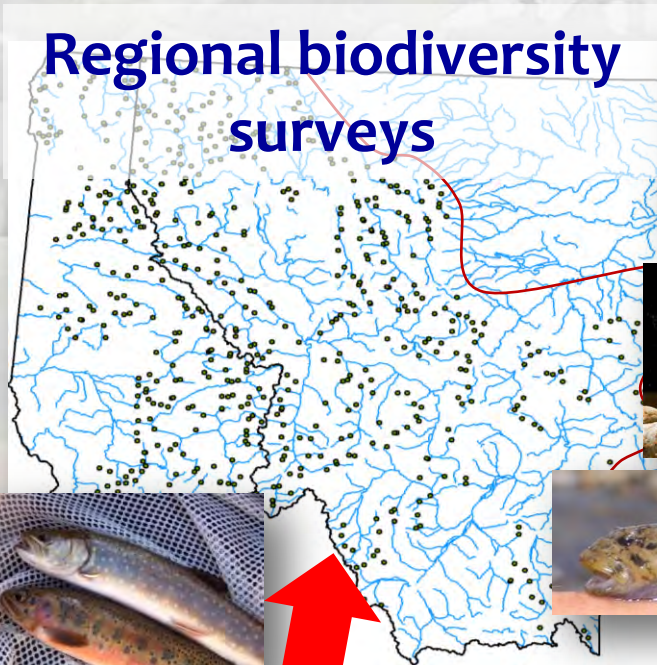


Boise basin fish
database (n ~ 2,000)



Lots of Genetic Data Coming...

Regional biodiversity surveys



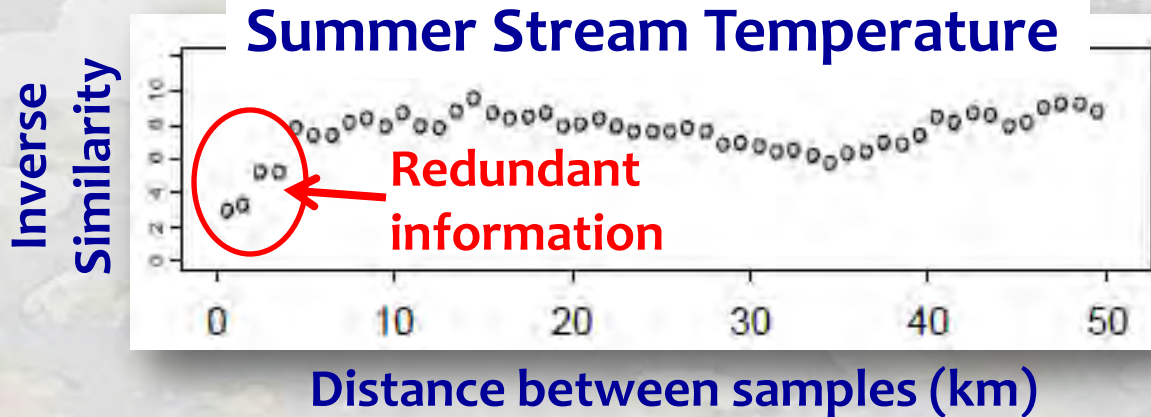
9/23/08
Date
Stream/J. Hoop Cr Roach (PIBO) UTM E UTM N Zone

110	145	120	190
113	167	125	195
126	137	121	211
109	167	121	191
202	167	106	180
210	167	110	178
162	180	112	142
123	116		171
96	88		147

Tissue Samples

Young et al. 2013; Schwartz et al. 2007; Campbell et al. 2012

Where Data are Sparse, Spatial Models Can Guide Efficient Monitoring Design



Sampling distribution Too many...



A Stream InterNet is Possible

Technology exists. Spatial stream models, computing horsepower, & geospatial technologies provide the basic “routers, switches, servers, and search algorithms” to develop & transfer massive amounts of accurate information about stream resources.

Needed. All agencies experiencing declining budgets & need to do more with less. Also have mandates to address overarching, cross-boundary threats posed by climate change & human population growth.

Scalable. Nationally available geospatial data, growing aquatic databases, & large customer base comprised of natural resource stewards from dozens of resource organizations across the country.

Wanted. New & useful information developed from data that local resource stewards collected. “Killer Apps” can be designed to translate information into formats that empower local decision makers.

Costs. Minimal

Value. Priceless. How do you value good information?



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

Dan Isaak, Seth Wenger¹, Erin Peterson², Jay Ver Hoef³, Charlie Luce, Steve Hostetler⁴, Jason Dunham⁴, Jeff Kershner⁴, Brett Roper, Dave Nagel, Dona Horan, Gwynne Chandler, Sharon Parkes, Sherry Wollrab

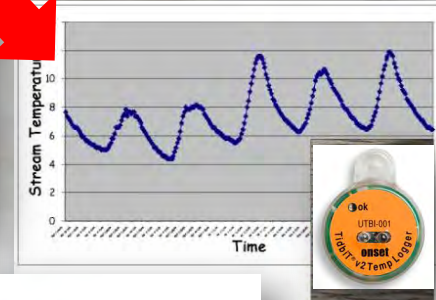
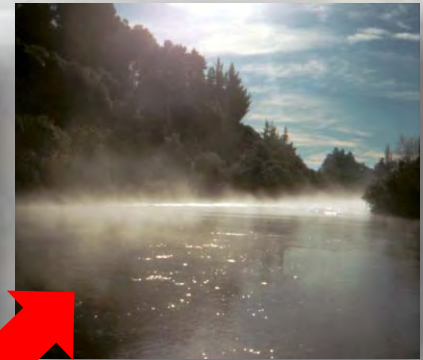
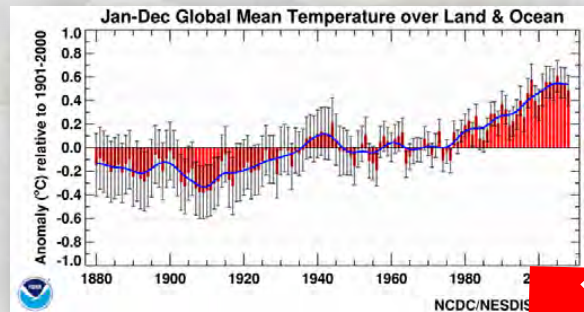
U.S. Forest Service

¹Trout Unlimited

²CSIRO

³NOAA

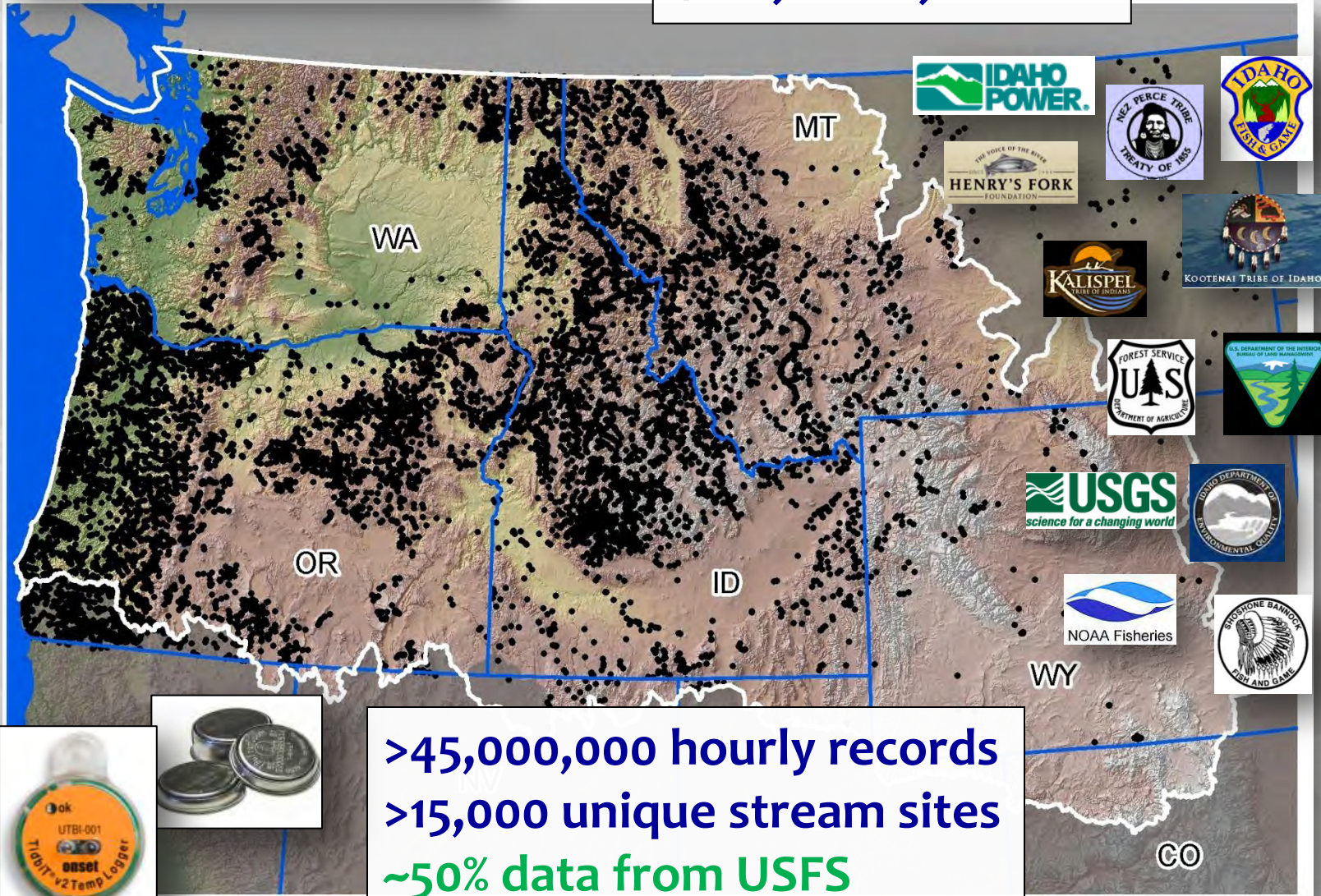
⁴USGS



NorWeST

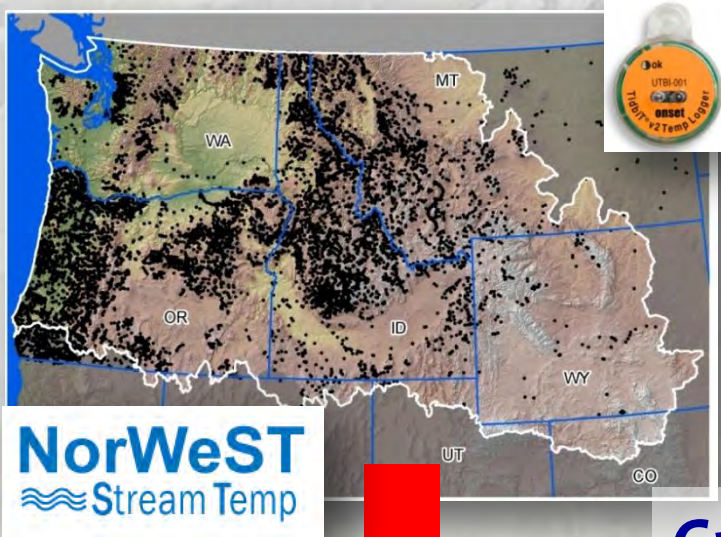
Stream Temp

>60 agencies
\$10,000,000

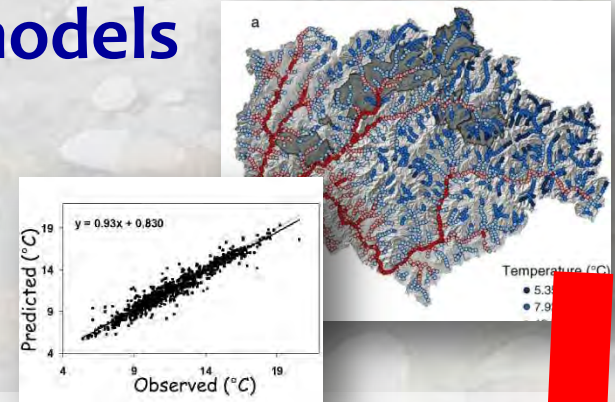


>45,000,000 hourly records
>15,000 unique stream sites
~50% data from USFS

Regional Temperature Model

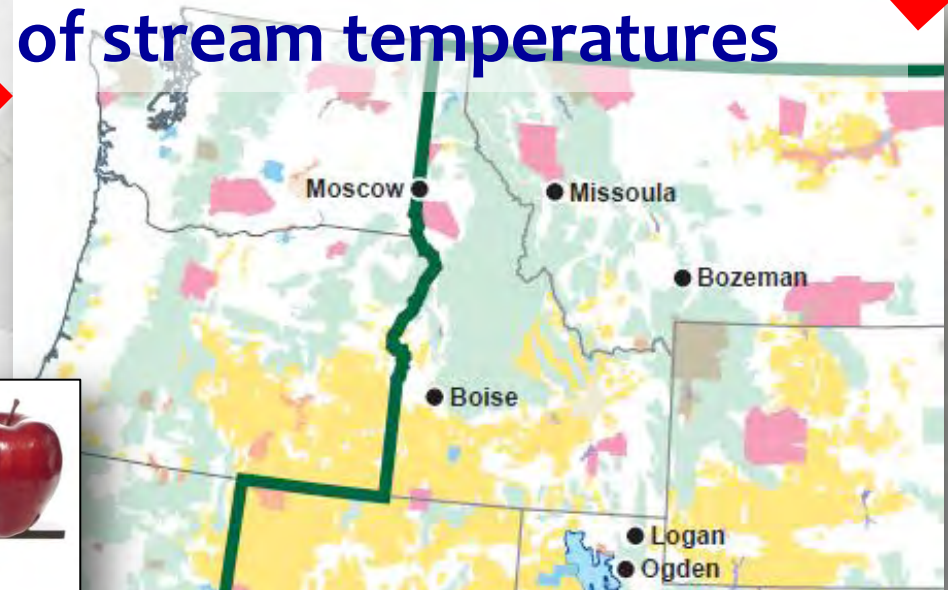
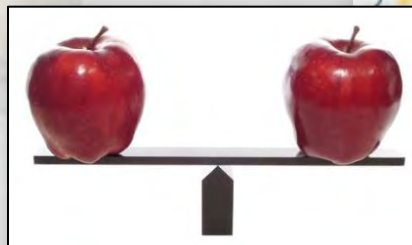


