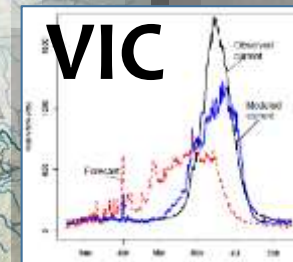
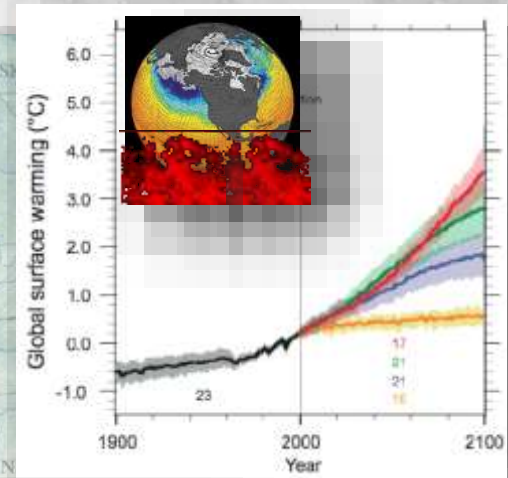
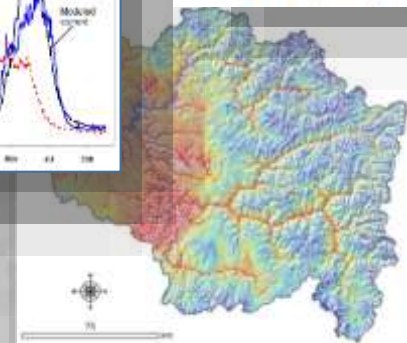


# Tools & Databases for Understanding & Predicting Local Effects of Climate Change on Anadromous Fishes & Habitats in the Columbia Basin

Dan Isaak, US Forest Service Research

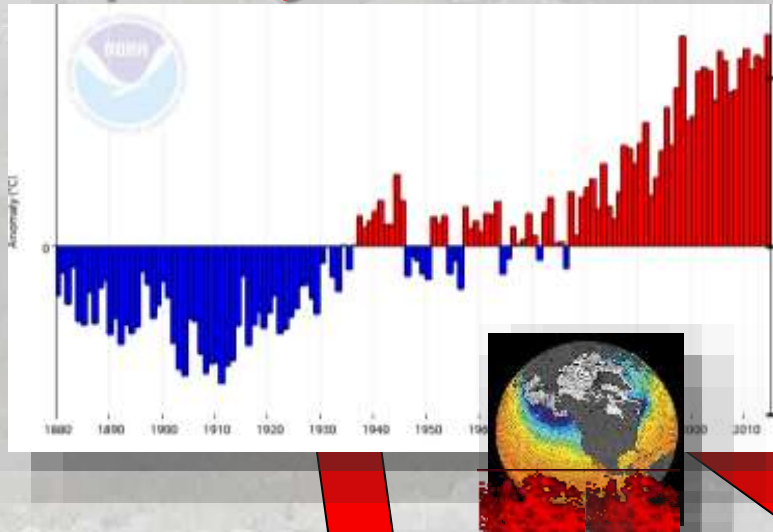


**NorWeST**  
Stream Temp



# There's a Lot on the Line...

## 2014 & 2015 Set New Records



## Tribal & Recreational Fisheries



## Land Use & Water Development



## ESA Listed Species





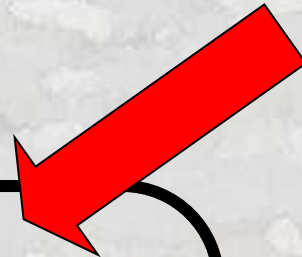
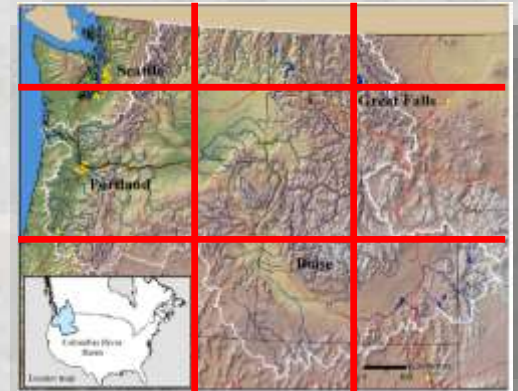
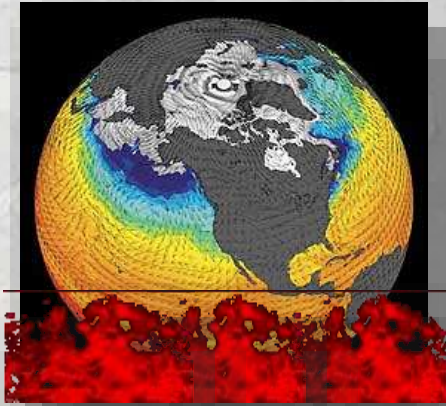
# Need: High-Resolution Stream Scenarios

Global climate models

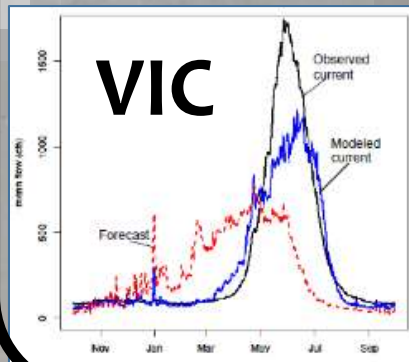
Resolution: 1000s of kilometers

Regional patterns

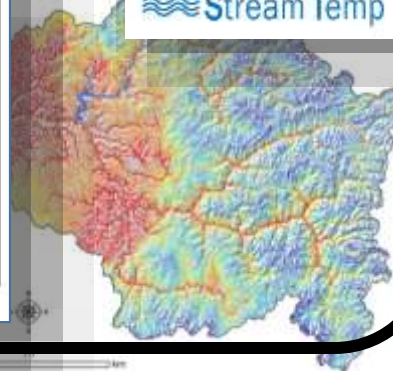
Resolution: 10s kilometers



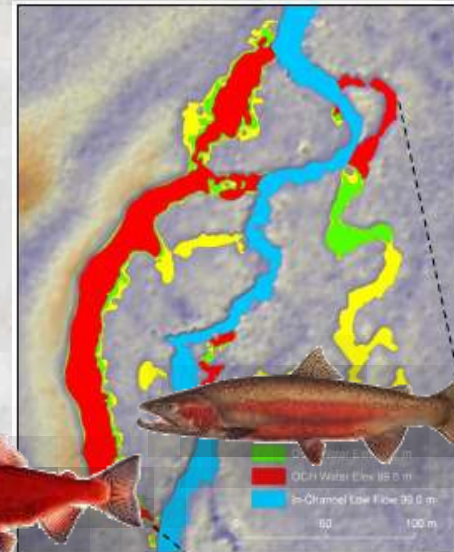
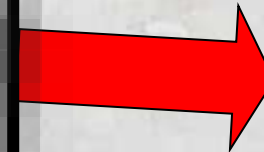
River network  
temperature & flow



NorWeST  
Stream Temp

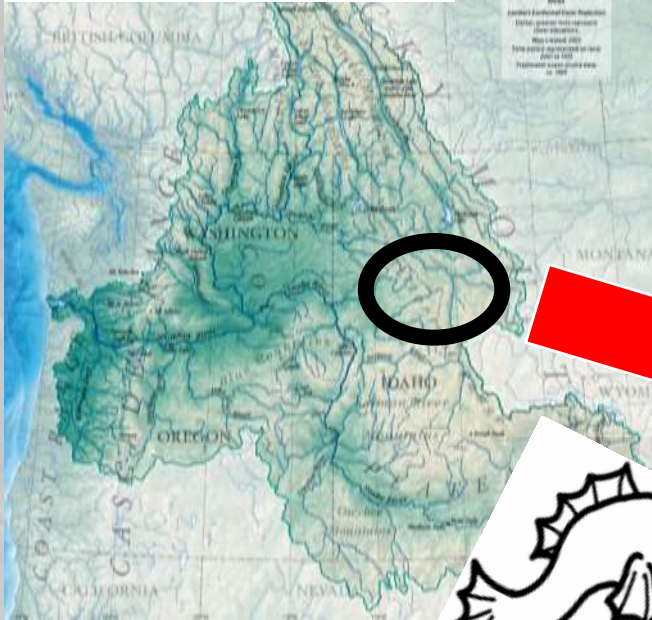


Stream  
reach

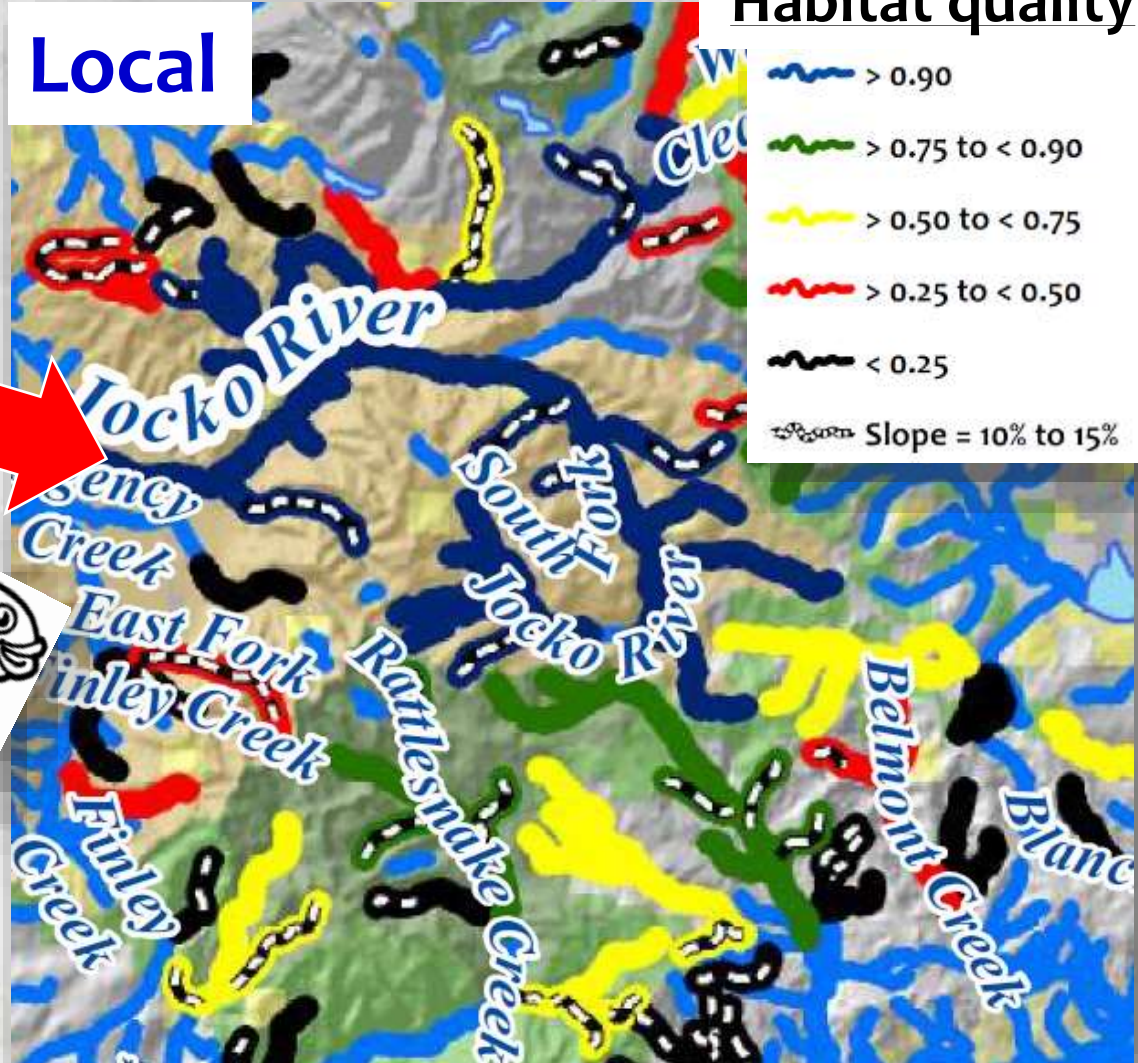


# Precise Information Across Broad Scales

Rangewide



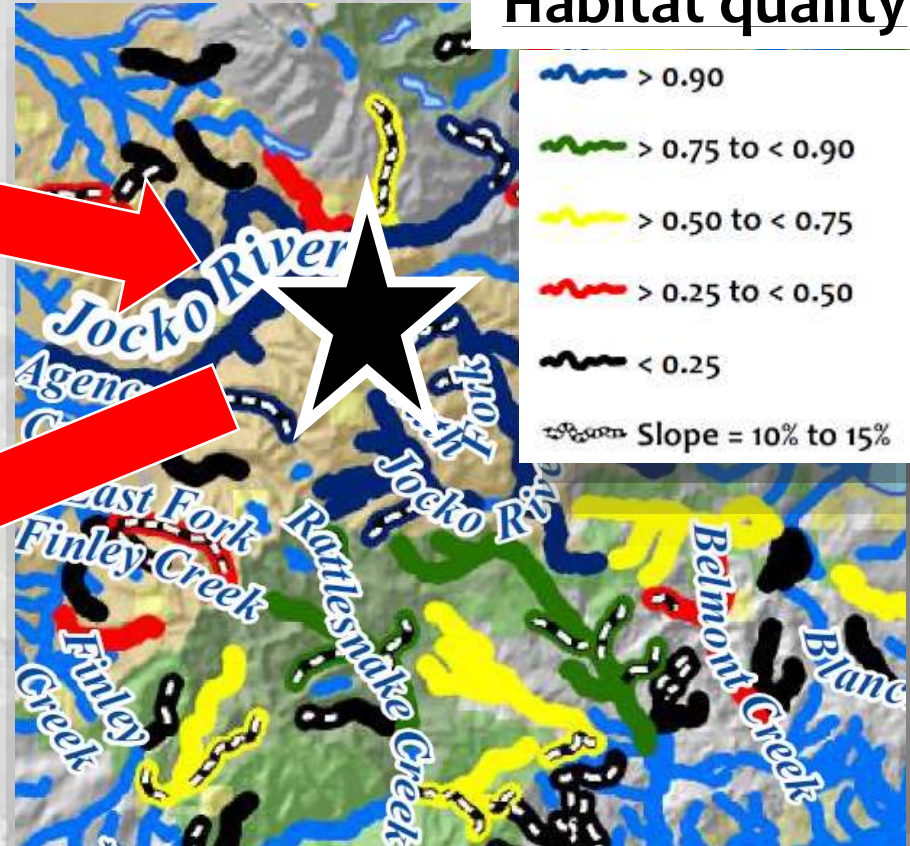
Local



See both the Forest AND the Trees!

# Precise Information Across Broad Scales

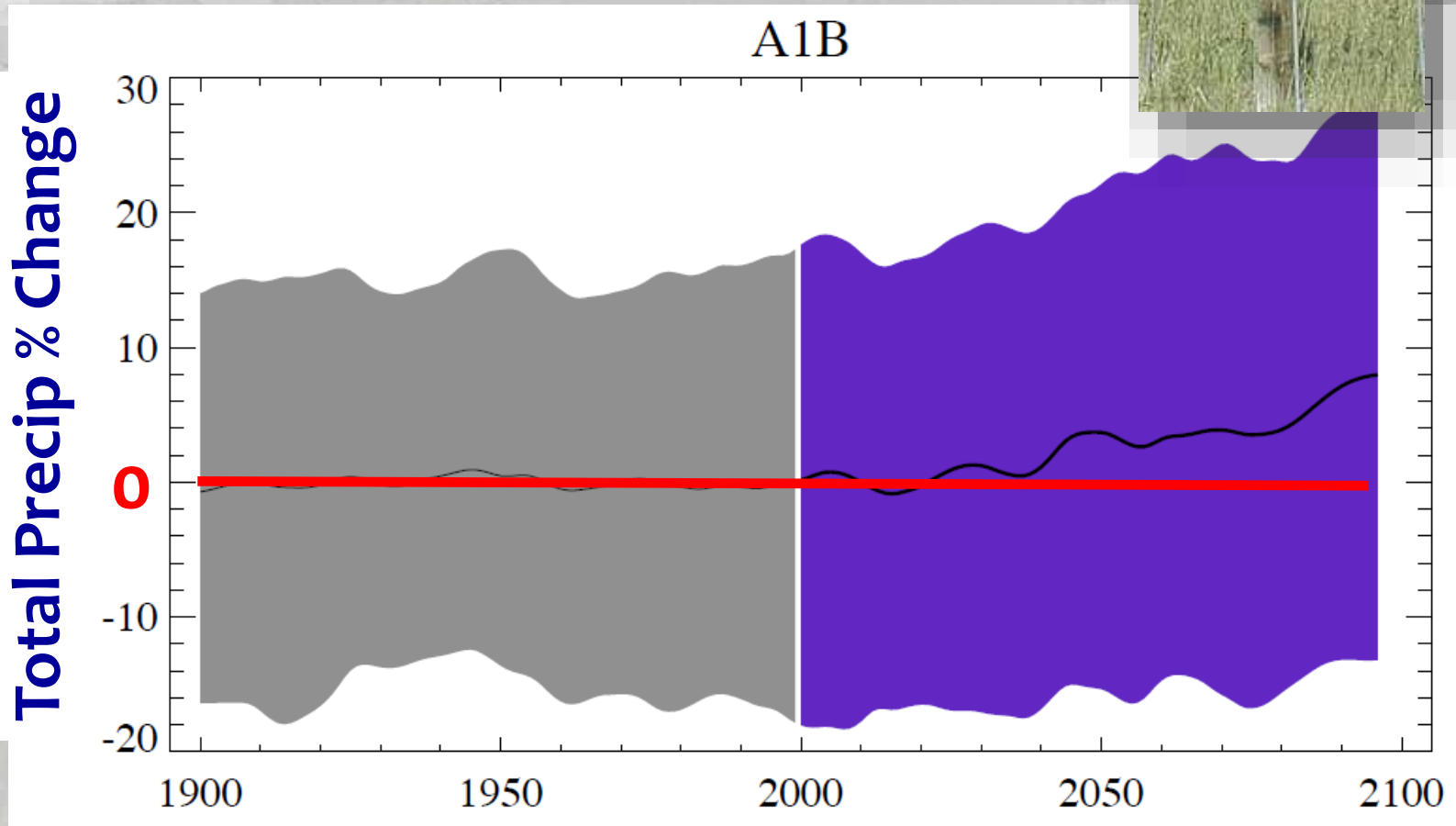
## Empowers Local Decision Makers & Agency Planning