Accurate temperature models

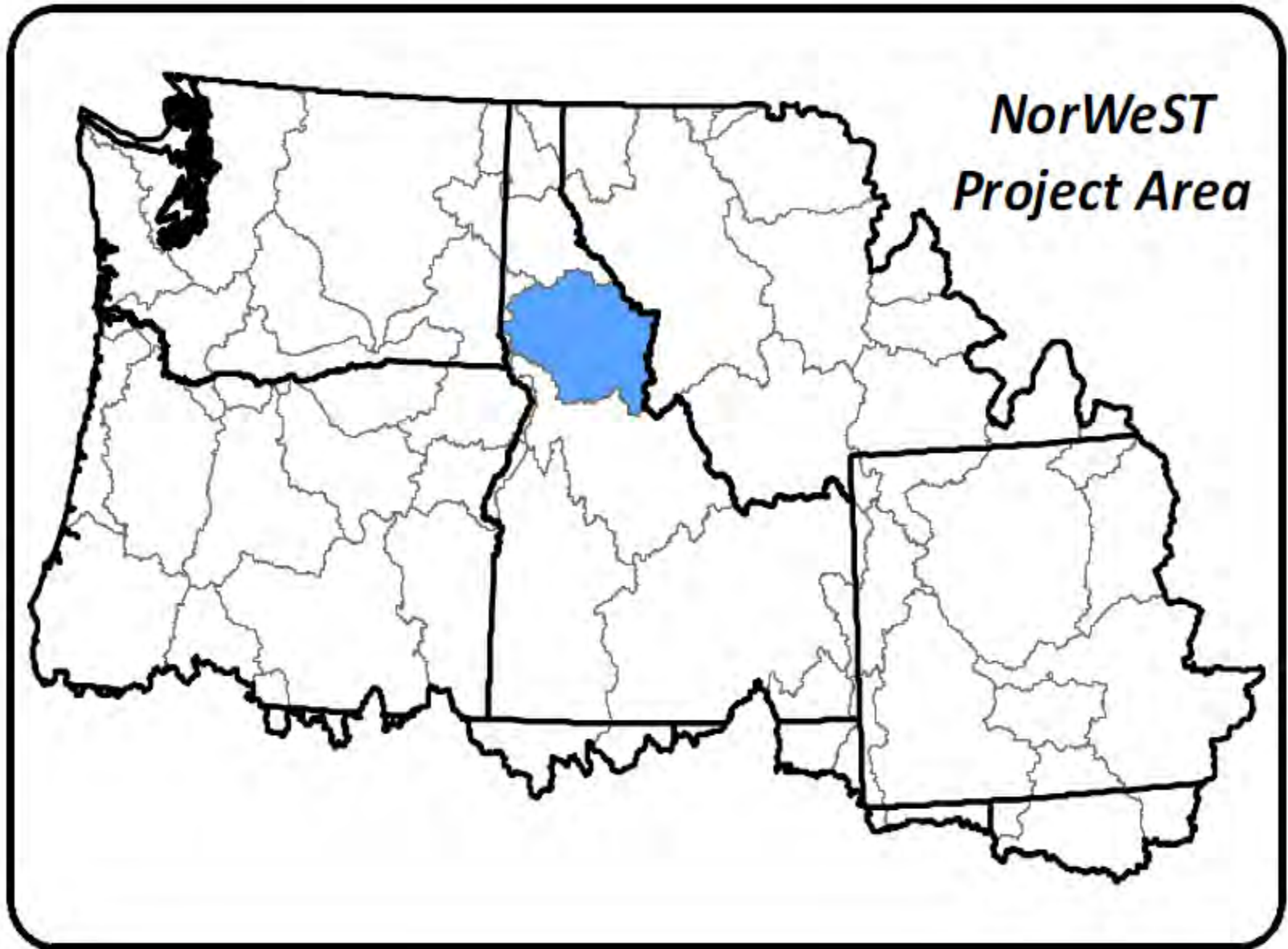


Cross-jurisdictional “maps” of stream temperatures

Consistent datum for strategic assessments across 350,000 stream kilometers



Example: Clearwater River Basin

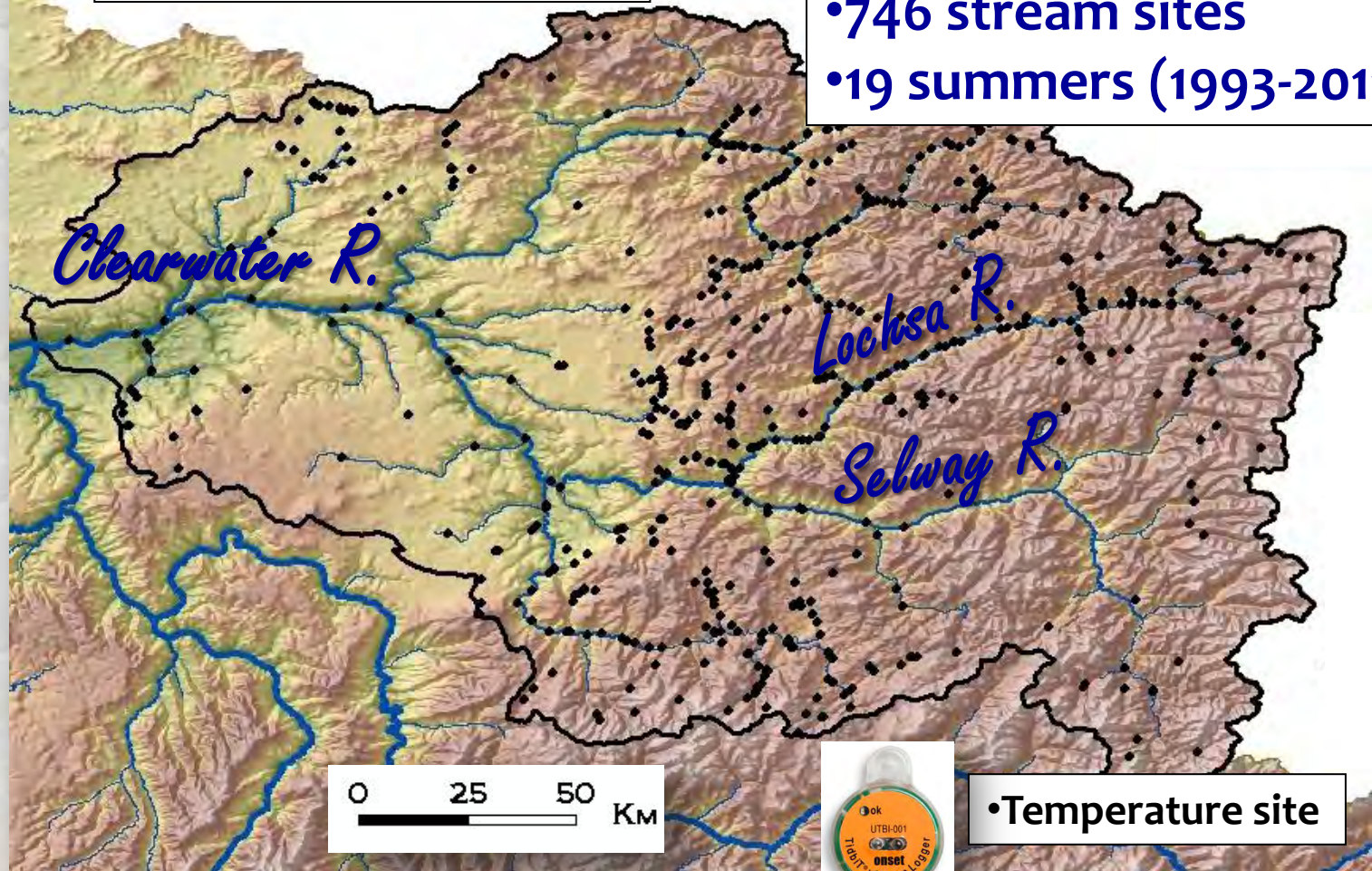


Example: Clearwater River Basin

Data extracted from NorWeST

16,700 stream km

- 4,487 August means
- 746 stream sites
- 19 summers (1993-2011)



0 25 50 Km



•Temperature site



Clearwater River Temp Model

n = 4,487

Covariate Predictors

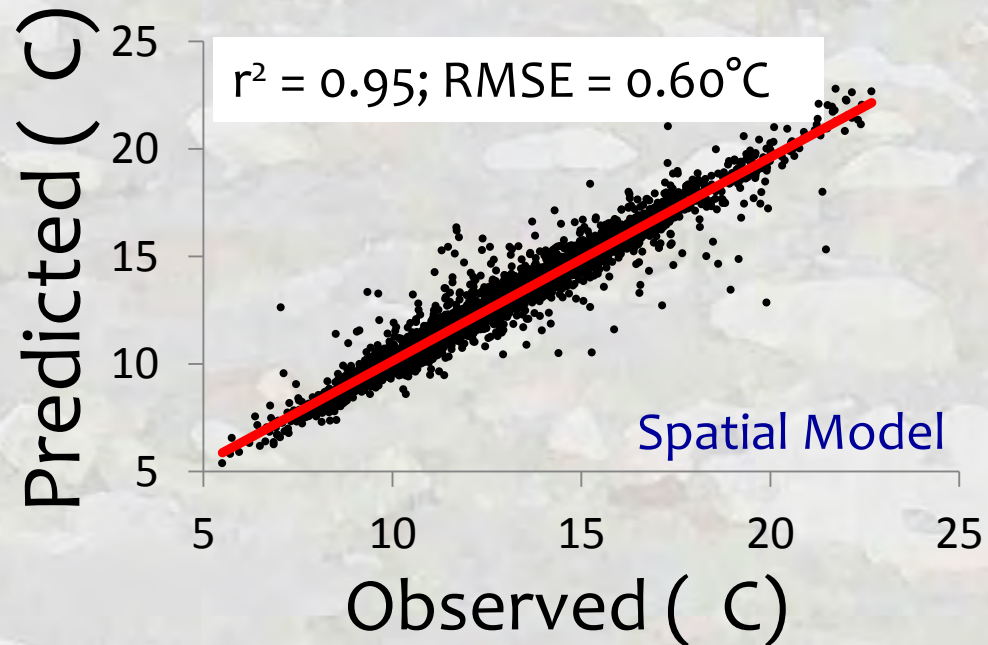
1. Elevation (m)
2. Canopy (%)
3. Stream slope (%)
4. Ave Precipitation (mm)
5. Latitude (km)
6. Lakes upstream (%)
7. Baseflow Index
8. Watershed size (km²)
9. Discharge (m³/s)
10. Air Temperature (°C)

USGS gage data

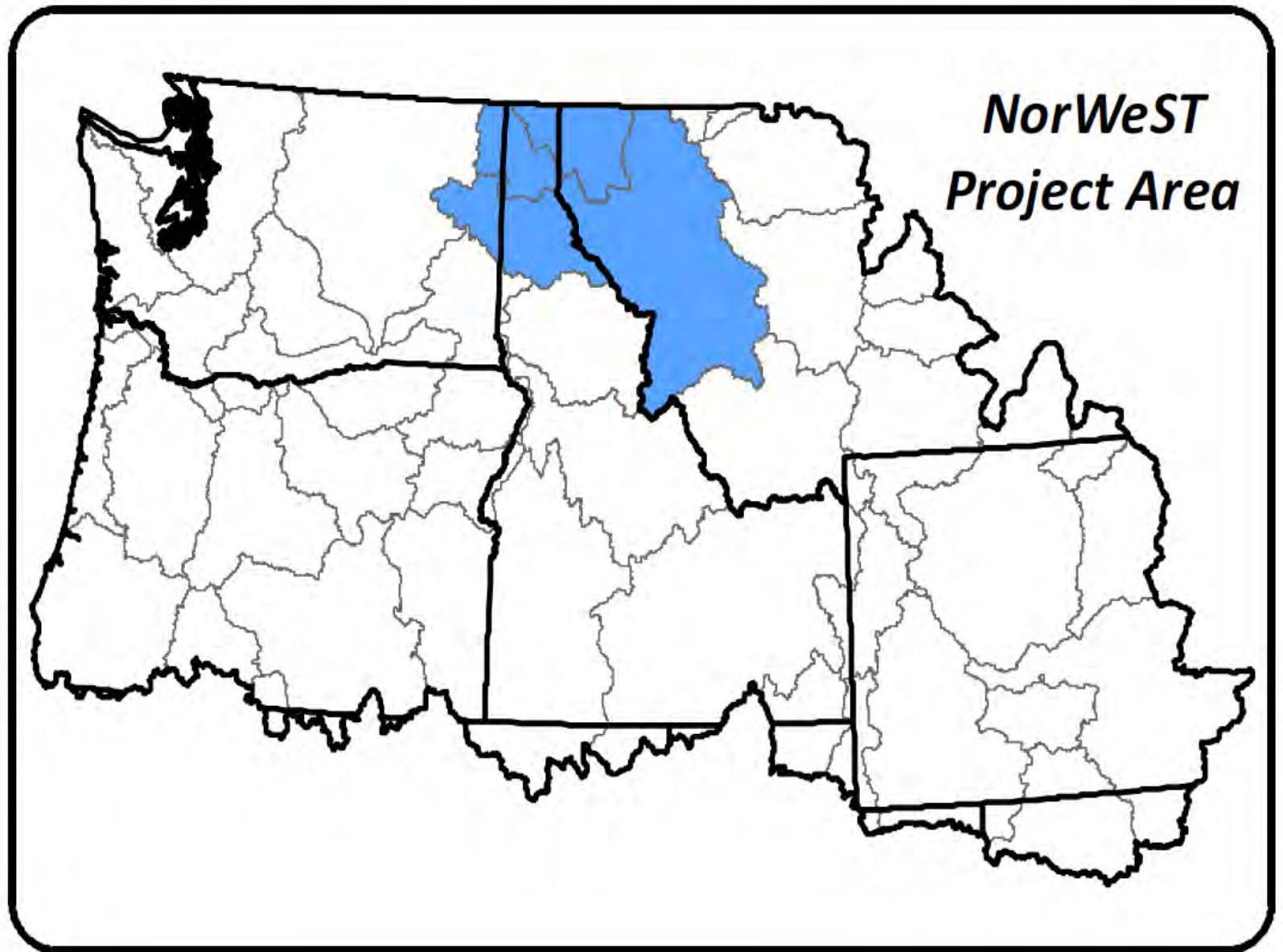
RegCM3 NCEP reanalysis

Hostetler et al. 2011

Mean August Temperature

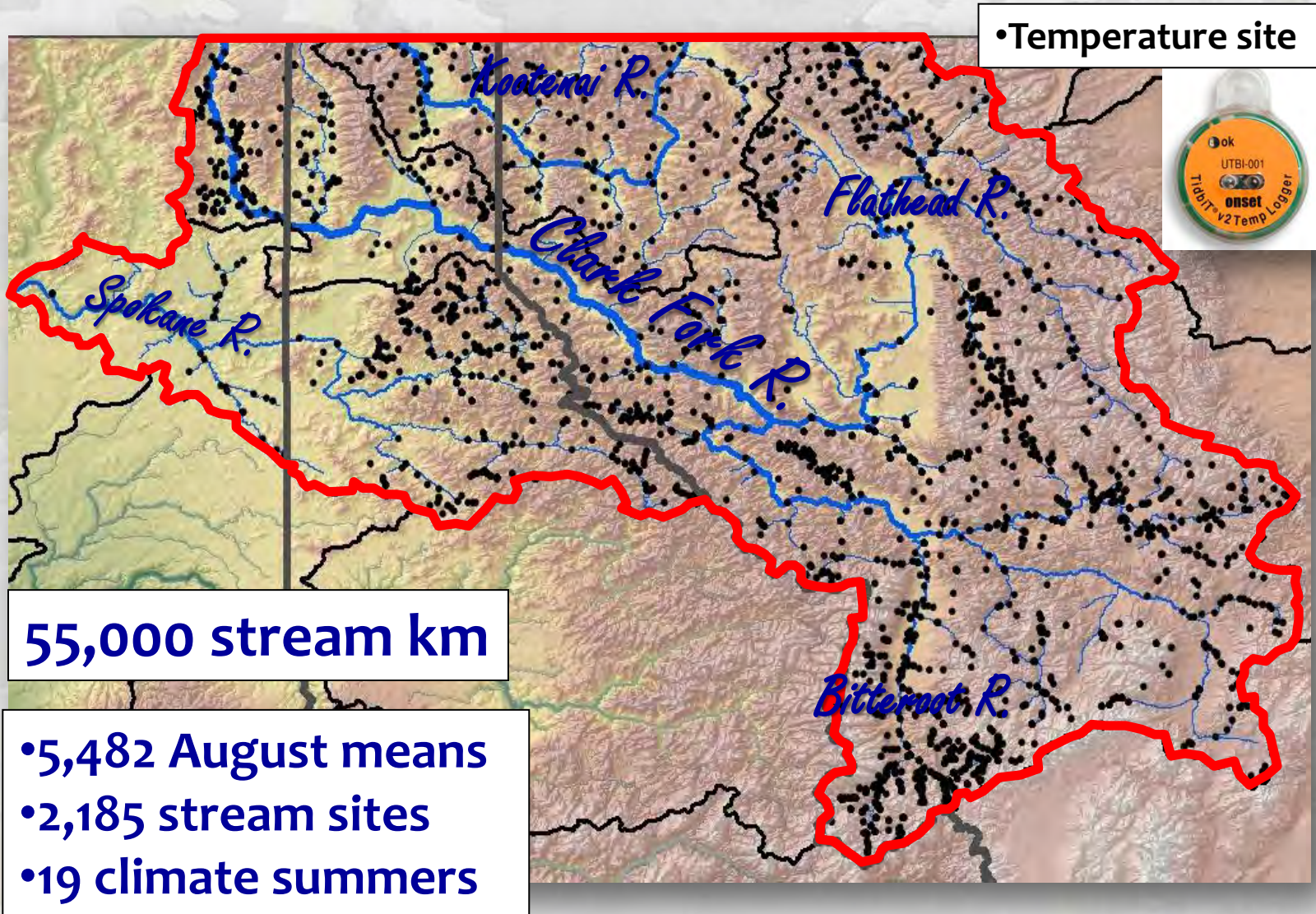


Example: SpoKoot River Basins



Example: SpoKoot River Basins

Data extracted from NorWeST



SpoKoot River Temp Model

n = 5,482

Covariate Predictors

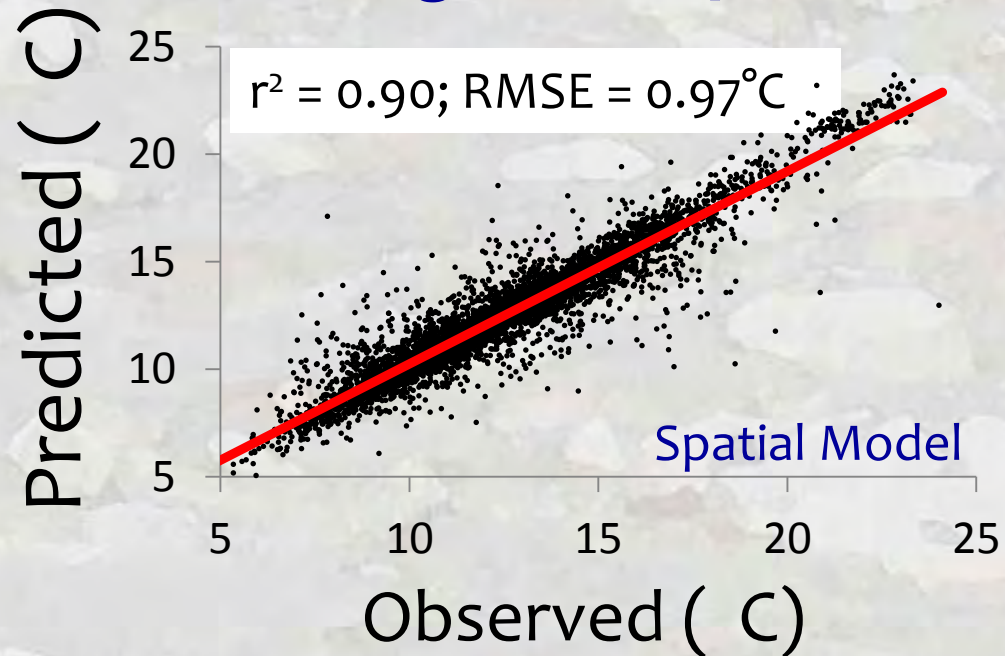
1. Elevation (m)
2. Canopy (%)
3. Stream slope (%)
4. Ave Precipitation (mm)
5. Latitude (km)
6. Lakes upstream (%)
7. Baseflow Index
8. Watershed size (km²)
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USGS gage data

RegCM3 NCEP reanalysis

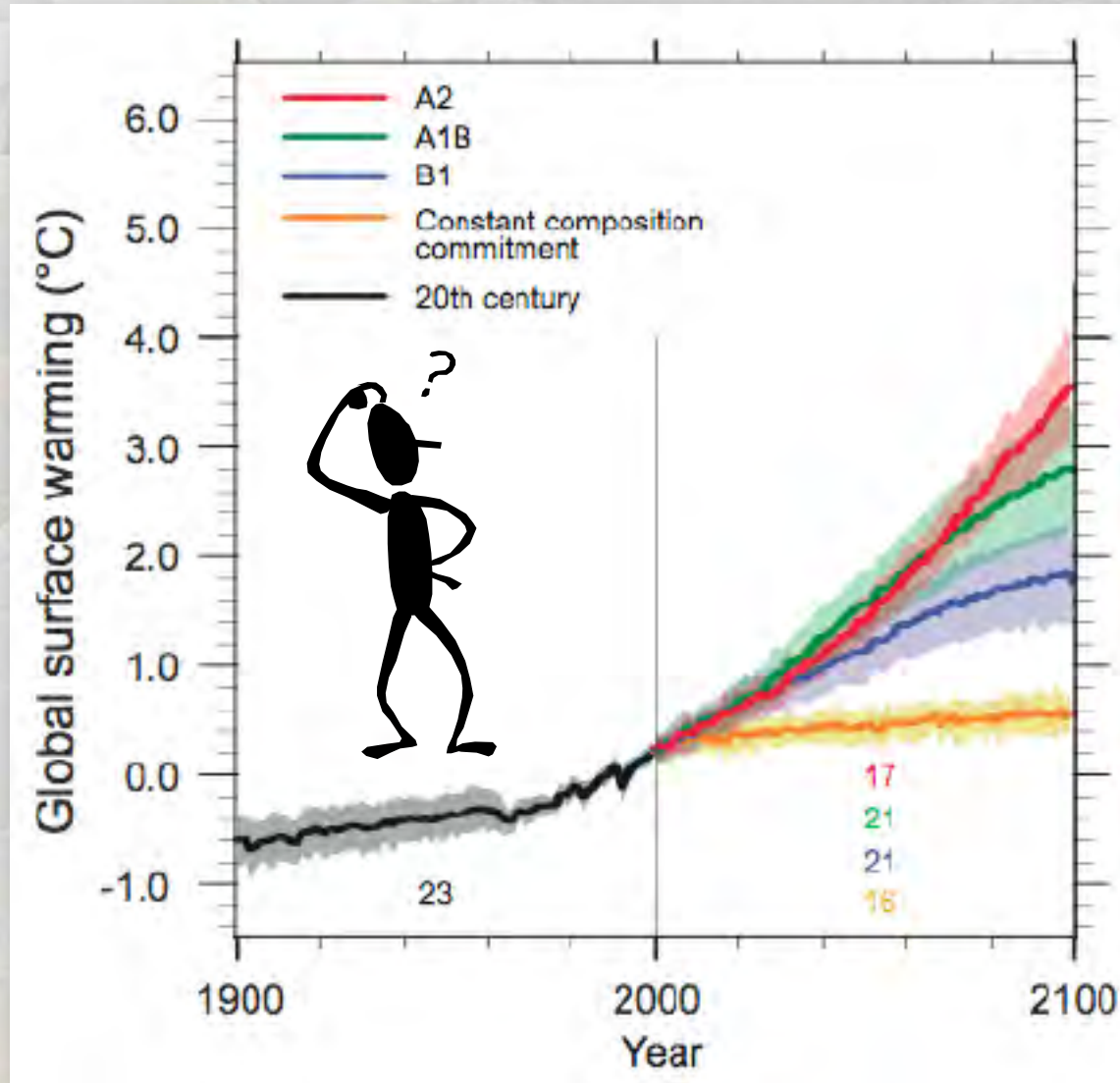
Hostetler et al. 2011

Mean August Temperature



Models Enable Climate Scenario Maps

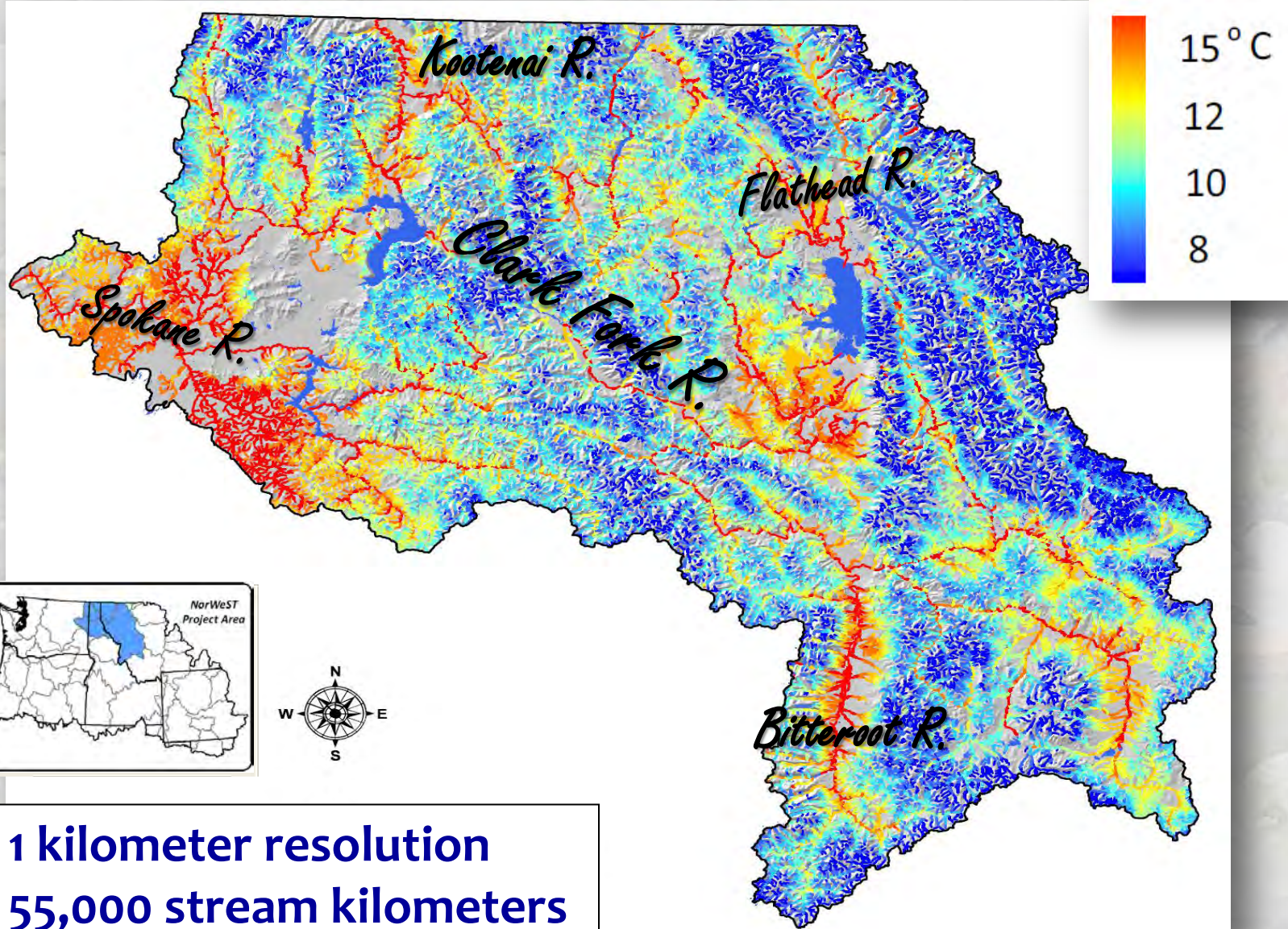
Many possibilities exist...



Adjust air & discharge values to represent scenarios

Historic Scenario: SpoKoot Unit (S1_93-11)

1993-2011 mean August stream temperatures

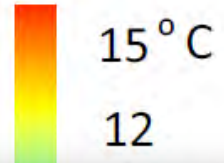
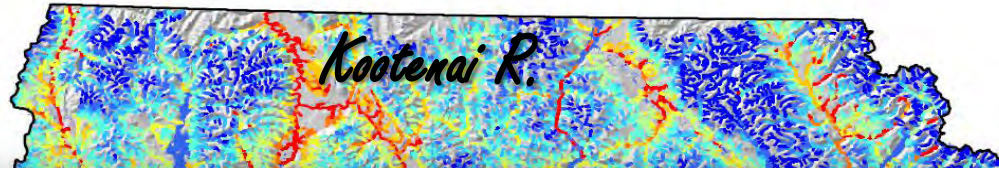


1 kilometer resolution
55,000 stream kilometers



Historic Scenario: SpoKoot Unit (S1_93-11)

1993-2011 mean August stream temperatures



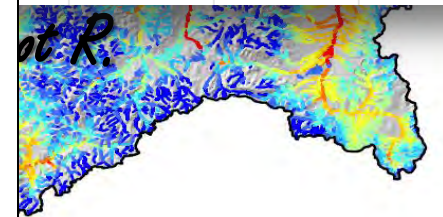
C	D	E	F	G	H	I	J	K	L	M
CANOPY	SLOPE	PRECIP	CUMDRAINAGE	COORD	NLCD11PC	NLCD12PC	BFI	Air_August	Flow_August	Stream_August
2.82	0.08857	299.6256	19.833	1623663.32	0	0	79	14.02	35.71	12.0812903
2.82	0.08857	299.6256	19.833	1623663.32	0	0	79	13.20	40.52	12.333771
2.82	0.08857	299.6256	19.833	1623663.32	0	0	79	13.00	38.99	11.4041581
12.23	0.03514	242.42	69.271	1620504.73	0.012	0	80	15.84	18.47	12.2216452
12.23										11.0053548

R1 Forests Completed...

- Nez Perce NF
- Bitterroot NF
- Clearwater NF
- Panhandle NF
- **Lolo NF**
- Kootenai NF
- Flathead NF
- Helena NF
- Deerlodge NF

Scenarios coming for ~40 additional forests in R1, 2, 4, and 6

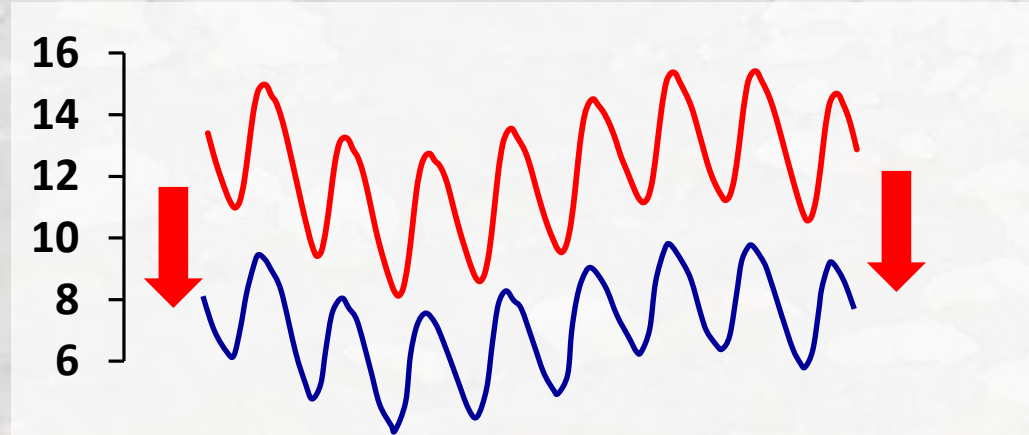
75	13.59	32.75
75	13.59	32.75
75	13.59	32.75



Application: Quantify Thermal Degradation

What is the thermal “intrinsic potential” of a stream?

“How much cooler could we make this stream?”



1) Pick “degraded” and “healthy” streams to compare

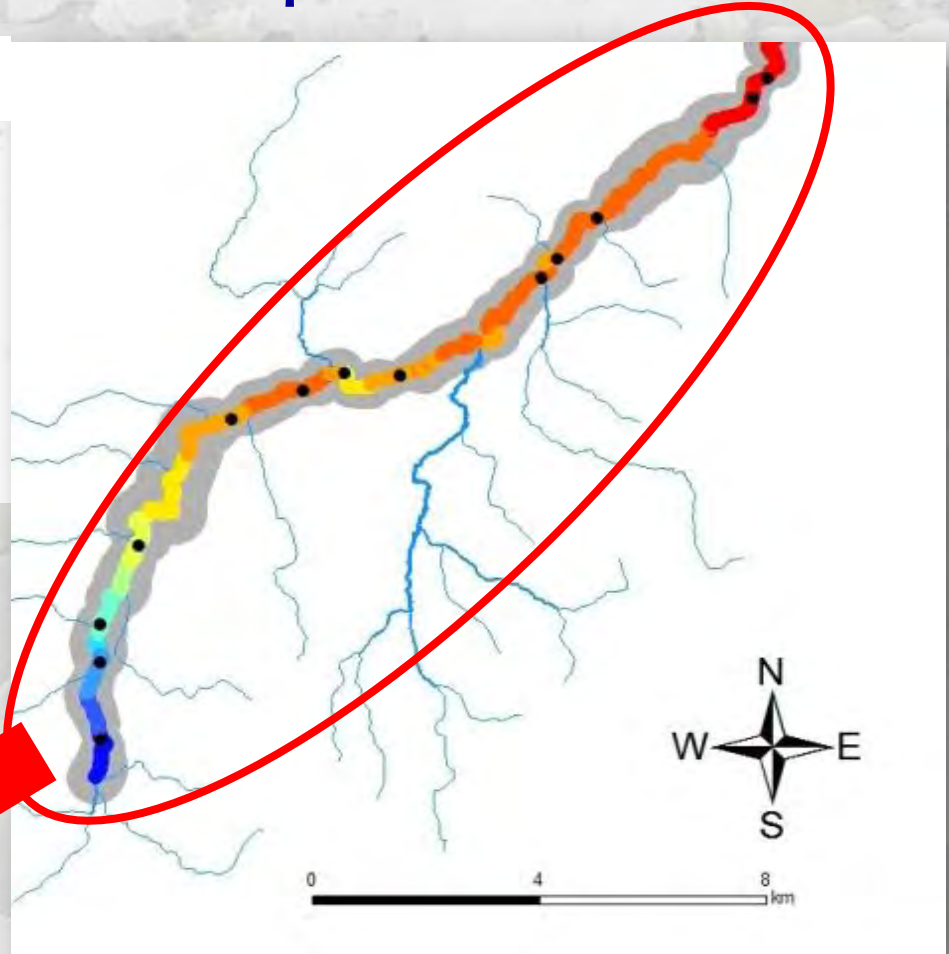
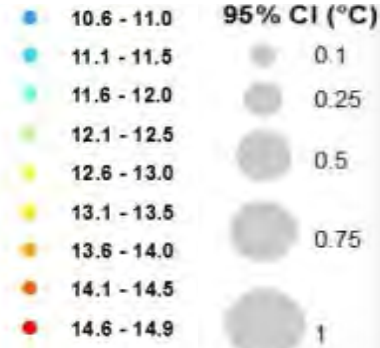


Application: Quantify Thermal Degradation

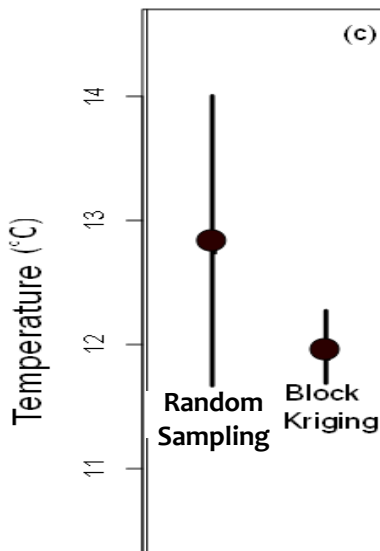
2) Block-krige estimates of temperature at desired scale



Temperature (°C)



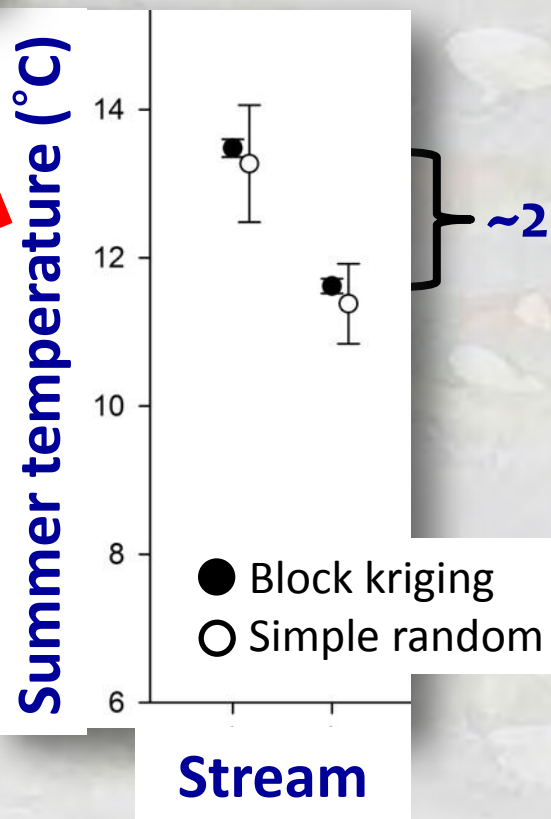
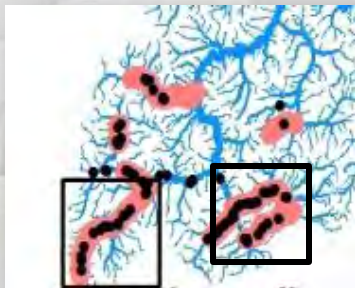
Bear Valley Creek
Mean Temperature



Precise & unbiased estimates

Application: Quantify Thermal Degradation

3) Compare estimates among streams



~2°C cooling is possible



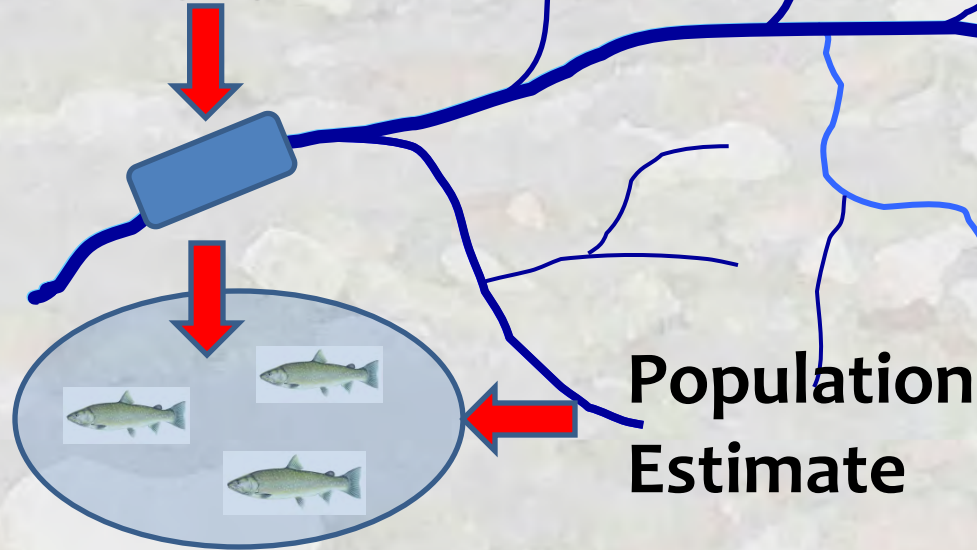
Block-Kriging of Fish Populations

Population Estimates at Relevant Scales



How Many Fish
Live Here?