**Highest priority investment!**

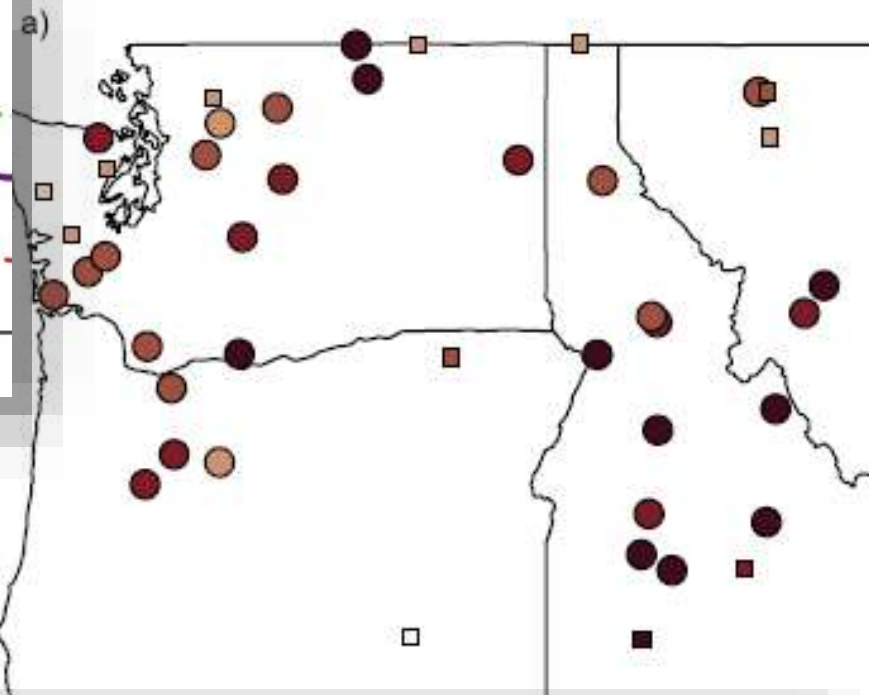
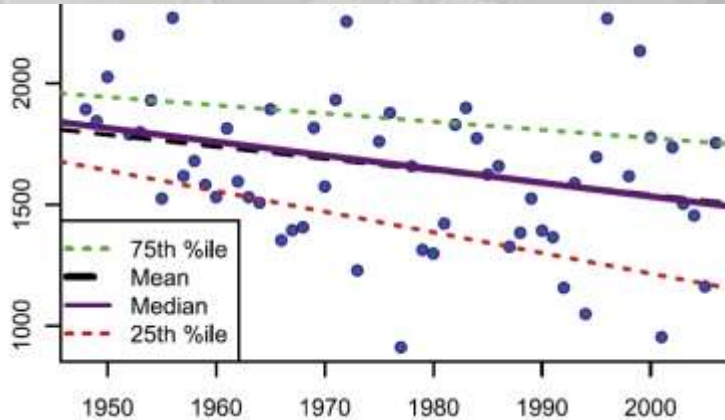
# A Wetter or Drier Future?

## Forecasts are uncertain...



# BUT... Summer Low Flows Have Been Decreasing for Decades (1948-2006)

Summer flow

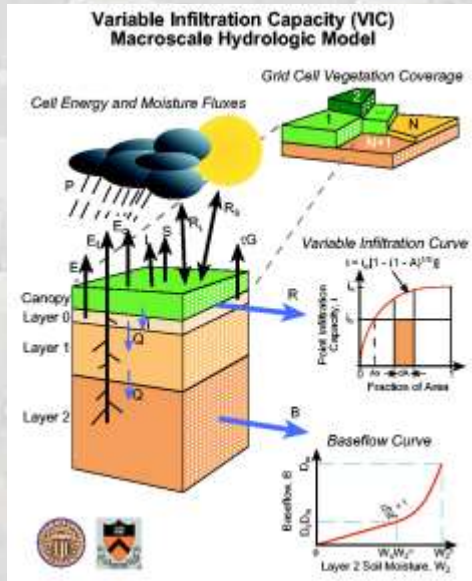


Luce and Holden 2009. Declining annual streamflow distributions in the PNW, 1948-2006. *Geophysical Research Letters* **36**: L16401.

Luce et al. 2013. The missing mountain water. *Science* **342**: 1360-1364.

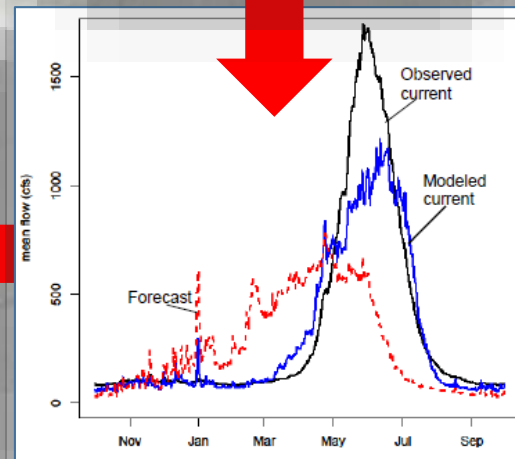
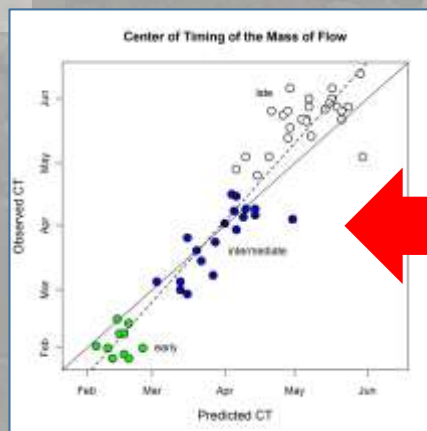


# VIC Hydrologic Model - All Stream Reaches



## Ecologically Relevant Flow Metrics

- Summer flow
- Mean flow
- Winter flood frequency
- Median flow date

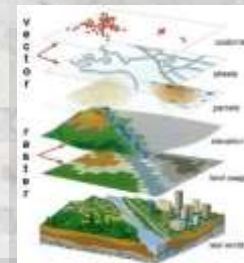
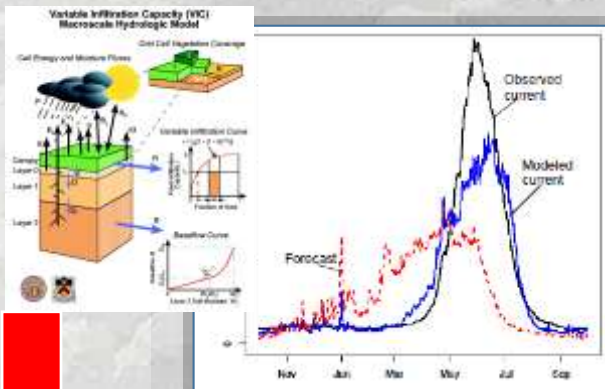


Wenger et al. 2010. Macroscale hydrologic modeling of ecologically relevant flow metrics. *Water Resources Research* 46, W09513

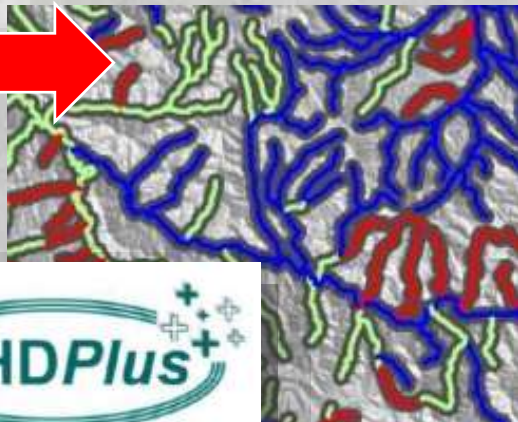
Hamlet et al. 2013. An Overview of the Columbia Basin Climate Change Scenarios Project: Approach, Methods, and Summary of Key Results. *Atmosphere-Ocean* 51:392-415.