Sample
Reach



Traditional Estimation Scale =
Reach (10's – 100's meters)

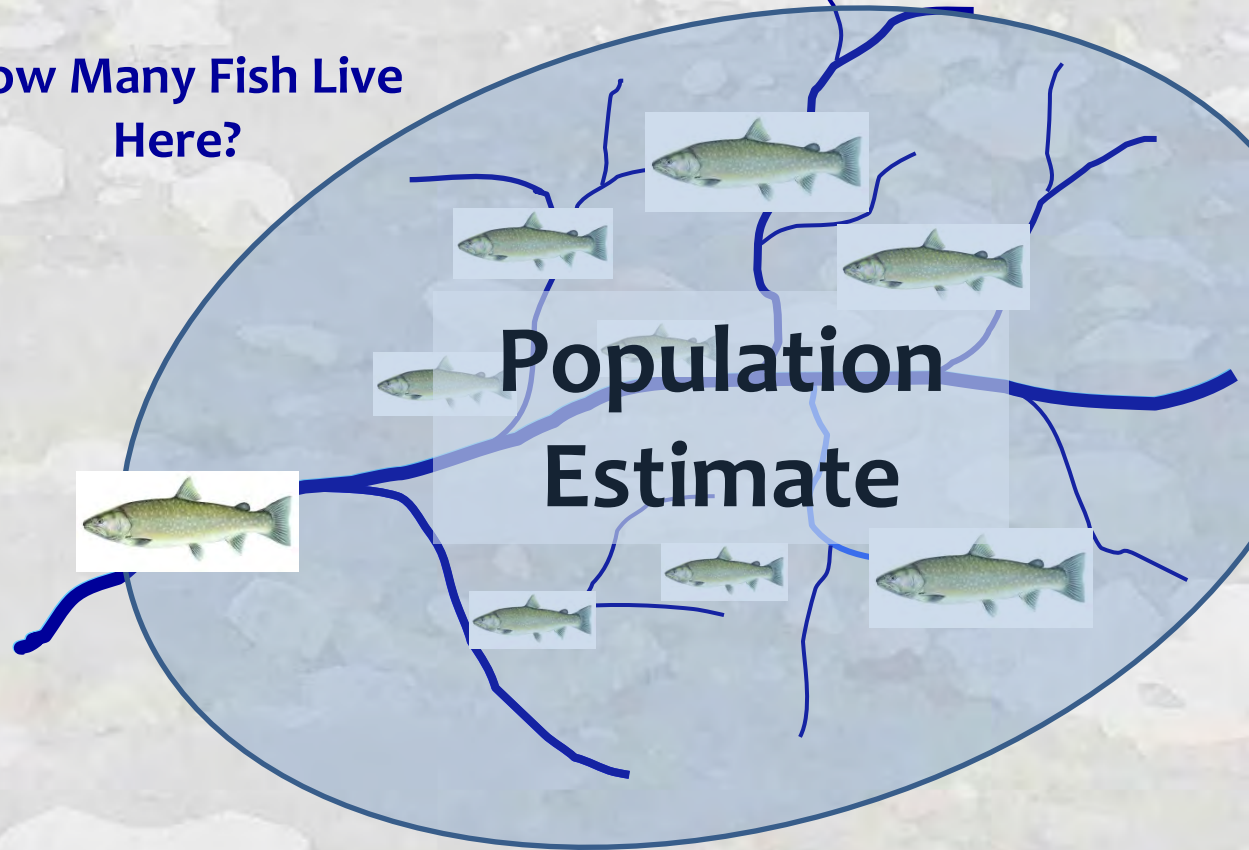


Block-Kriging of Fish Populations

Population Estimates at Relevant Scales



How Many Fish Live Here?



Desired Estimation Scale =

Stream & Network (1000's – 10,000's meters)



Block-Kriging of Fish Populations

Population Estimates at Relevant Scales

Environ Ecol Stat (2008) 15:3–13
DOI 10.1007/s10651-007-0035-y

Spatial methods for plot-based sampling
of wildlife populations

Jay M. Ver Hoef

- Terrestrial applications are common
- Theory now exists for streams

ECO SCIENCE

9 (2) : 152-161 (2002)

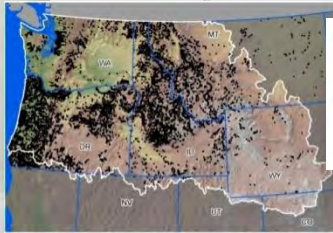
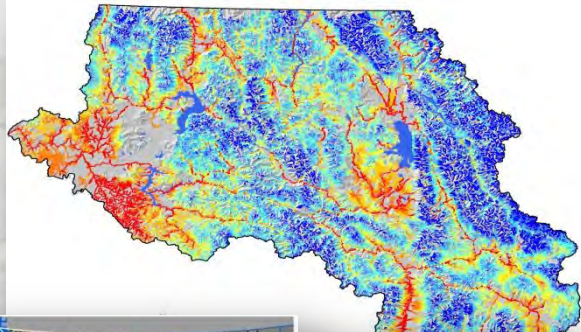
Sampling and geostatistics for spatial data¹

Jay VER HOEF, Alaska Department of Fish and Game, 1300 College Road, Fairbanks, Alaska 99701, U.S.A.,
e-mail: jay_ver_hoef@fishgame.state.ak.us

**Desired Estimation Scale =
Stream & Network (1000's – 10,000's meters)**

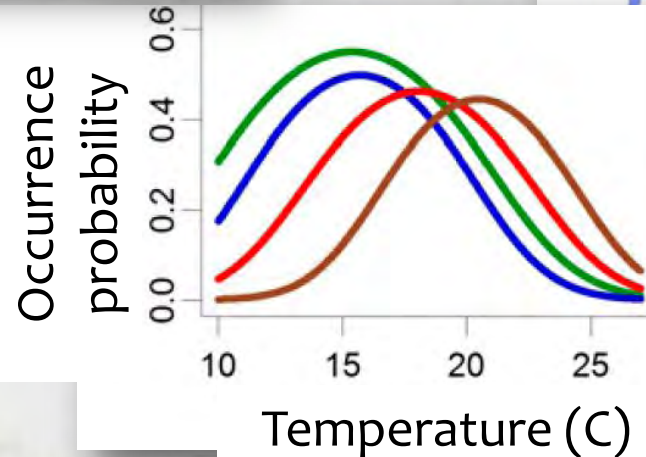
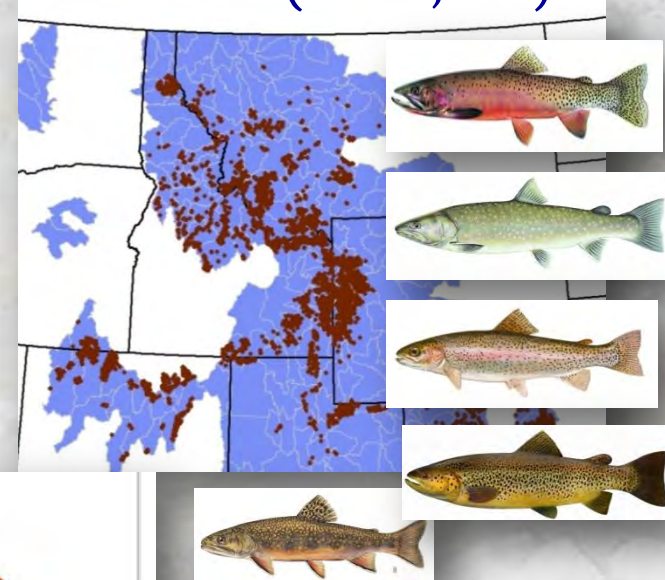
Develop Accurate & Consistent Thermal Criteria

Stream temperature maps



NorWeST
Stream Temp

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*

Thermal Niches For All Stream Critters

Just need georeferenced biological survey data

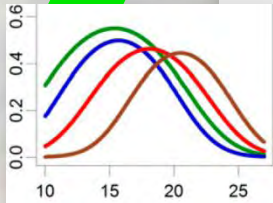
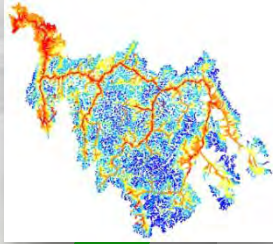


Too warm... Too cold... Just right

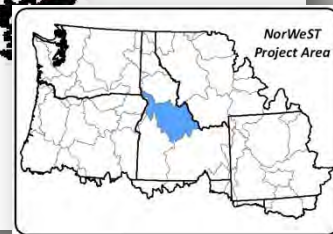
Salmon River Bull Trout Habitats

2002-2011 Historical

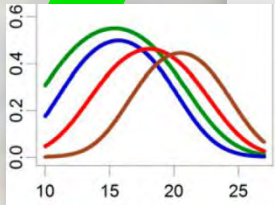
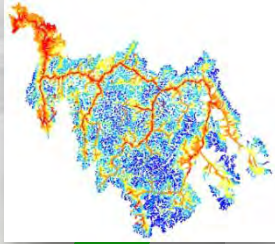
11.2 °C isotherm



■ Suitable
■ Unsuitable



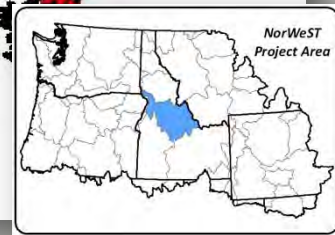
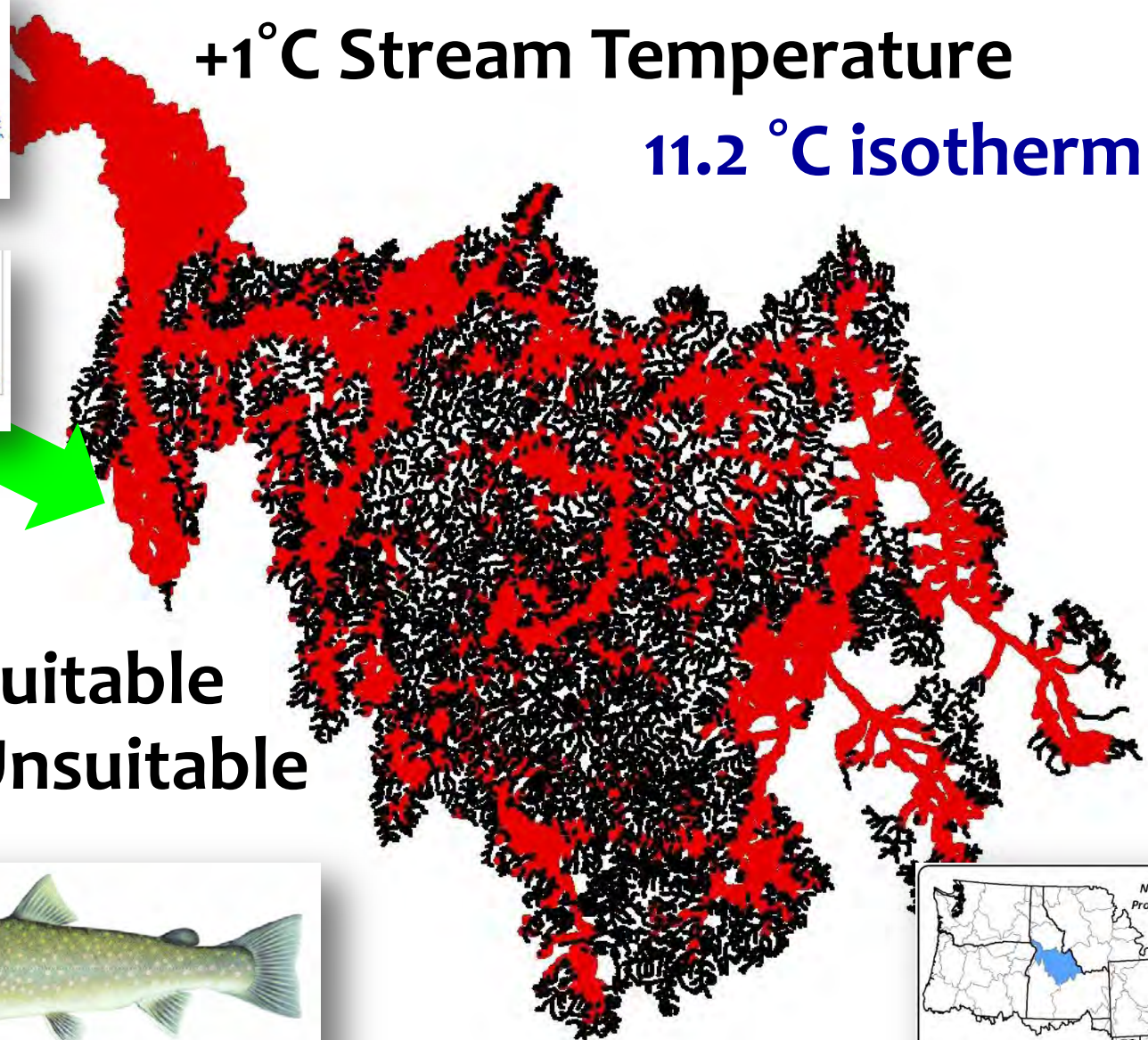
Salmon River Bull Trout Habitats



+1°C Stream Temperature

11.2 °C isotherm

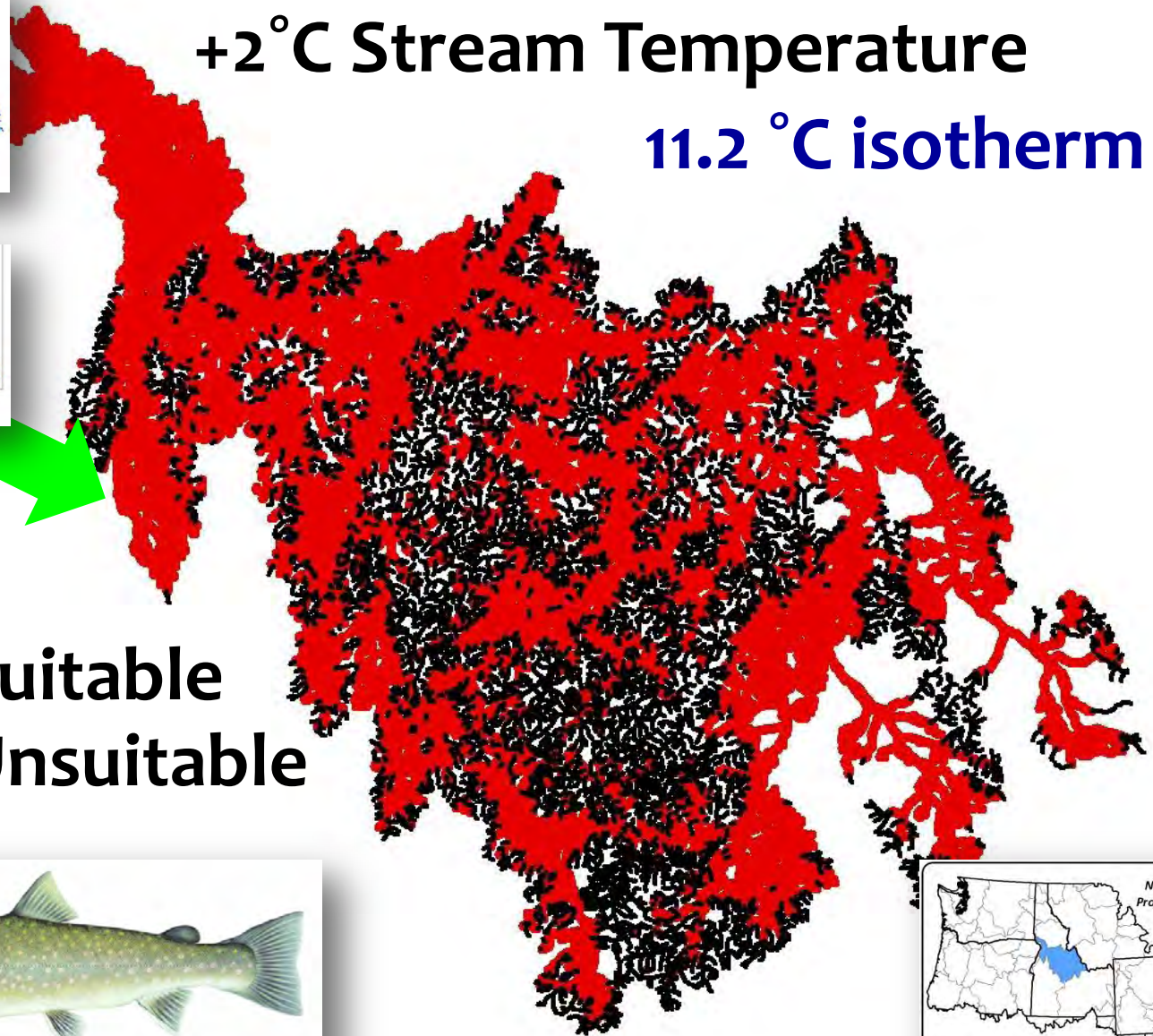
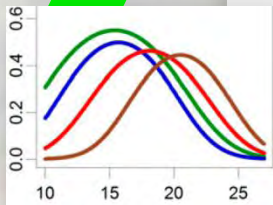
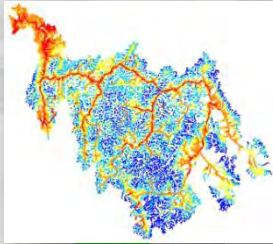
■ Suitable
■ Unsuitable



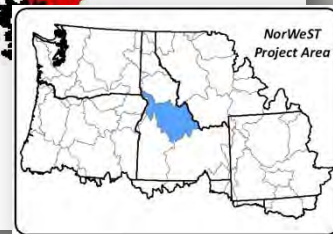
Salmon River Bull Trout Habitats

+2°C Stream Temperature

11.2 °C isotherm

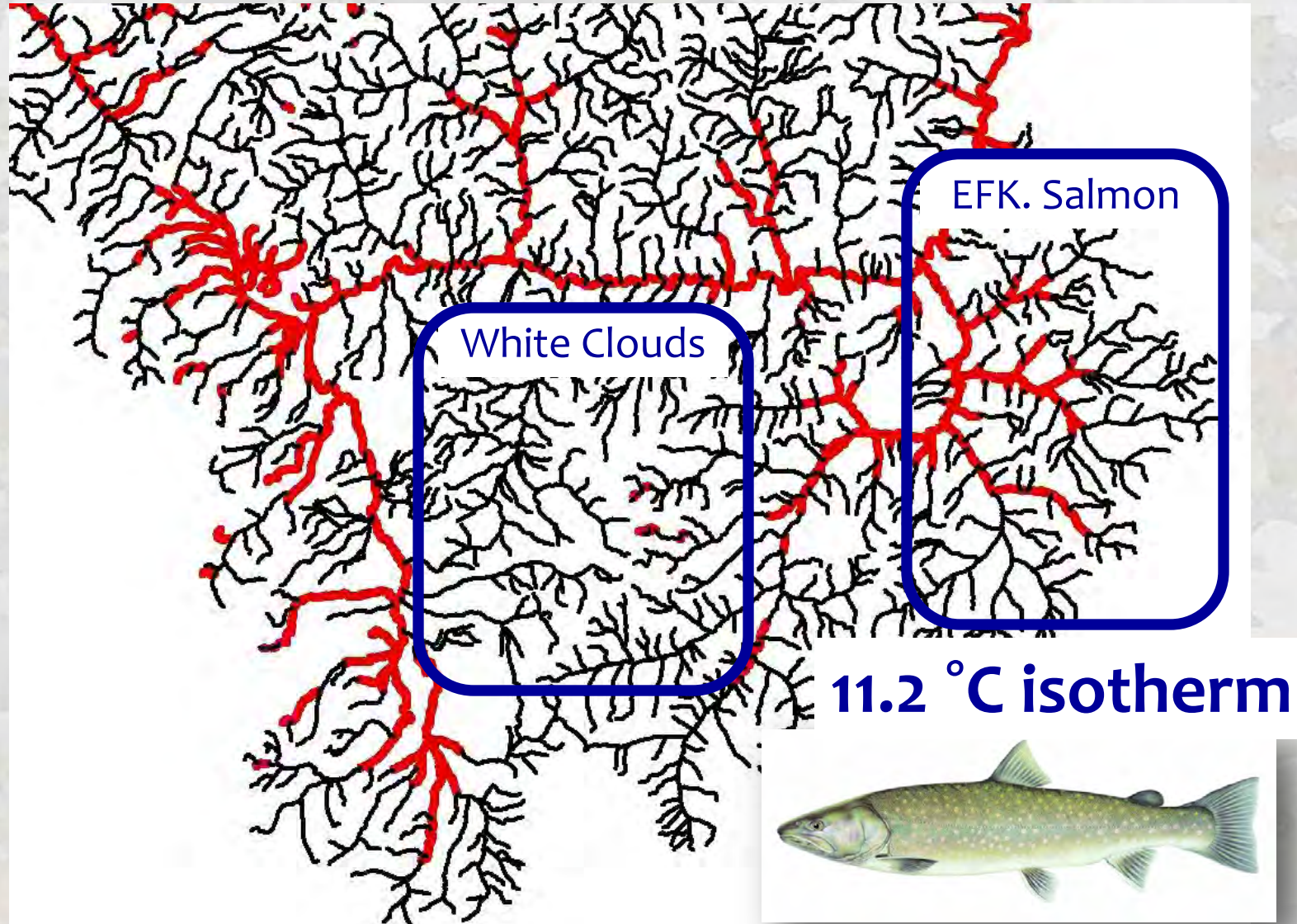


■ Suitable
■ Unsuitable



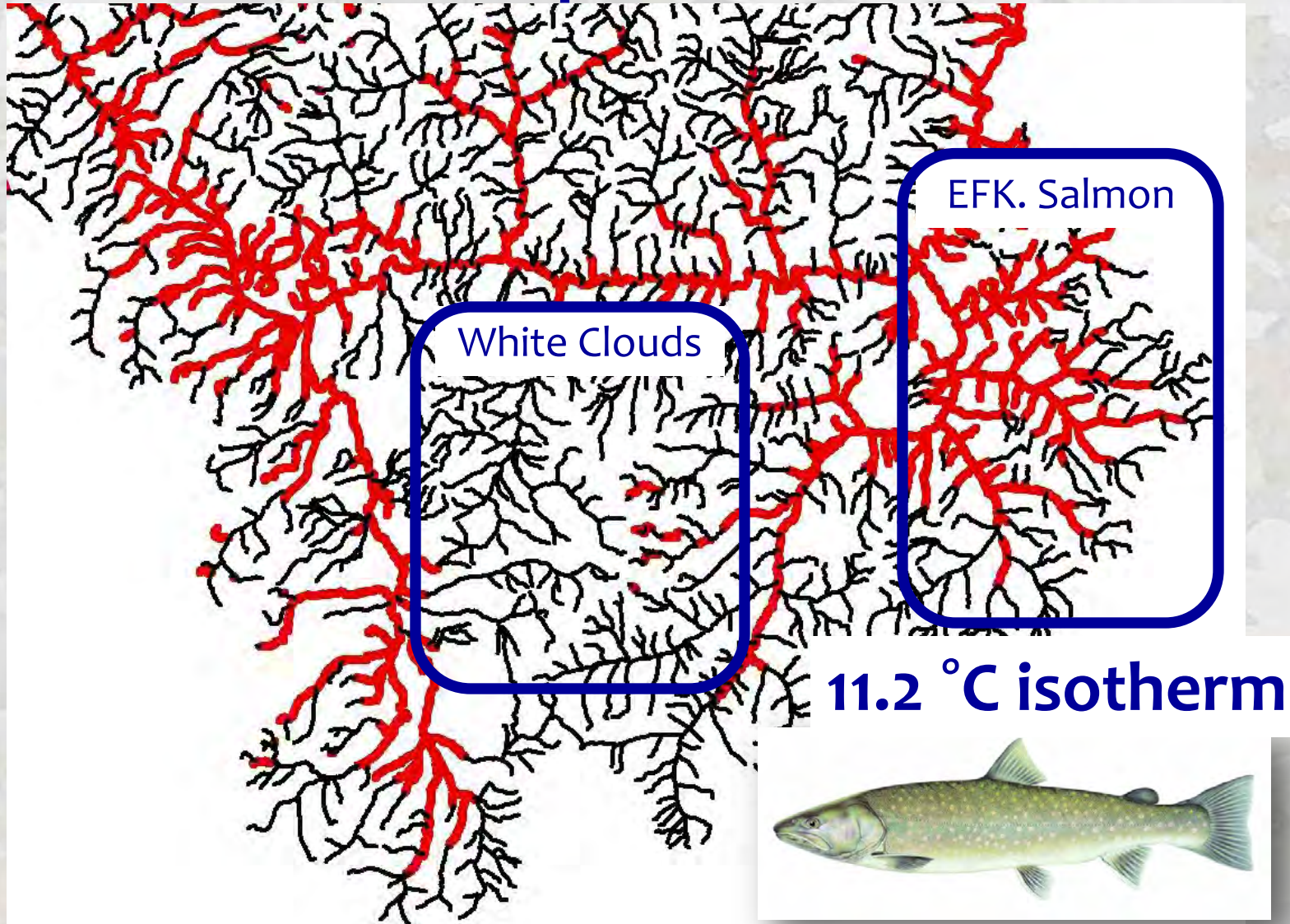
Spatial Variation in Habitat Loss

2002-2011 historical scenario

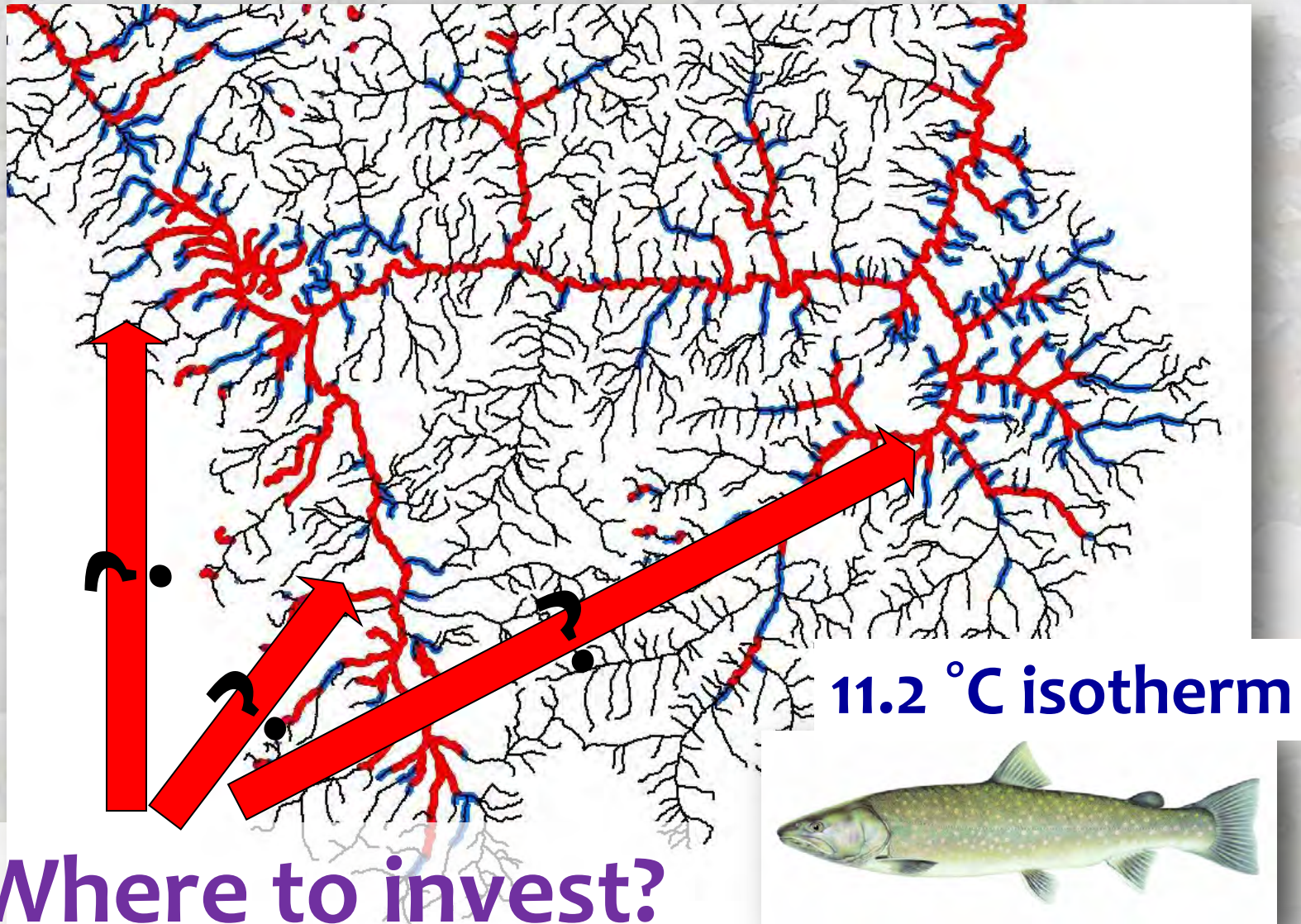


Spatial Variation in Habitat Loss

+1°C stream temperature scenario



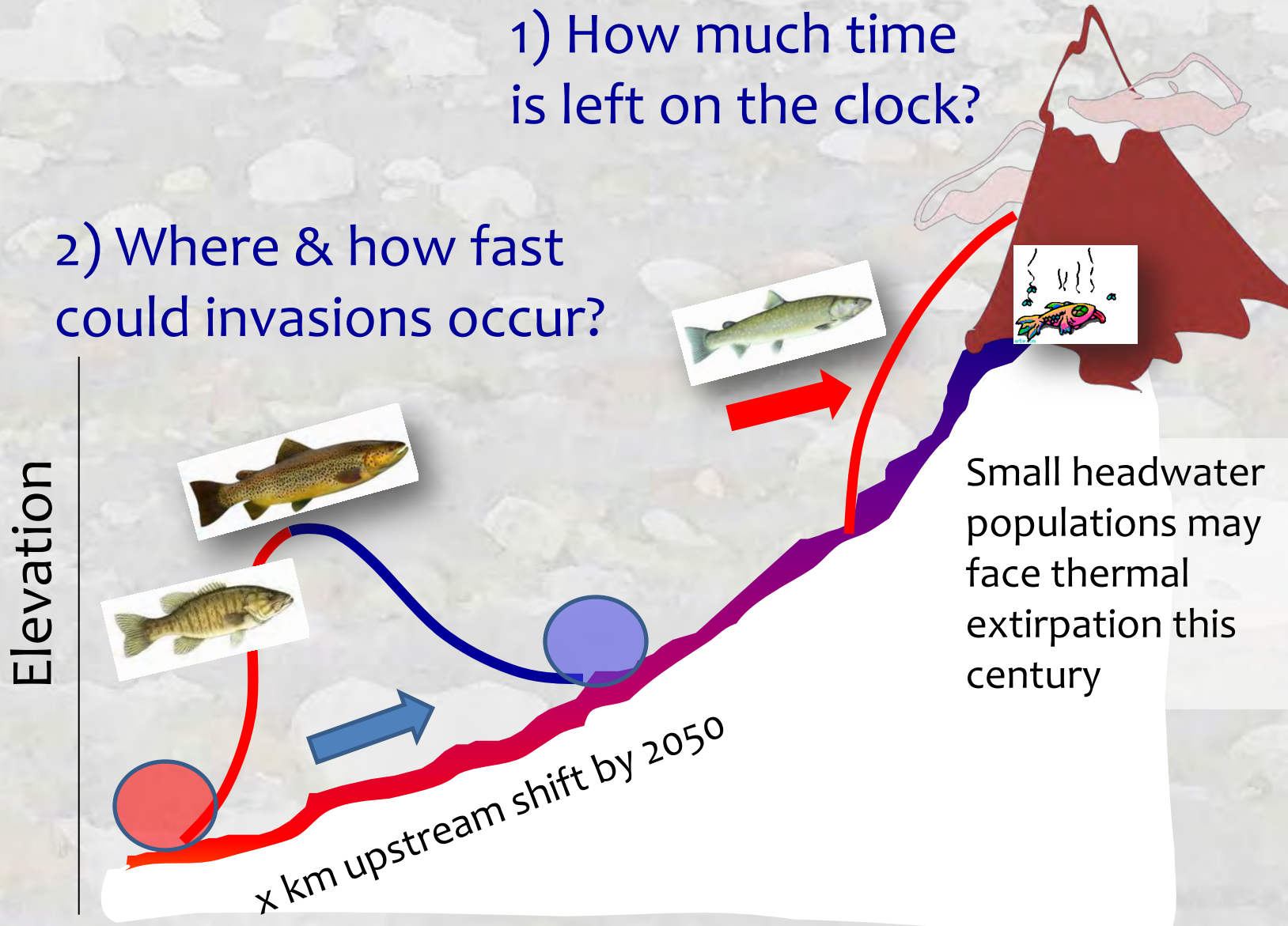
Difference Map Shows Vulnerable Habitats +1°C stream temperature scenario



Precise Information Regarding Potential Species Invasions & Population Extirpations

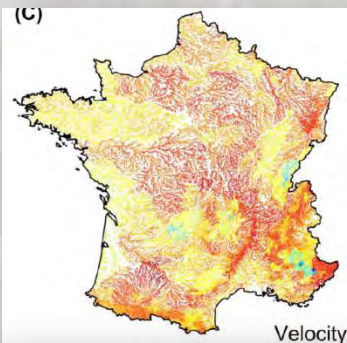
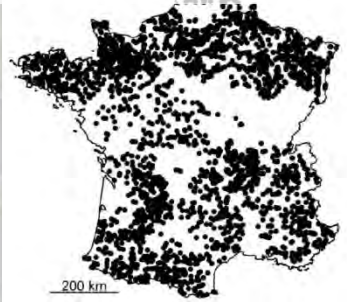
1) How much time is left on the clock?

2) Where & how fast could invasions occur?



Climate is Causing Stream Fish

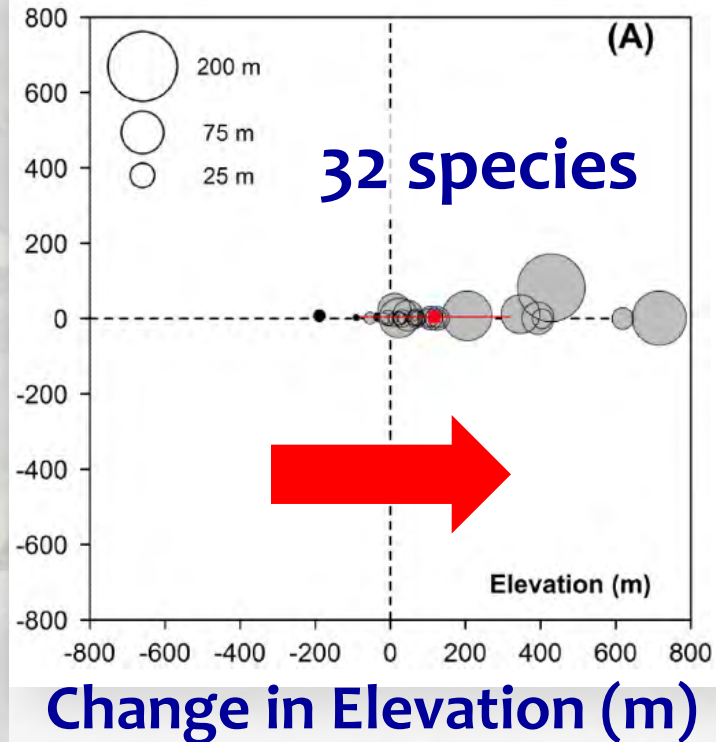
Fish surveys
(n = 3,500)



Velocity of climate change
-50 0 50 100 150

Distributions to Shift...