# Website: Western U.S. Streamflow Metrics

- ArcGIS shapefiles
- A1B climate scenarios



Reach-scale resolution

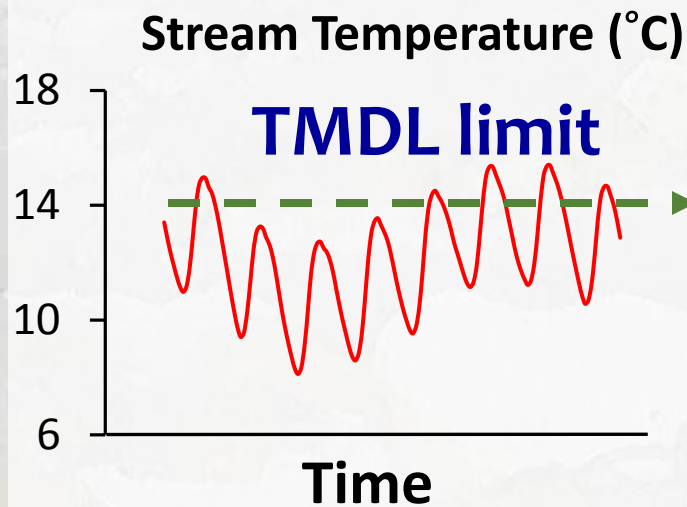
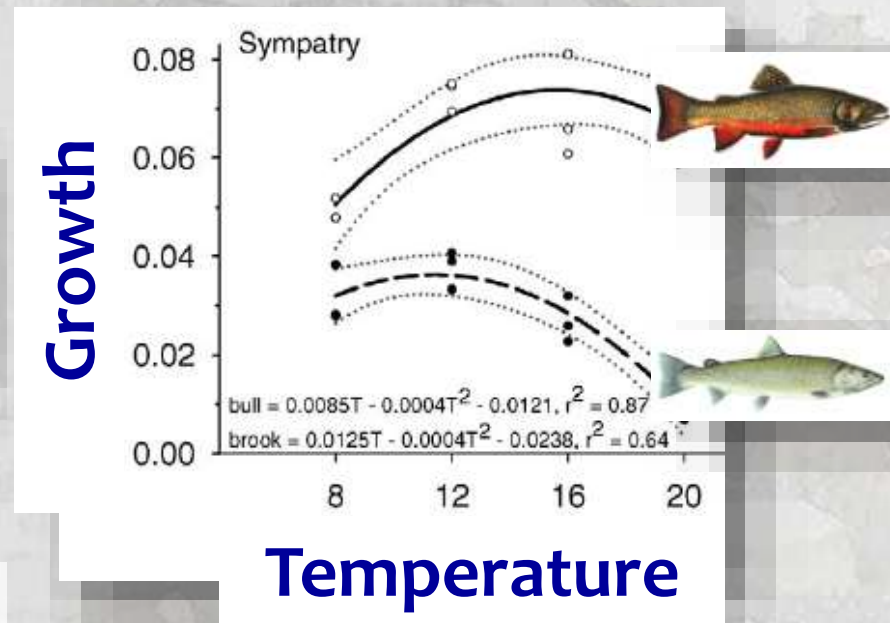


Google “Stream flow Metrics”  
or go here...

[www.fs.fed.us/rm/boise/AWAE/projects/modeled\\_stream\\_flow\\_metrics.shtml](http://www.fs.fed.us/rm/boise/AWAE/projects/modeled_stream_flow_metrics.shtml)



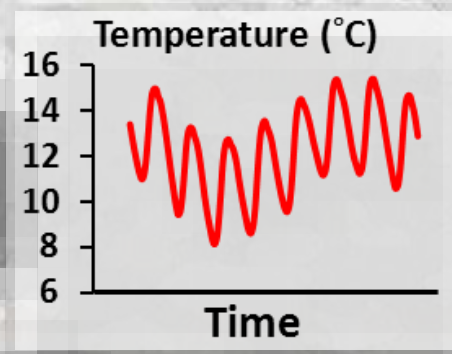
# Temperature is Destiny for Cold-Blooded Stream Critters



**Too Hot!**



# Huge Amounts of Stream Temperature Monitoring...



**>200,000,000 hourly records**  
**>20,000 unique stream sites**



# Apply BIG Data Mining Techniques

## 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 (km<sup>2</sup>)
9. Glacier (%)

10. Discharge (m<sup>3</sup>/s)

**USGS gage data**

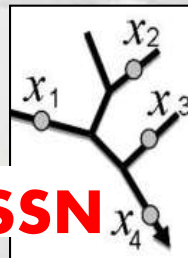
11. Air Temperature (°C)