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

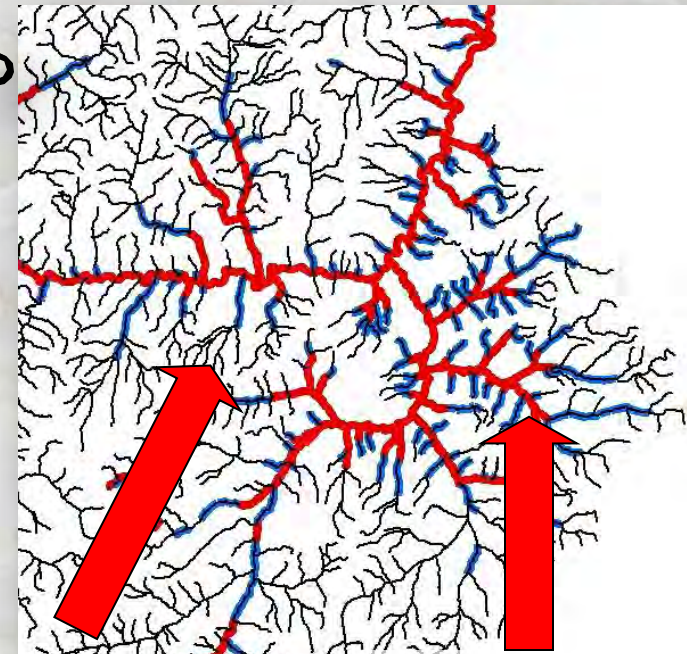
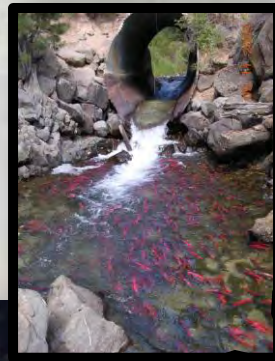


... but shifts are slower than Climate Velocity

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

Strategic Prioritization of Restoration Actions is Possible

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



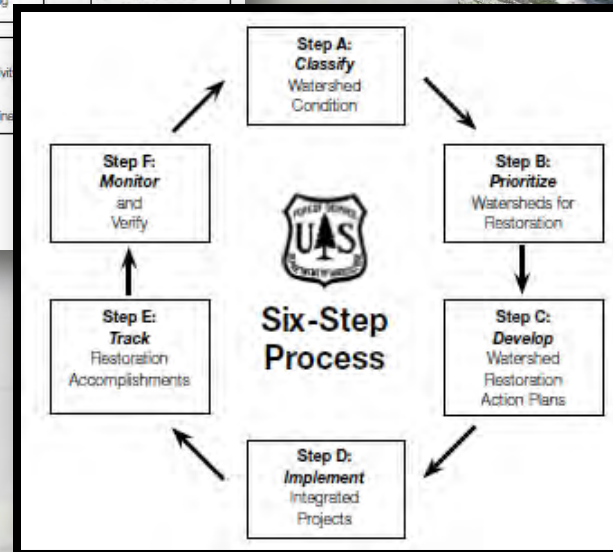
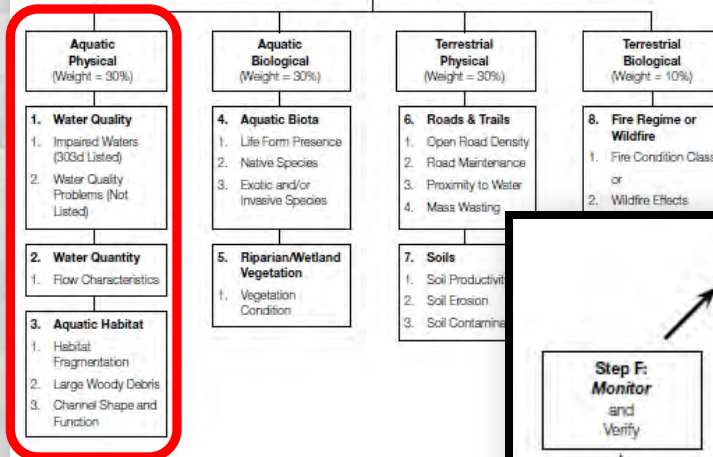
**High
Priority**

**Low
Priority**



Integrate with...

Watershed Condition Indicators



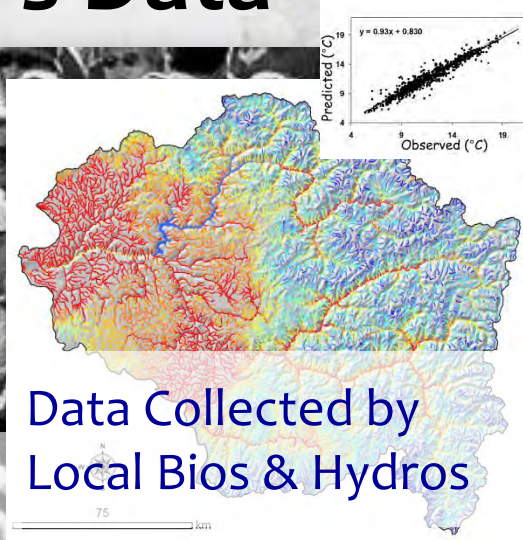
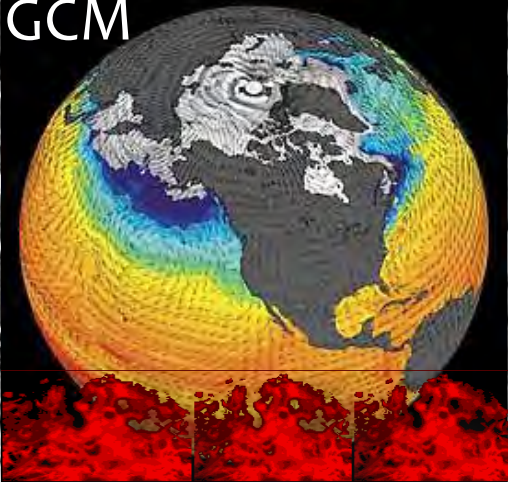
Forest Plan Revisions

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

Proposed
Land Management Plan
Clearwater National Forest

NorWeST is a “Crowd-Sourced” Model Developed from Everyone’s Data

GCM



Data Collected by Local Bios & Hydros

Coordinated,
Interagency
Responses?

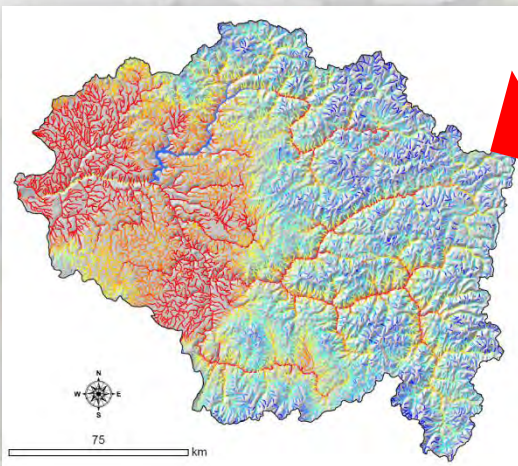


Management
Actions

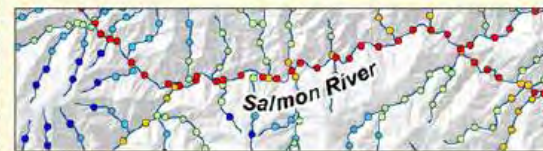


NorWeST Website Distributes Temperature Data as GIS Layers

1) GIS shapefiles of stream temperature scenarios

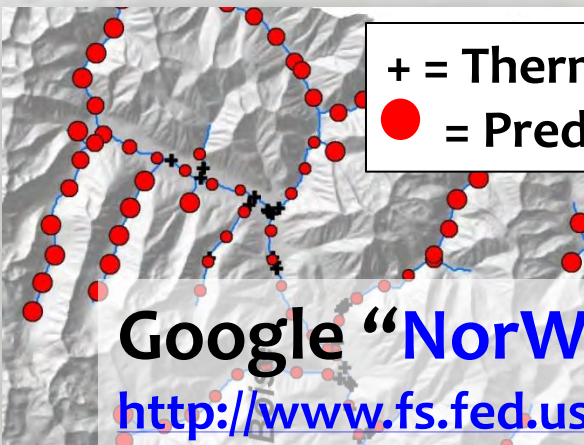


NorWeST
Stream Temp



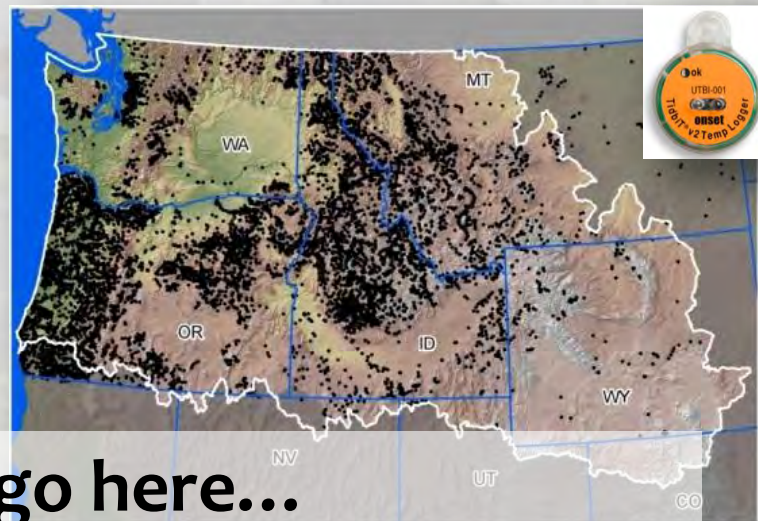
Regional Database and Modeled Stream Temperatures

2) GIS shapefiles of stream temperature model prediction precision



+ = Thermograph
● = Prediction SE

3) Temperature data summaries

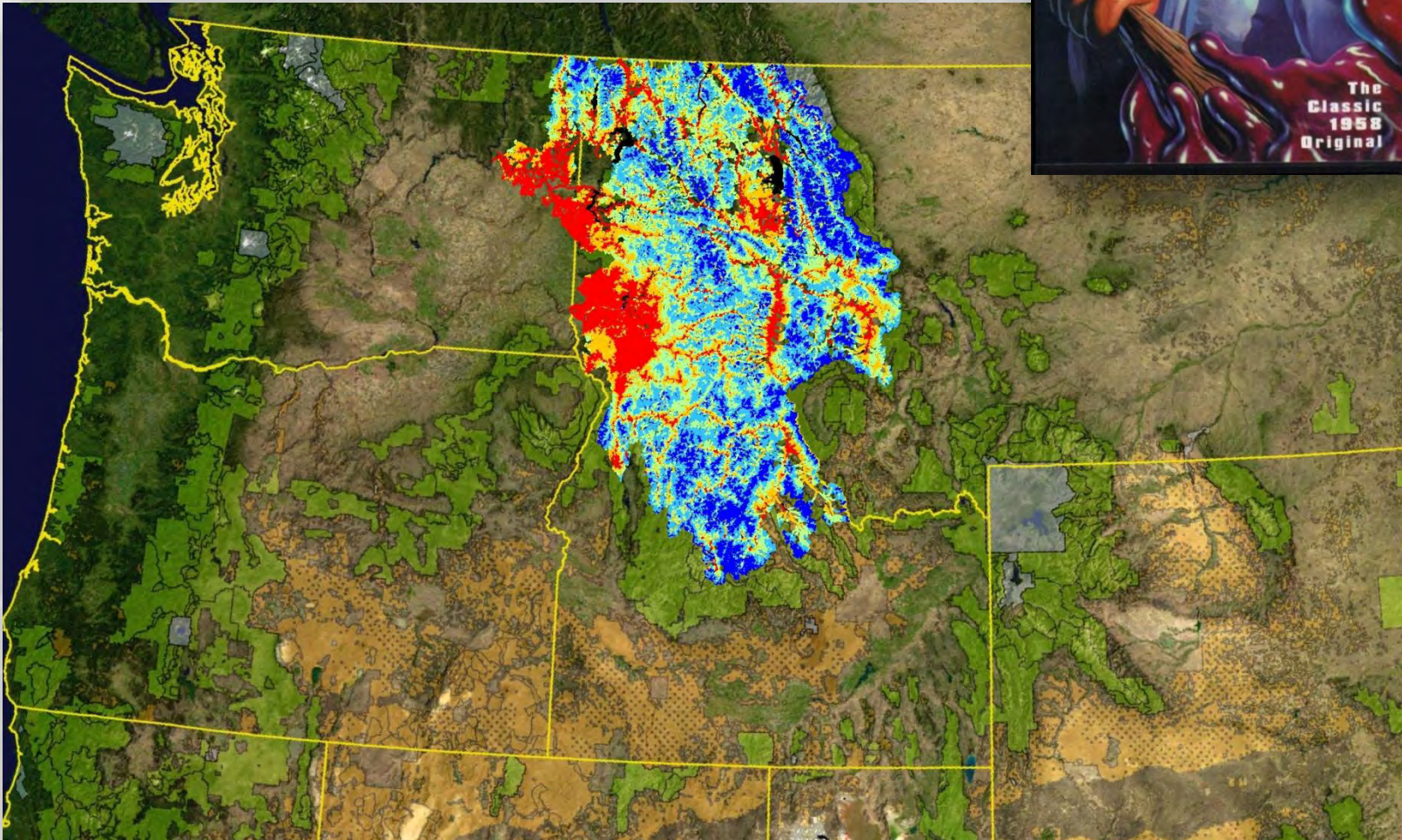
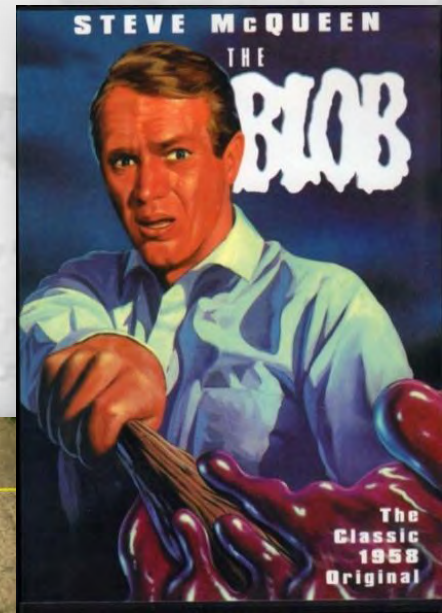


Google **"NorWeST"** or go here...

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

NorWeST Blob Growing...

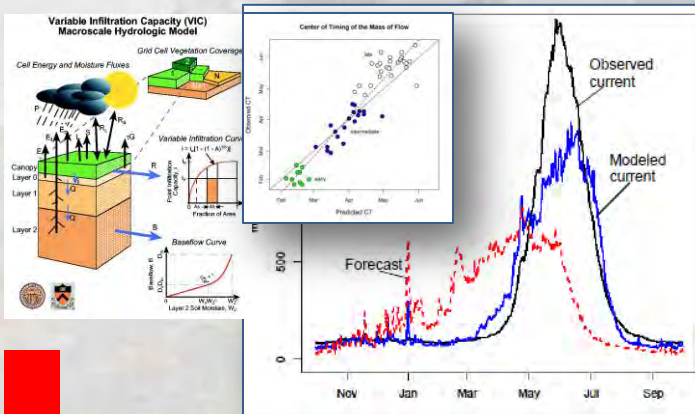
- 14,370 summers of data swallowed
- 92,000 stream kilometers of thermal ooze mapped



VIC Streamflow Scenarios – Western US

C. Luce expanding VIC nationally

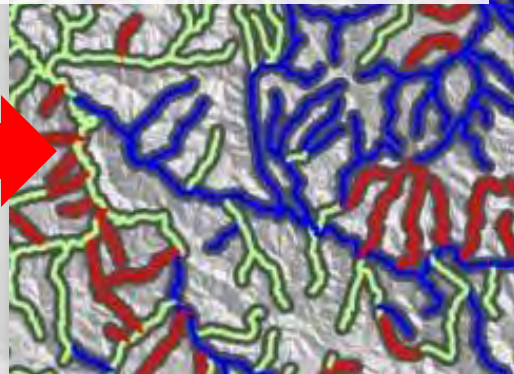
VIC Modeled Flow Metrics



... for the western U.S.



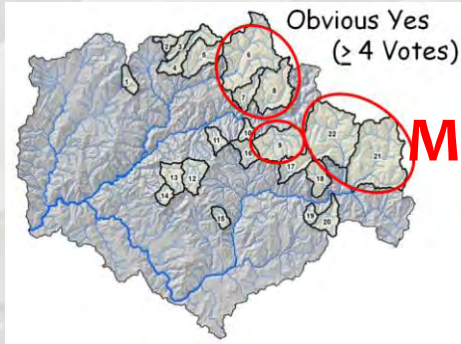
NHD+ stream segments
& climate scenarios



Website:

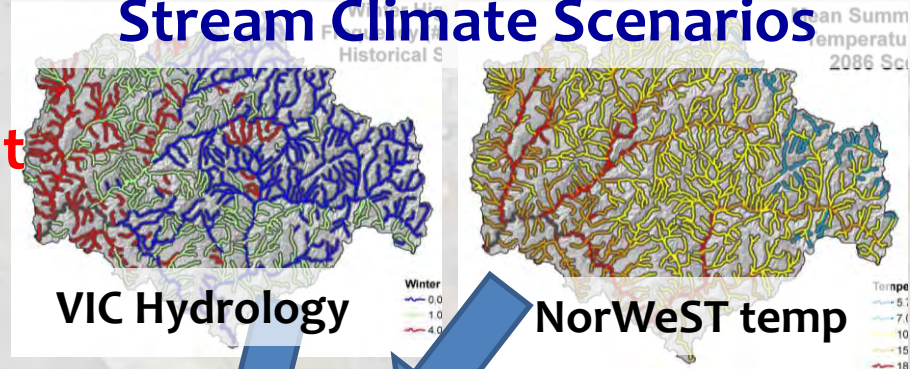
http://www.fs.fed.us/rm/boise/AWAE/projects/modeled_stream_flow_metrics.shtml

Better Spatial Data = Better Resource Decisions

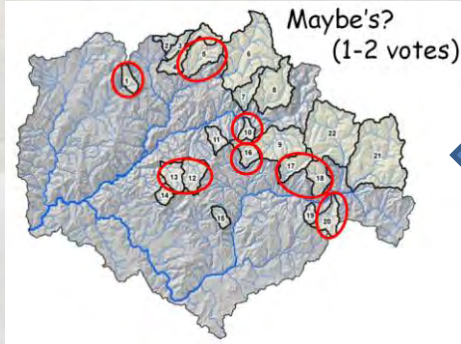


Management
Priorities

Stream Climate Scenarios



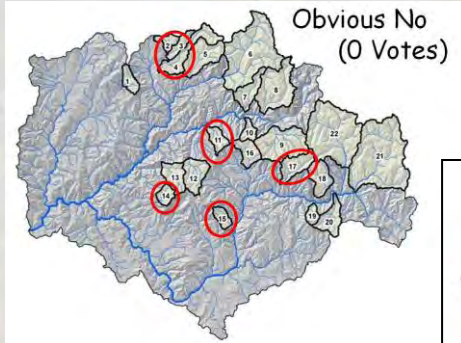
Yes



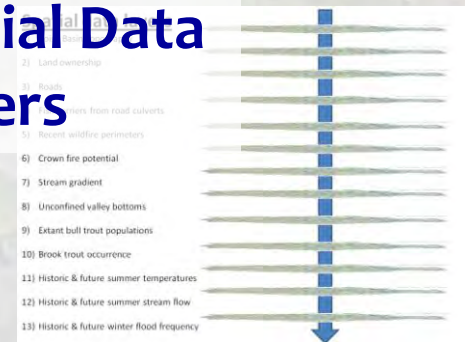
Maybe?