**RegCM3 NCEP reanalysis**

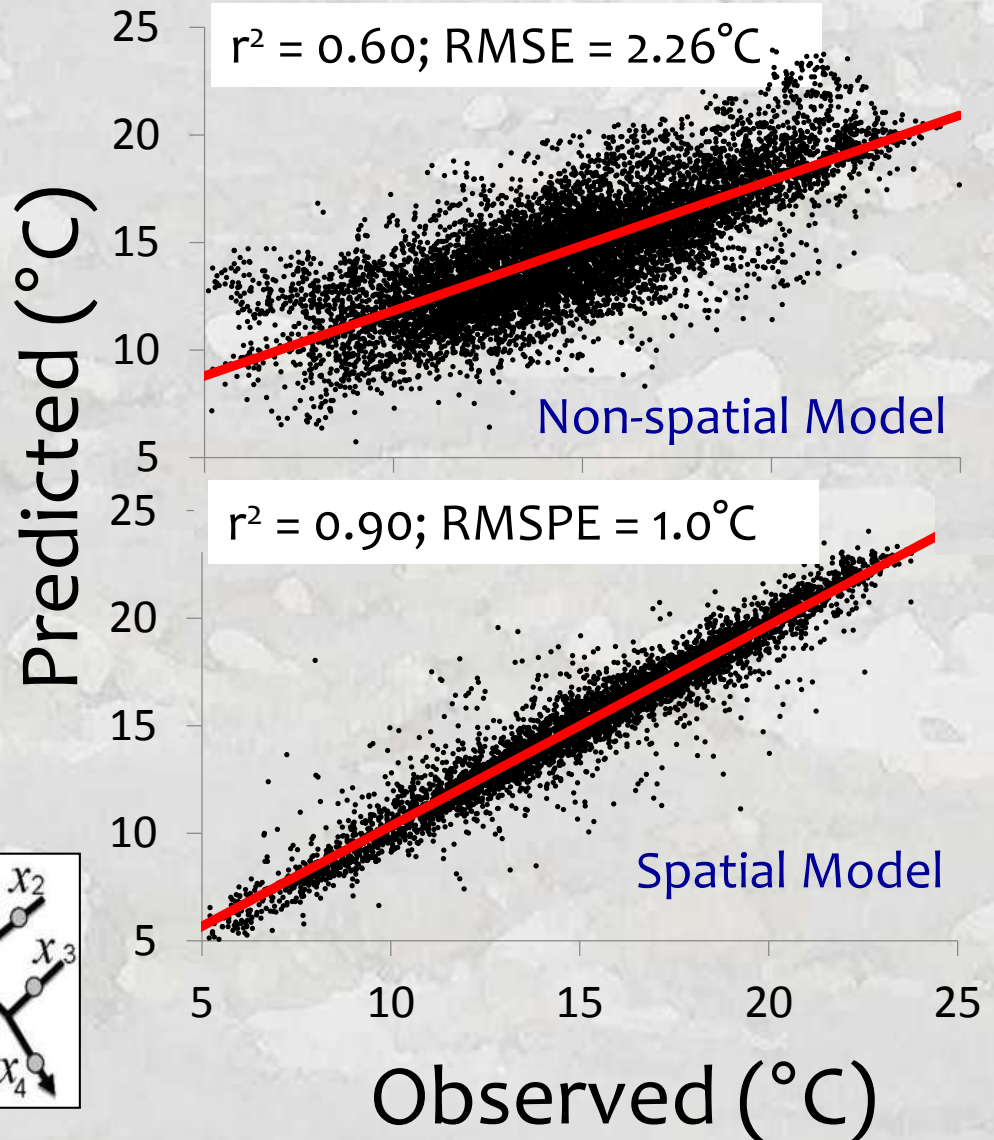
**Hostetler et al. 2011**

*Ecological Applications*

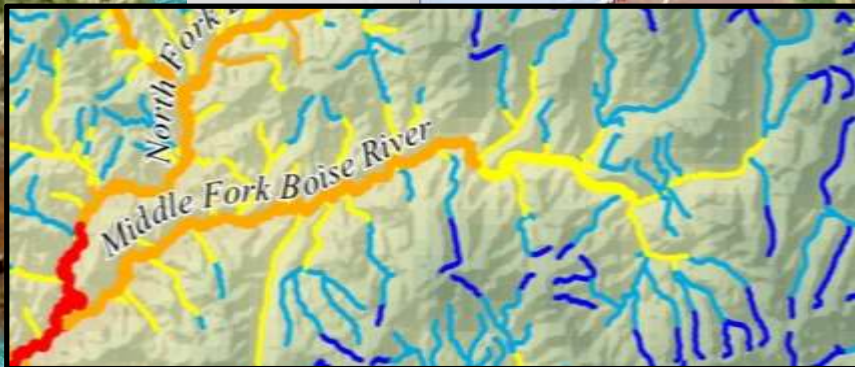
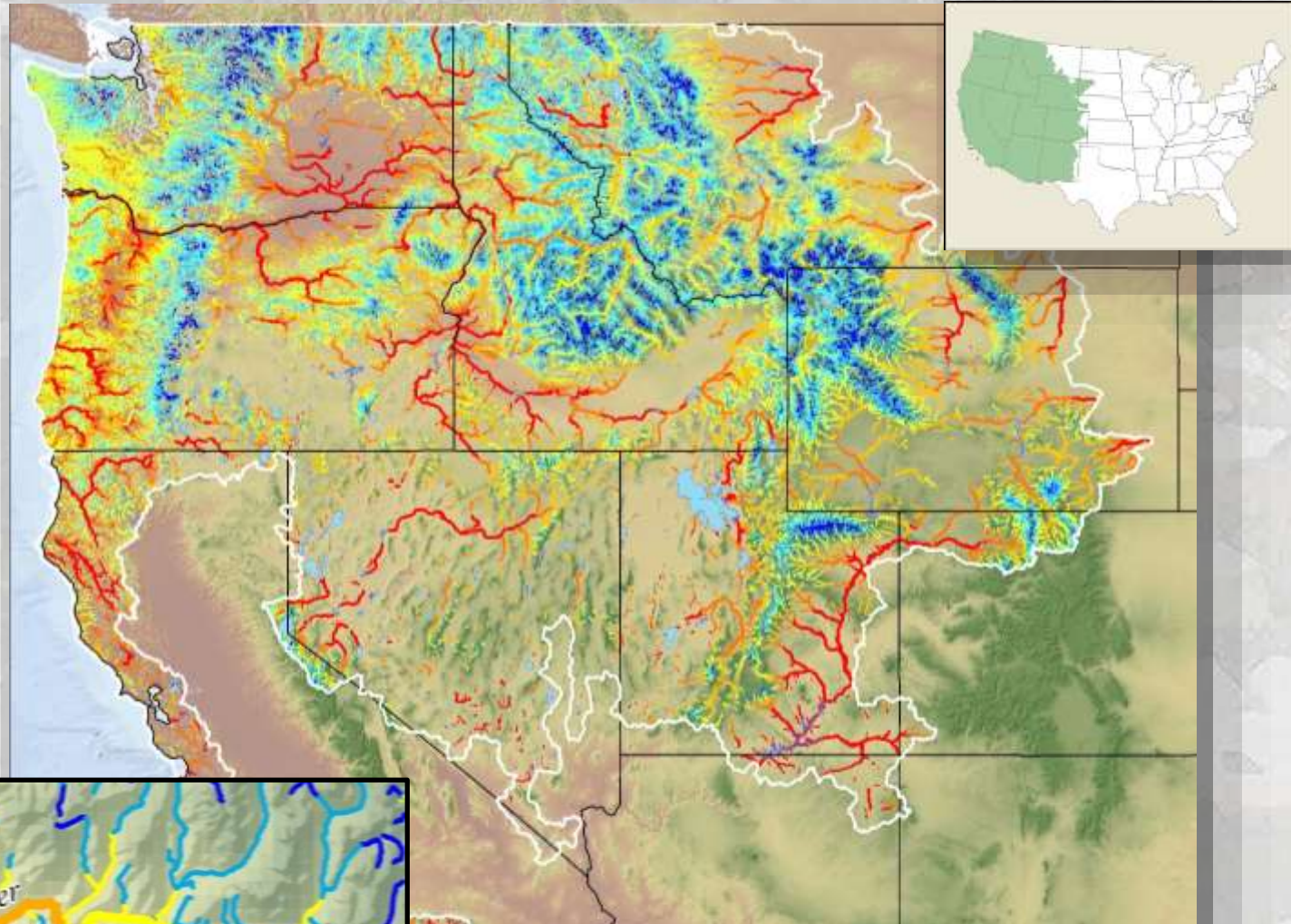
20:1350-1370.



## Mean August Temperature



# High-Resolution Stream & River Scenarios



**1-km resolution**  
**1,000,000 stream kilometers**



# 30 NorWeST Climate Scenarios

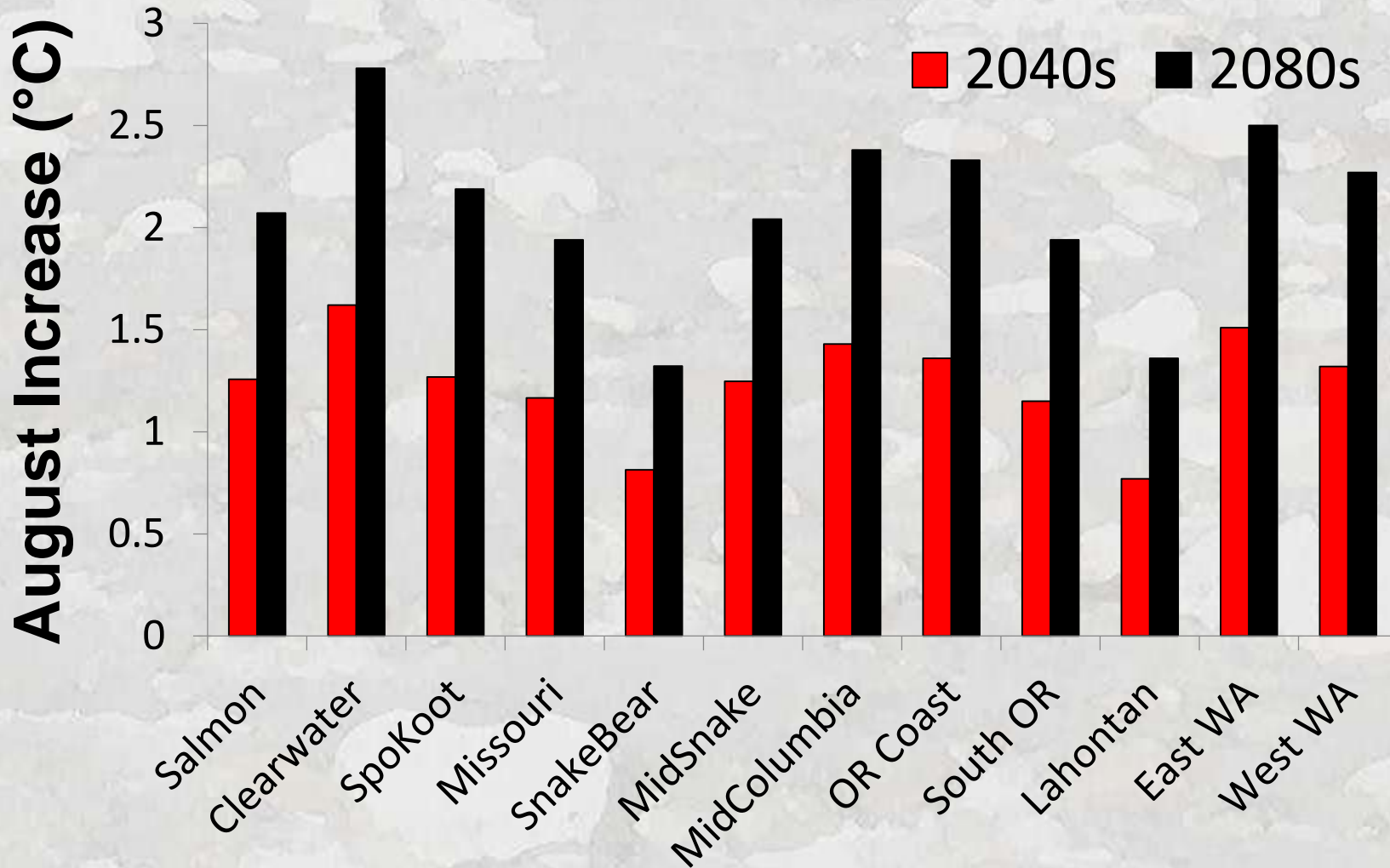
<b>Scenario</b>	<b>Description</b>
S1_93_11	Historical scenario representing 19 year average August mean stream temperatures for 1993-2011
S2_02_11	Historical scenario representing 10 year average August mean stream temperatures for 2002-2011
S3_1993	Historical scenario representing August mean stream temperatures for 1993
S4_1994	Historical scenario representing August mean stream temperatures for 1994
Etc...	
S23-33	10 Future scenarios...

**\*Extensive metadata on website**



# Future Increases Relative to 2000s Baseline

## CIG 10 GCM ensemble for A1B trajectory



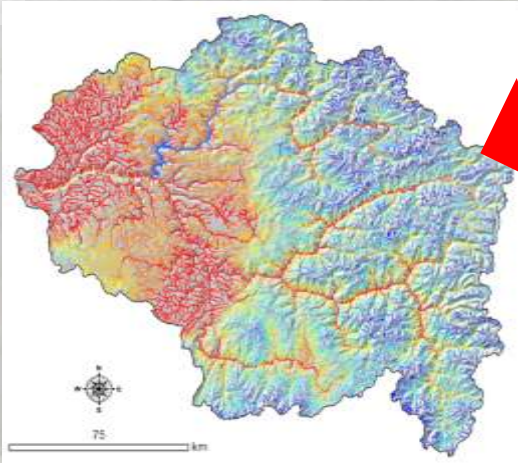
\*Variation within basins +/-50% from sensitivity adjustment



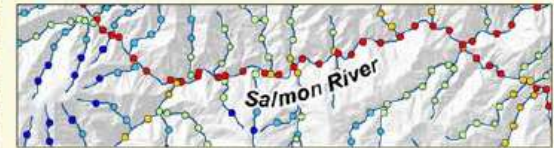


# Website: Temperature Scenarios & Data in User-Friendly Formats

1) GIS shapefiles of stream temperature scenarios

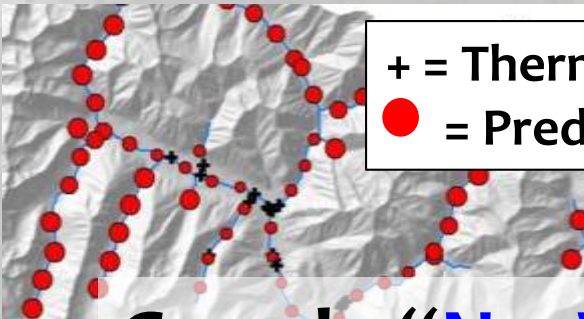


**NorWeST**  
Stream Temp



*Regional Database and Modeled Stream Temperatures*

2) GIS shapefiles of stream temperature model prediction precision



+ = Thermograph  
● = Prediction SE

3) Temperature data summaries

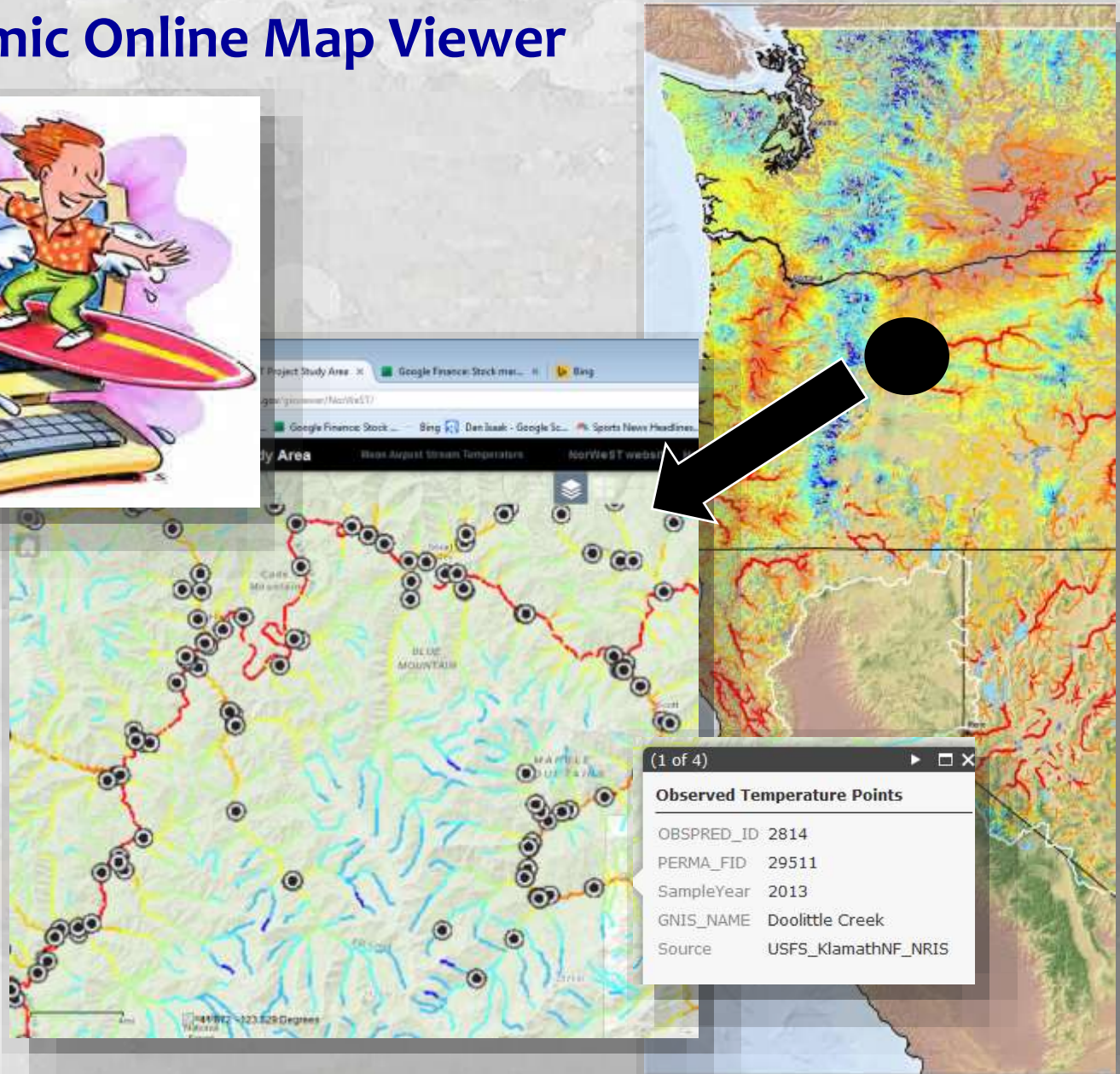


Google **NorWeST** or go here...

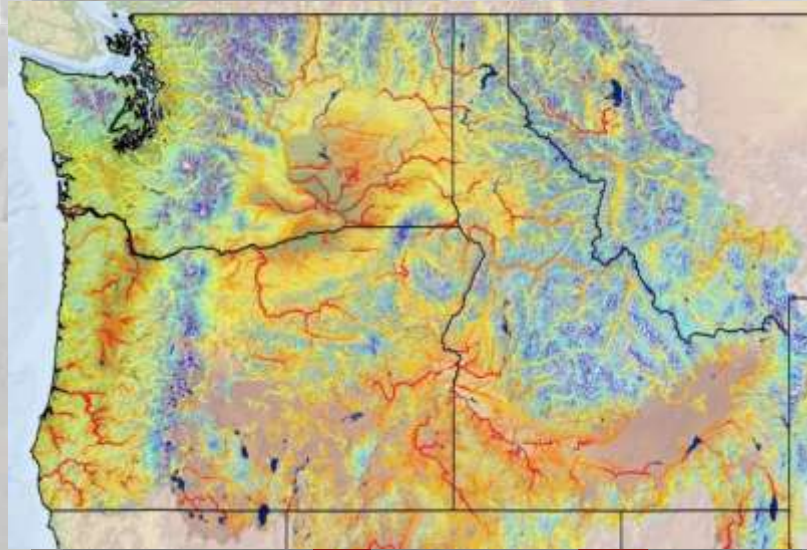
<http://www.fs.fed.us/rm/boise/AWAE/projects/NorWeST.shtml>

# Websurf from your Desktop

## ★ Dynamic Online Map Viewer



# Temperature Applications

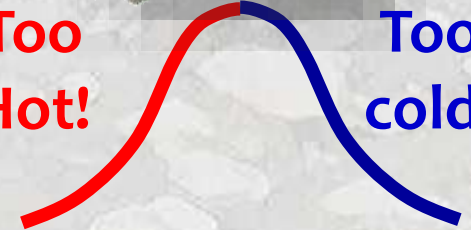


Regulatory temperature standards

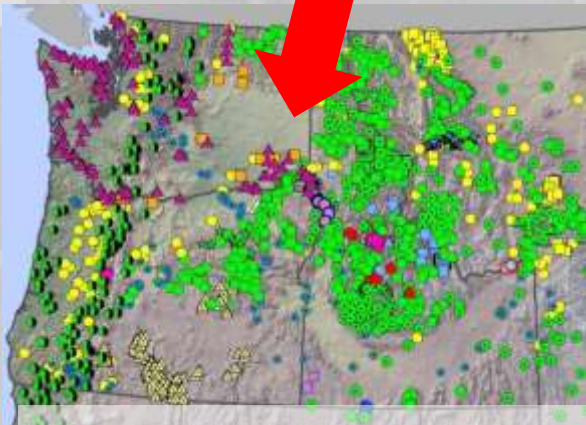


Too Hot!

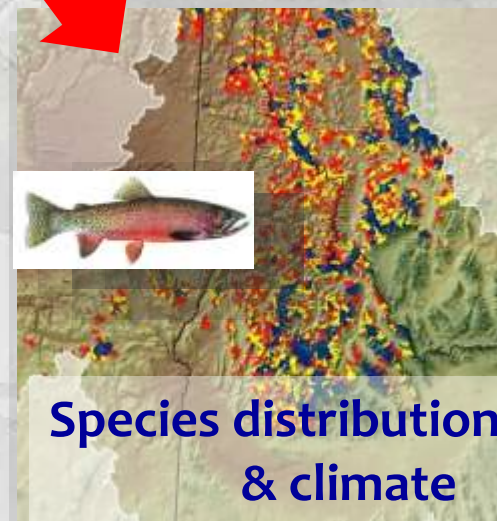
Too cold!



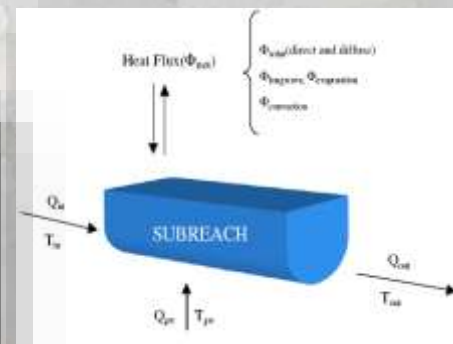
Data access accelerates temperature R&D



Coordinated Interagency monitoring



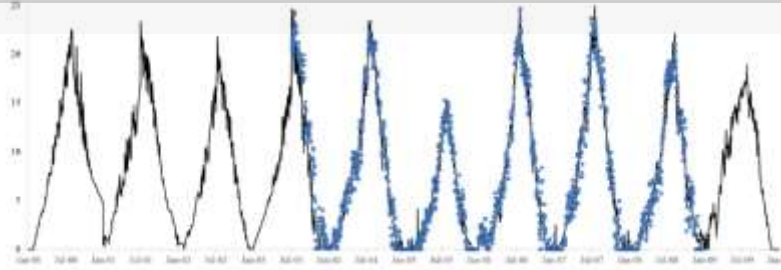
Species distribution models & climate assessments