Decision
Support Tool

No

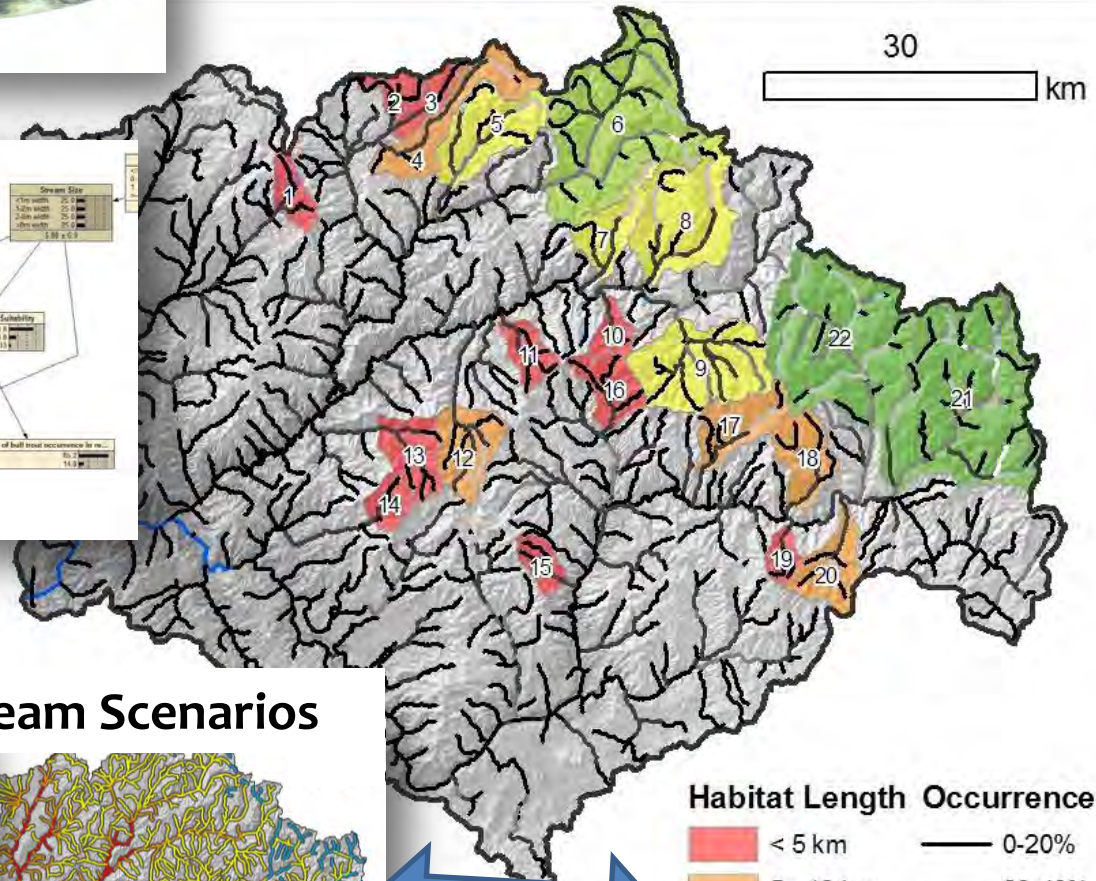
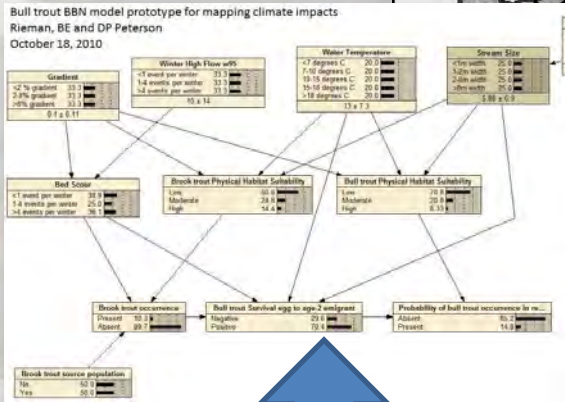
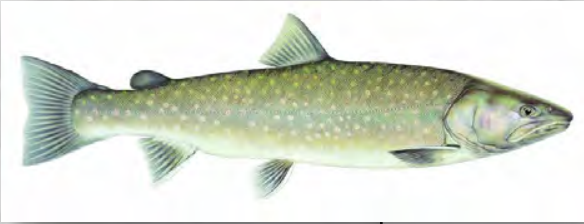


Spatial Data Layers

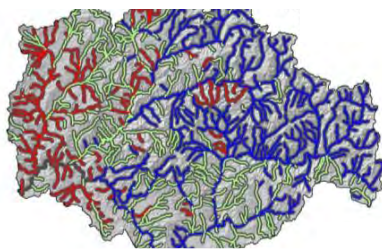


Bull Trout Climate Decision Support Tool

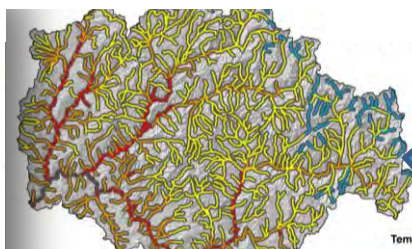
Tool runs on regionally consistent data layers



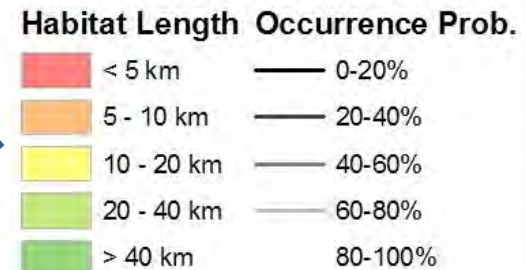
Downscaled Stream Scenarios



Streamflow

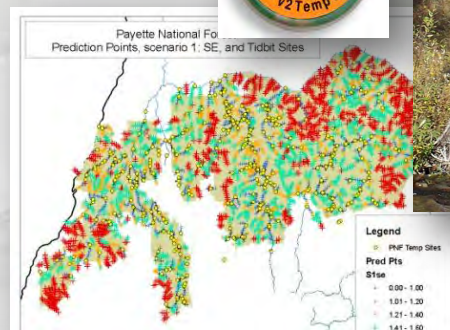
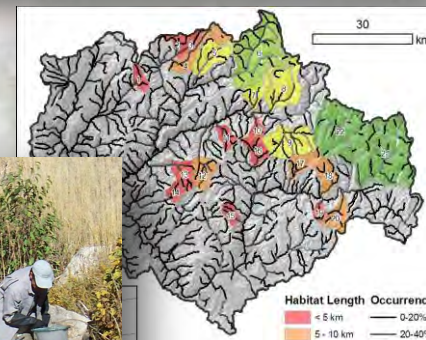


Stream Temperature



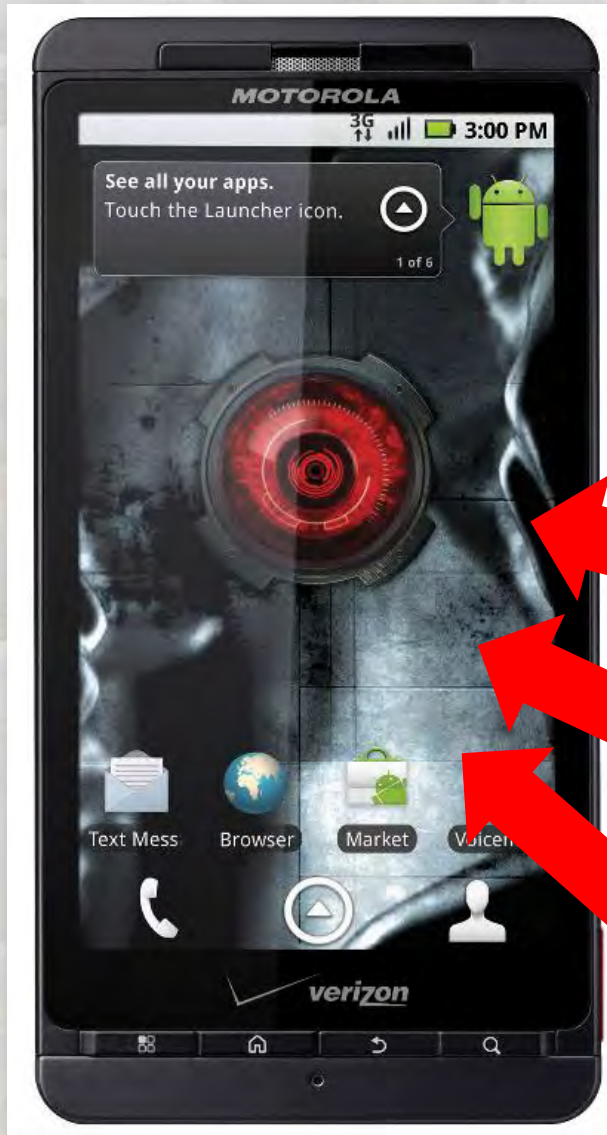
NorWeST Facilitating Related Projects

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



NorWeST Facilitating Related Projects

“Apps” Run on a Consistent Data Network



ate vulnerability
climate decision
etal., 2011)
out monitoring
(9)
Definitions &
ic mod
(S. Wenger, In
ature

A collage of images illustrating environmental data and field research. It includes:

- A circular temperature logger labeled 'onset Tidbit v2 Temp Logger' with ID 'UTBI-001'.
- A map showing a watershed area with color-coded regions (red, yellow, green) and a scale bar of 30 km.
- A photograph of a field researcher in a blue cap and backpack using a tool in a stream.
- A map showing a network of points (red and green) with a legend for 'PNF Temp Sites' and 'Pred Pts'.
- A photograph of a green fish, likely a trout or salmon.

Habitat Length Occurrence

< 5 km	0-20%
5-10 km	20-40%

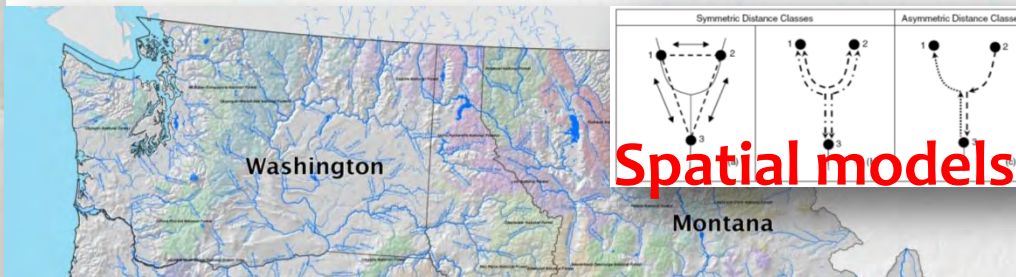
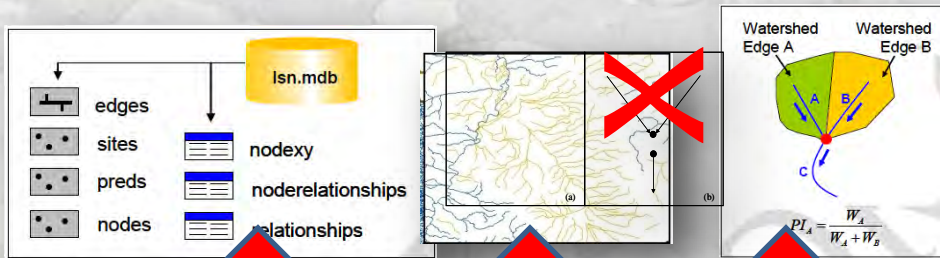
Legend

- PNF Temp Sites
- Pred Pts
- Site
- 0.00-1.00
- 1.01-1.20
- 1.21-1.40
- 1.41-1.60



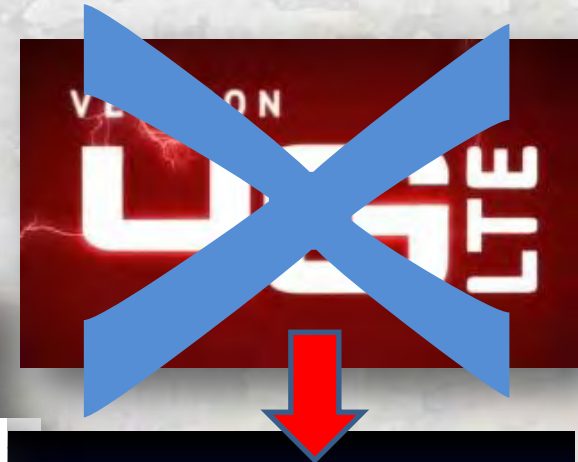
An InterNet for Stream Data

Technical & GIS infrastructure now exist



Just need spatial stream datasets

- USFS Regions 1, 2, 4, 6
- 50 National Forests



1G LCC
Accurate & consistent scaling of information

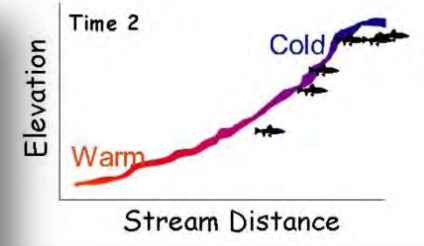
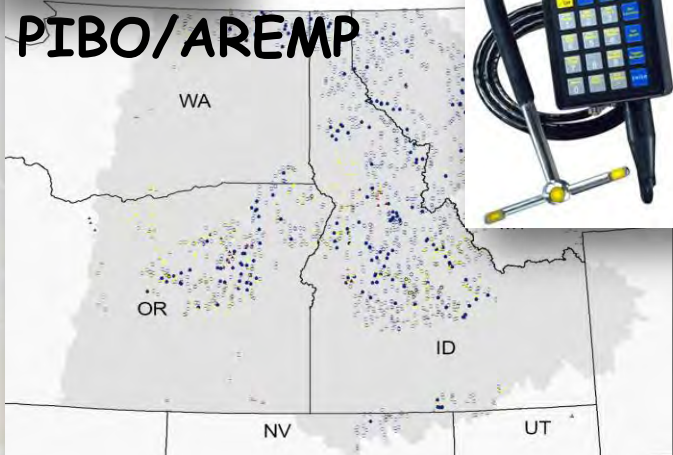
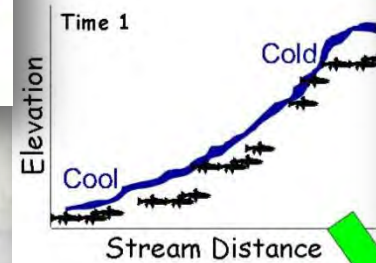
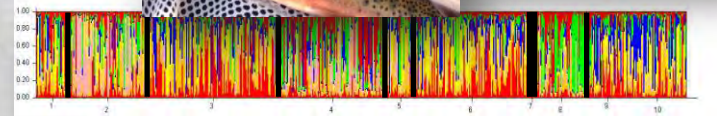


Internet Needs Consistent Data “Packets”

Standardized data collection protocols



Date	Stream	Willows	Catch	Reach	(PIBO)
			110		
			113		
			176		

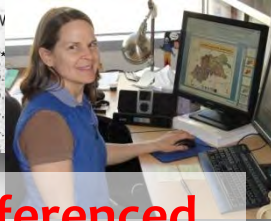


Data Needs to be Accessible

Data In  Information Out

	A	B	C
1			
2	Stream: Elk Creek		
3	Georeference: 610234 E, 4402546 W		
4			
5	Date	Time	Temp (°F)
6	7/15/2005	21:23	15
7	7/15/2005	21:53	15
8	7/15/2005	22:23	14
9	7/15/2005	22:53	14
10	7/15/2005	23:23	13

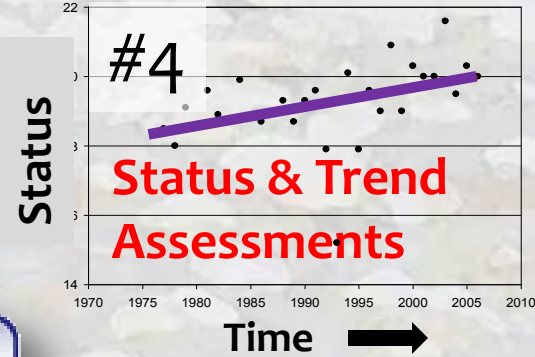
#1



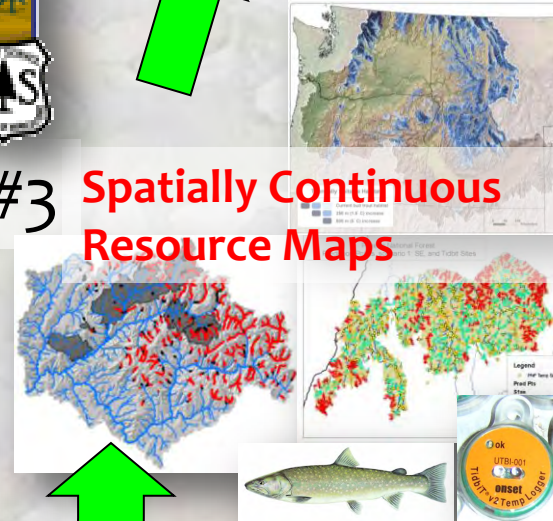
Spatially referenced,
corporate database