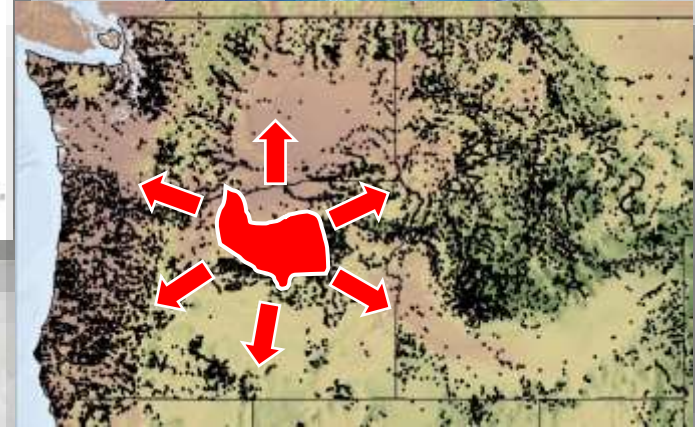
# Broader Application of Latest Thermal Models



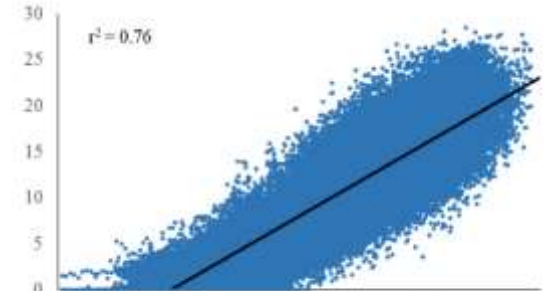
Daily stream temperature



Month-Year



Daily stream temperature

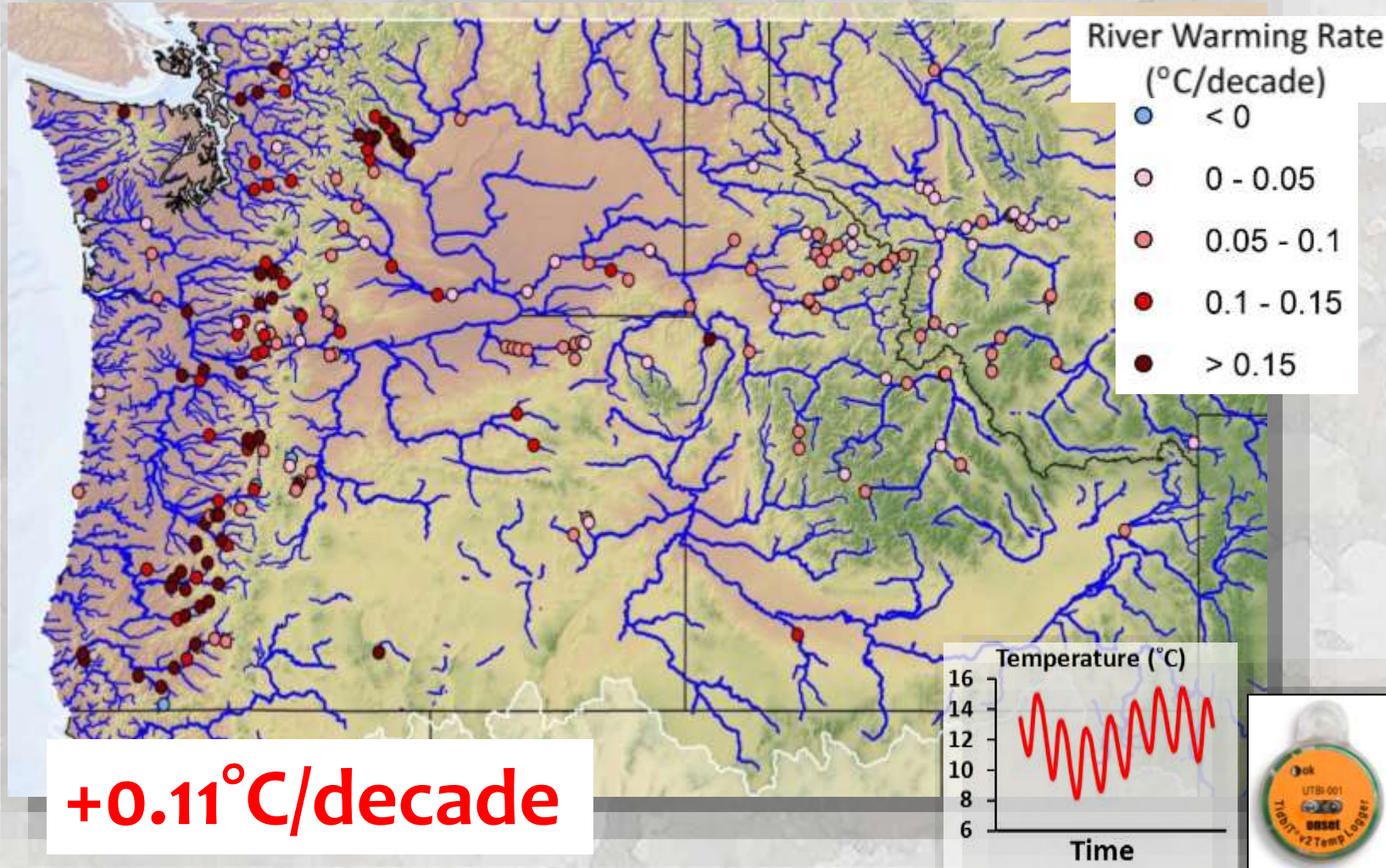


Land surface temperature

McNyset, Volk & Jordan. 2015. Predicting spatially & temporally continuous stream temperatures from remotely sensed land surface temperatures. *Water* 7: 6827-6846.

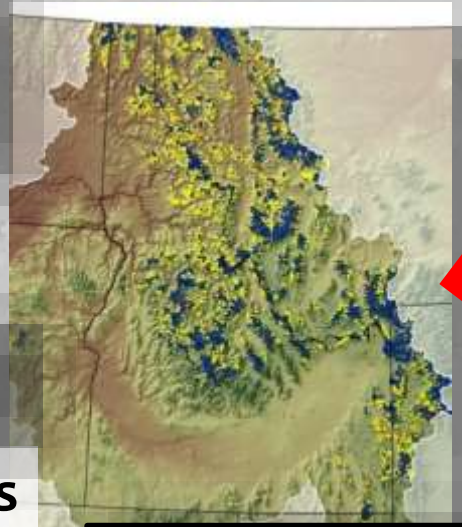
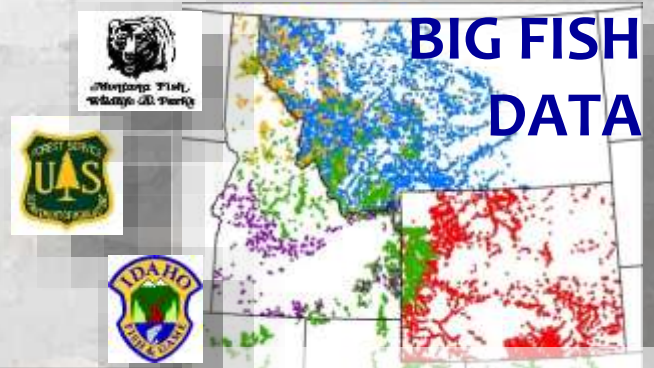
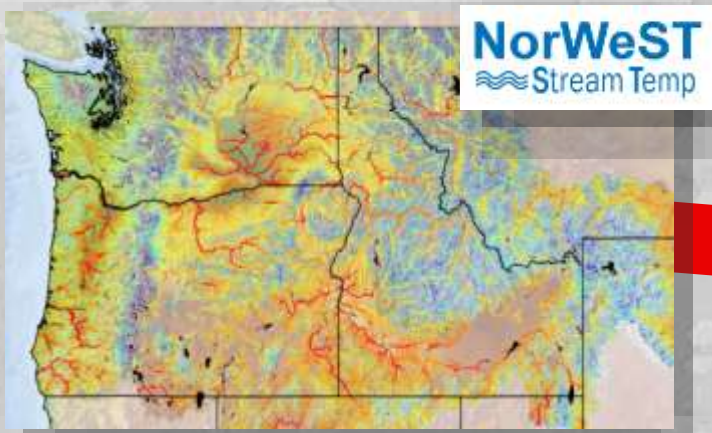
# Summer River Temp Trends (1968-2011)

245 sites with >10 year monitoring records

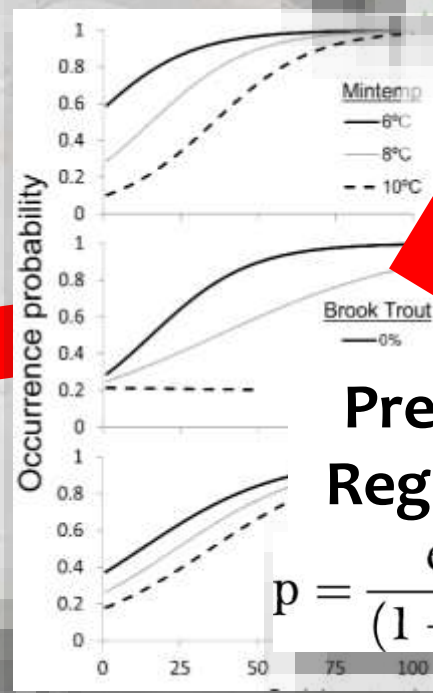


Isaak et al. 2016. Slow climate velocities of mountain streams. *Proceedings of the National Academy of Sciences* DOI:10.1073/pnas.1522429113