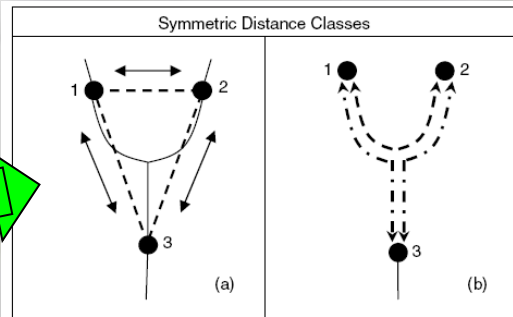
Aquatic
Surveys
Module



#3 Spatially Continuous
Resource Maps



#2 Analysis



#2a

More data,
monitoring
design



Let's Never Live this Nightmare Again

USFS has an awesome amount of data...
...that is awesomely disorganized



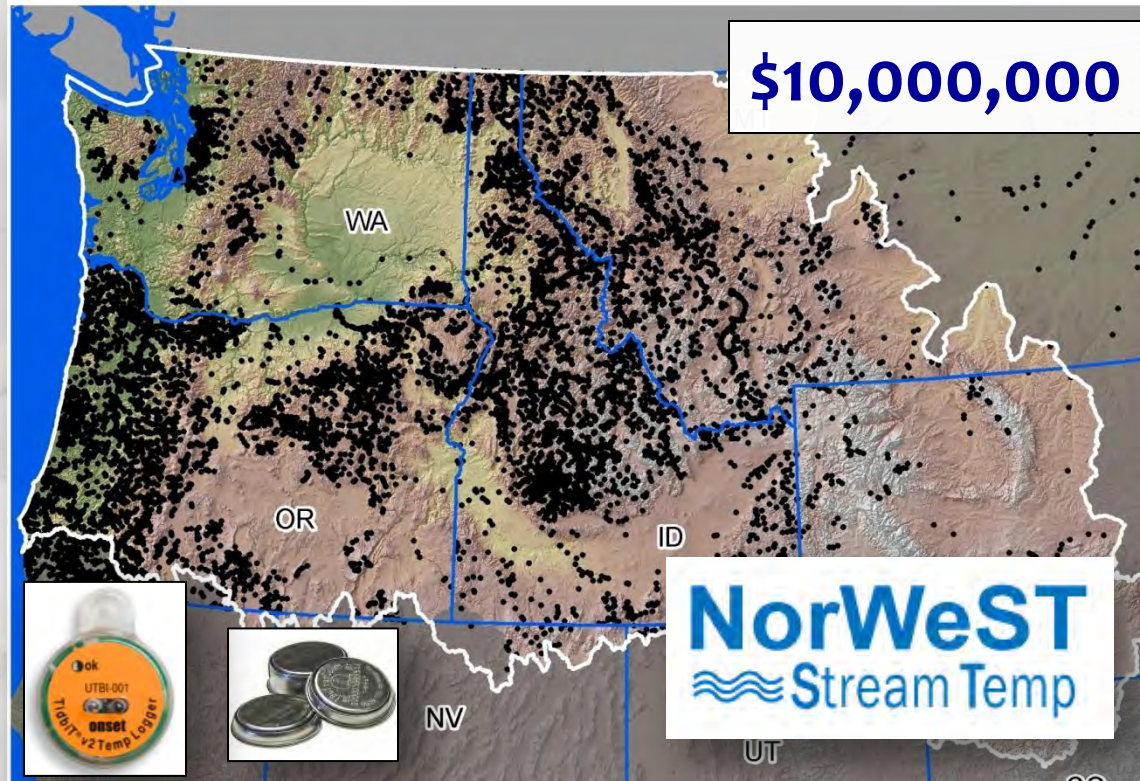
>45,000,000 hourly records
>15,000 unique stream sites
~50% data from USFS



We have millions
of \$'s in "free"
data if organized

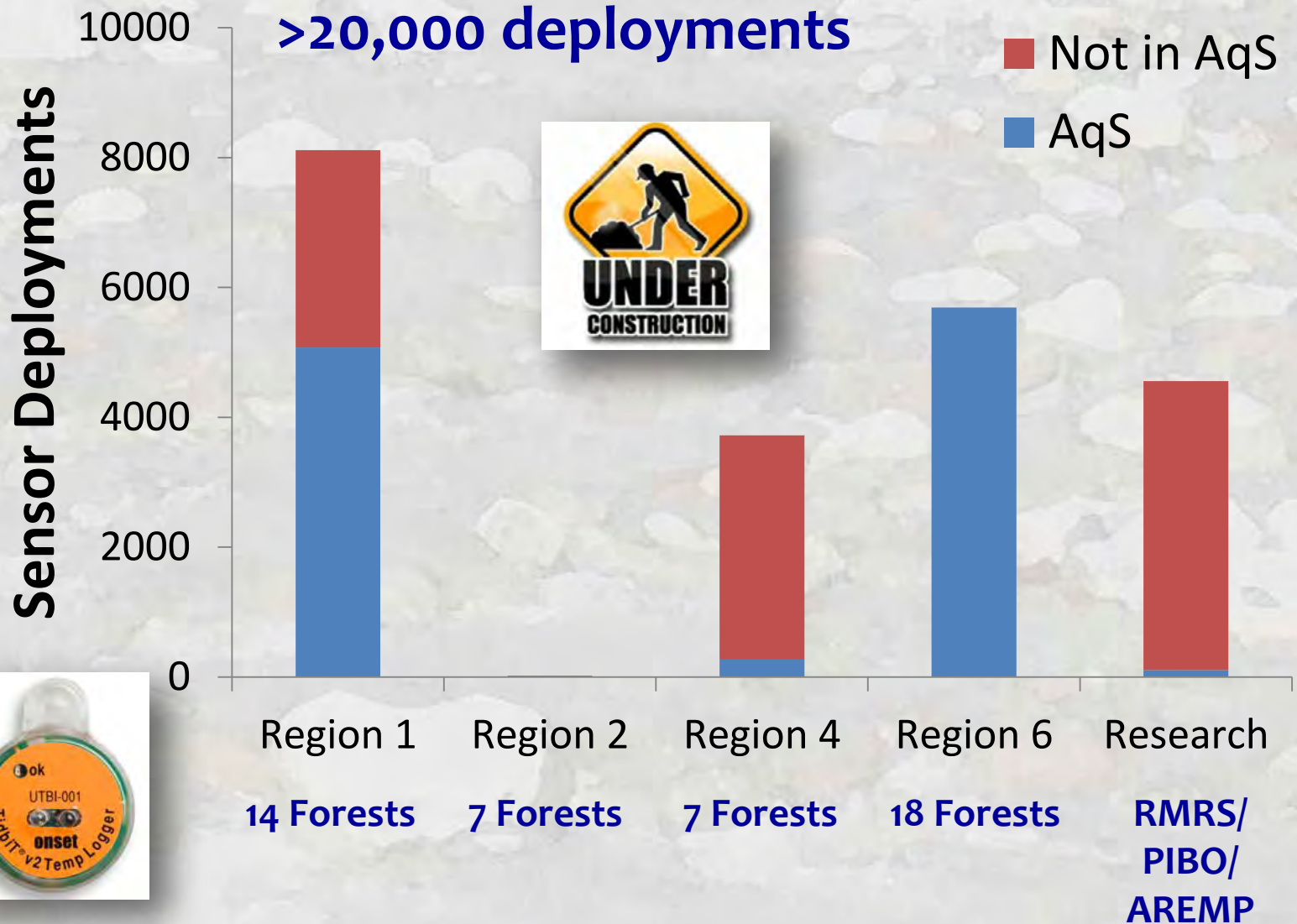
Biggest value is
information
developed from
these data

\$10,000,000



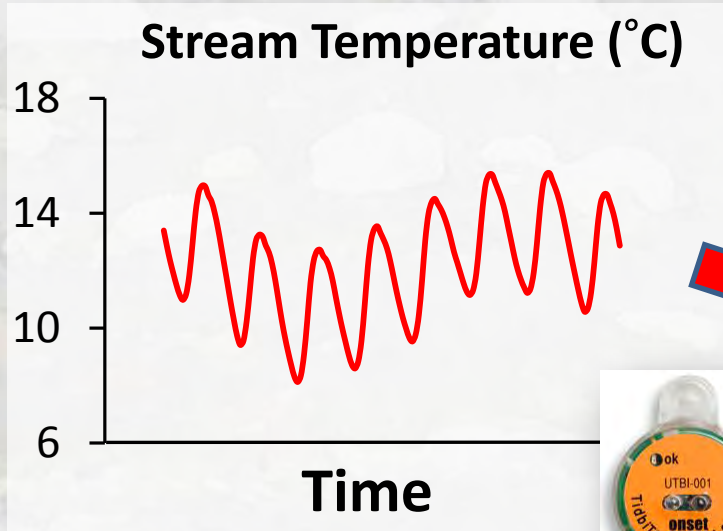
NorWeST
Stream Temp

Legacy Temperature Data Migration for Forests in NorWeST area



Aquatic Surveys Module in NRM

Temperature Surveys Tool in AqS
Data Entry, Uploading, Maintenance Interface



Feature Inspector

- Location
 - Boas Creek_LTWI
 - Beaver Creek on 2114_LL_TWT
 - Big Bend Creek at the Mouth_LTWI
 - Black Rock Fork at the Mouth_LTWI
 - Boulder Creek Watershed_LTWI
 - Boulder Creek at the Mouth_LTWI
 - Brice Creek below Adams Creek_LTWI
 - Buckeye Creek at the Mouth_LTWI
 - Call Creek basin Station_LTWI
 - Carton Creek at the mouth_LTWI
 - Castle Rock Fork at the Mouth_LTWI
 - Cedar Creek at the Mouth_LTWI
 - Clay Creek at the Mouth_LTWI
 - Clearwater River above Florence_LL_TWT
 - Clover Creek at the mouth_LTWI
 - Copperhead Creek at the mouth_LTWI
 - Cove Creek above Diamond Creek_LTWI
 - Coyote Creek Watershed #1_LTWI
 - Culbass Creek at the mouth_LTWI
 - Dinosaur Creek at the Mouth_LTWI
 - Elk Creek at Tike_LTWI
 - Jackson Creek near the Mouth_LTWI
 - Lake Creek below Diamond Lake_LTWI
 - Leopold Creek above Phelan Creek_LTWI
 - Little River above Claver Creek_LTWI
 - Little River below White Creek_LTWI
 - Palmer Creek at the Mouth_LTWI
 - Quartz Creek at the Mouth_LTWI
 - South Umpqua River above South Umpqua Fa
 - South Umpqua at Tabe Ranger Station_LTWI
 - Stevens Creek at the Mouth_LTWI
 - Shearhead above Carton_LTWI
 - Shearhead Creek at the Mouth_LTWI
 - Upper Shearhead below Little Fork_LTWI

SURVEYS

Survey Type	Name	Start Date	End Date	Physical
Temperature	Daily Min Max Temp	6/14/1976	6/20/1976	ec11894-4664-4cb-966d-9c30a
Temperature	Daily Min Max Temp	6/19/1976	7/2/1976	ec11894-4664-4cb-966d-9c30a
Temperature	Daily Min Max Temp	6/17/1982	6/17/1982	ec11894-4664-4cb-966d-9c30a
Temperature	Daily Min Max Temp	6/19/1984	6/30/1984	ec11894-4664-4cb-966d-9c30a
Temperature	Daily Min Max Temp	6/14/1985	6/21/1985	ec11894-4664-4cb-966d-9c30a
Temperature	Daily Min Max Temp	6/20/1986	6/23/1986	ec11894-4664-4cb-966d-9c30a
Temperature	Daily Min Max Temp	6/16/1987	7/27/1987	ec11894-4664-4cb-966d-9c30a
Temperature	Daily Min Max Temp	7/6/1988	9/22/1988	ec11894-4664-4cb-966d-9c30a
Temperature	Daily Min Max Temp	6/29/1989	10/11/1989	ec11894-4664-4cb-966d-9c30a
Temperature	Daily Min Max Temp	6/15/1990	3/9/1990	ec11894-4664-4cb-966d-9c30a
Temperature	Daily Min Max Temp	6/8/1991	9/22/1991	ec11894-4664-4cb-966d-9c30a
Temperature	Daily Min Max Temp	6/19/1993	9/7/1993	ec11894-4664-4cb-966d-9c30a
Temperature	Daily Min Max Temp	6/4/1997	6/17/1997	ec11894-4664-4cb-966d-9c30a

Attachments

Attachment	File Type	Attachment Date	Attachment Time	Name
	JPEG	6/26/2012	11:39	LakeCR US E004 6-25-2012
	JPEG	6/26/2012	11:38	LakeCR OS E004 6-25-2012

Callie McConnell's development team is superb
Surveys/database structure can be evolved

Research/Management Synergy

A Large Land-base
190 Million Acres



“Boots-on-the-Ground”



USFS has ~600 fish bios/hydros.
(That’s an aquatics army!)



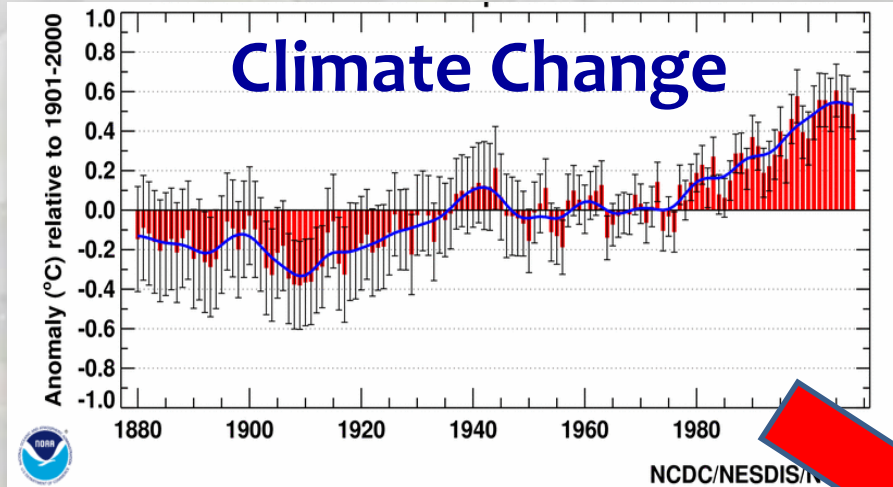
Lots of data
being collected



Research stations develop
information & connect people

More With Less, but What If...

It was Much More?



Urbanization & Population Growth

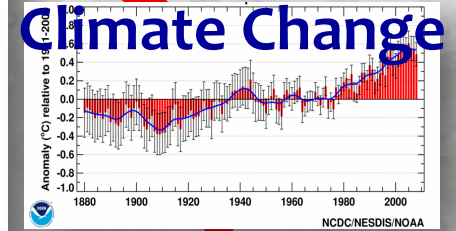
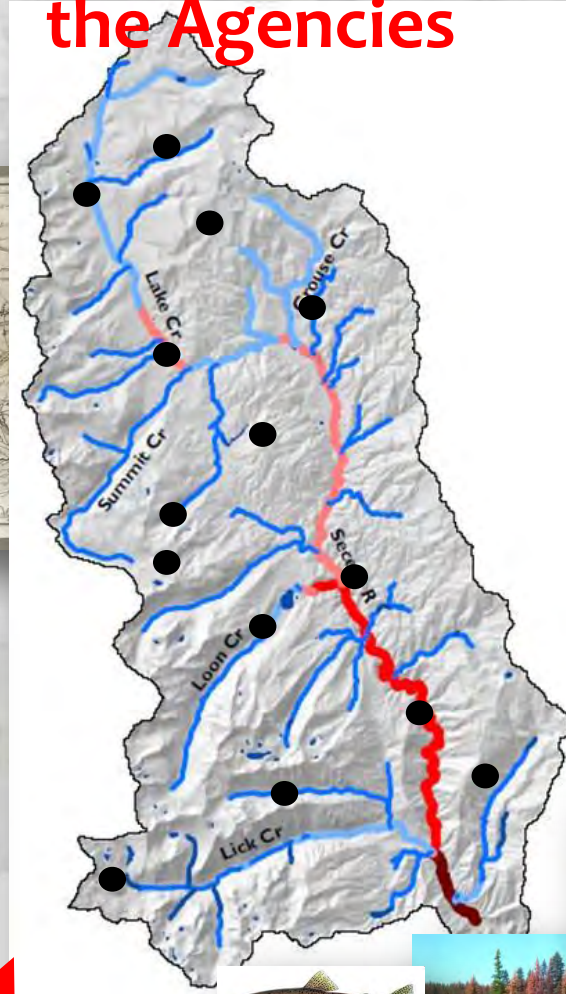


Shrinking Budgets



Connect the Dots to Map the Future

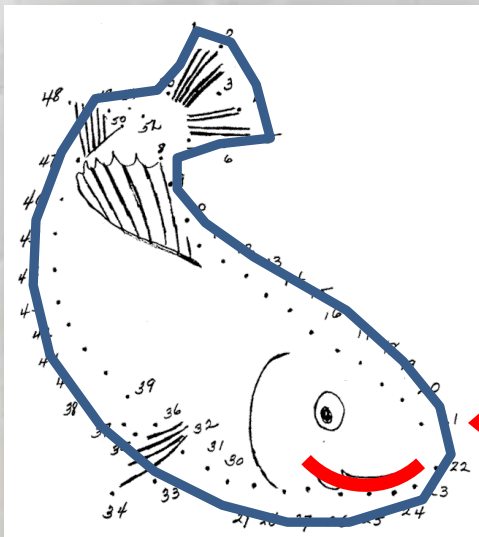
& the People & the Agencies



Urbanization & Population Growth



Land & Species Management





stream