# Species Distribution Models for Native Trout Climate Refugia



Precise Maps of Occurrence



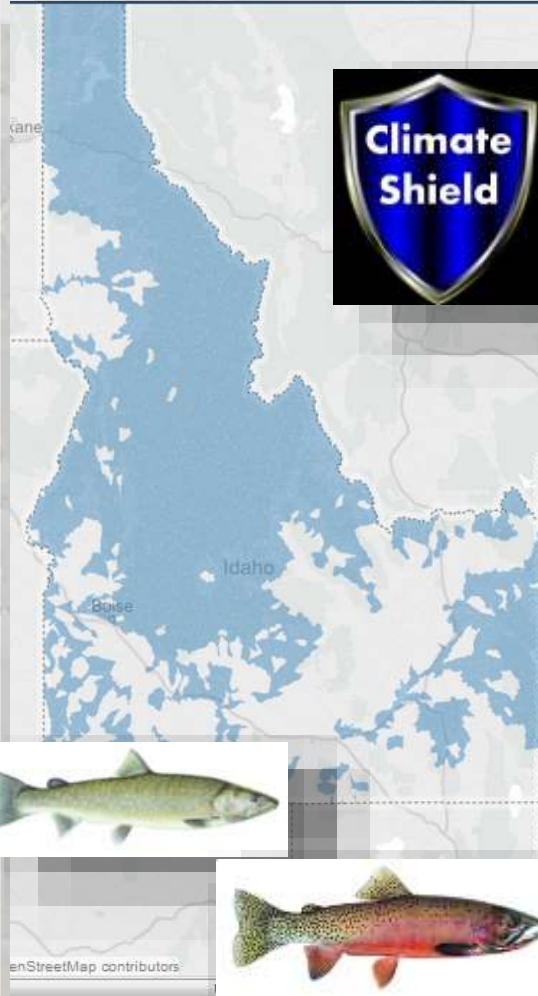
>4,000 sites  
>500 streams

Predictive Logistic Regression Models

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

# Trout Unlimited: Water Transactions Tool

Kurt Fesenmeyer  
& Sean McFall



Legend:

- Salmon
- Snake-Bear
- SpoKoot
- Utah

### Salmonid Distribution

<b>Bull Trout</b>	<b>Redband Trout</b>
<input checked="" type="checkbox"/> Not Present	<input checked="" type="checkbox"/> Not Present
<input checked="" type="checkbox"/> Present	<input checked="" type="checkbox"/> Present

<b>Westslope Cutthroat</b>	<b>Yellowstone Cutthroat</b>
<input checked="" type="checkbox"/> Not Present	<input checked="" type="checkbox"/> Not Present
<input checked="" type="checkbox"/> Present	<input checked="" type="checkbox"/> Present

### Climate Shield Data

Bull Trout Probability Occurrence - 1980 Scenario - 50% Brook Trout  
0  100

Bull Trout Probability of Occurrence - 2080 Scenario - 50% Brook Trout  
0  98

Cutthroat Trout Probability of Occurrence - 1980 Scenario - 50% Brook Trout  
0  100

Cutthroat Trout Probability of Occurrence - 2080 Scenario - 50% Brook Trout  
0  100

Water Use	Public Land Status
# of Dams 0 <input type="range"/> 7	% Public Lands 0 <input type="range"/> 100
# of Diversions 0 <input type="range"/> 100	% Managed for Biodiversity 0 <input type="range"/> 100

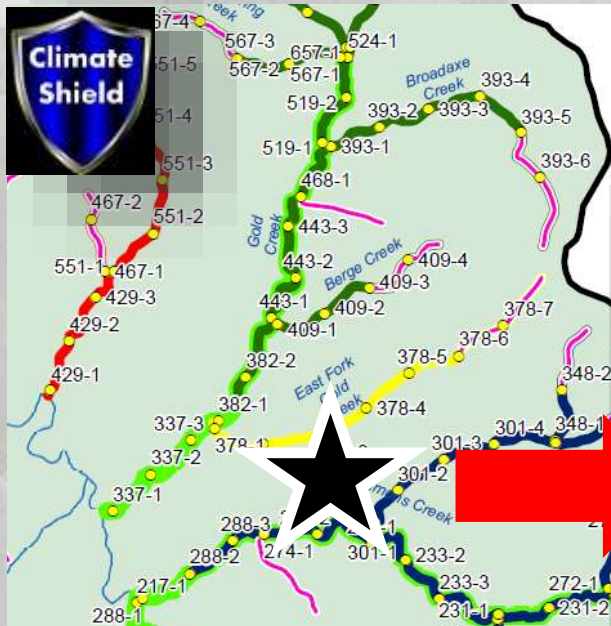
Dynamic queries of bull trout & cutthroat refuge habitats

# Trout Unlimited: Water Transactions Tool

Kurt Fesenmeyer  
& Sean McFall



Idaho Dept. of Water  
Resources – Water Rights  
& Diversion Database



## Step 7. IDWR water rights documentation

Idaho Department of Water Resources  
Water Rights Report  
WATER RIGHT ID: 11 1802

Owner Name	Name and Address
Current Owner	WATER RIGHTS ACQUISITION CO. 200 BLOC 34 SALAMAN, ID 83402 208709-4000
Beneficiary	WILLIAM W. BURELL 305 SOUTH CAPITOL BLVD STE 100 BOISE, ID 83727 208251-5000
Beneficiary	DAVEY LOGISTICS 1000 BRANSA AVE BOISE, ID 83702

Issue Date: 05-08-01  
Issue Reason: WATER RIGHTS ACQUISITION

Location of Point(s) of Diversion:  
NAPAVICUM CREEK, 1000 FT. FROM

On the left is what  
the WRReport  
contains.

On the right is what  
the WRMap link  
generates, a PDF of  
where the water is  
diverted to.



## Habitat quality

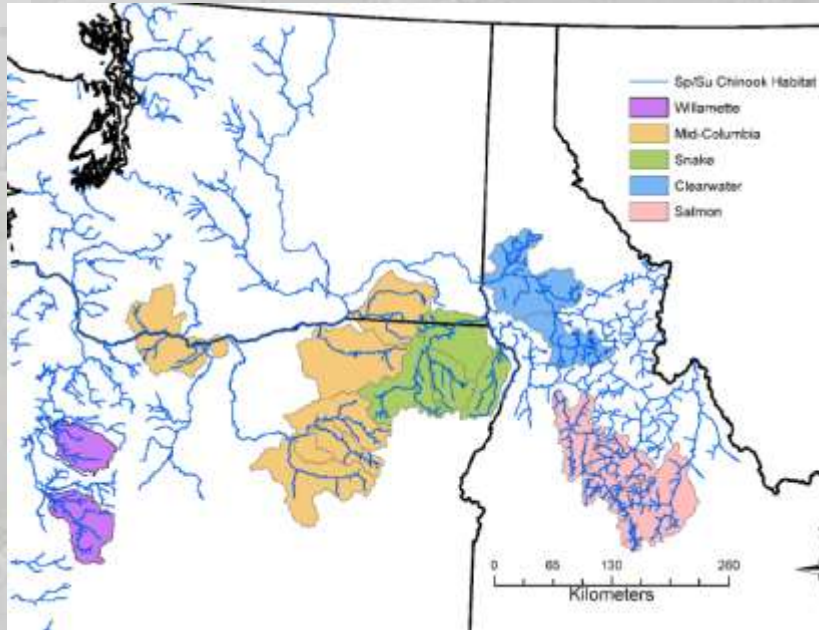
- > 0.90
- > 0.75 to < 0.90
- > 0.50 to < 0.75
- > 0.25 to < 0.50
- < 0.25
- Slope = 10% to 15%



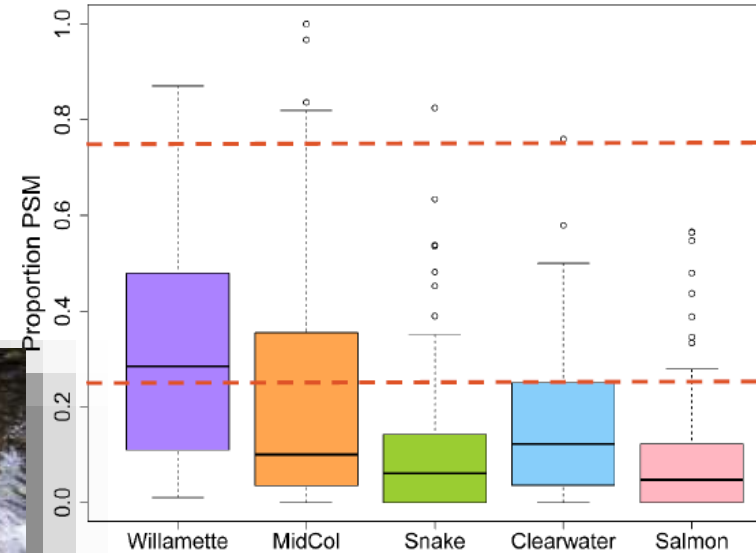
Climate-smart  
microtargeting of water  
rights acquisition or fish  
screening



# NorWeST Temperature & Prespawn Mortality in Salmon

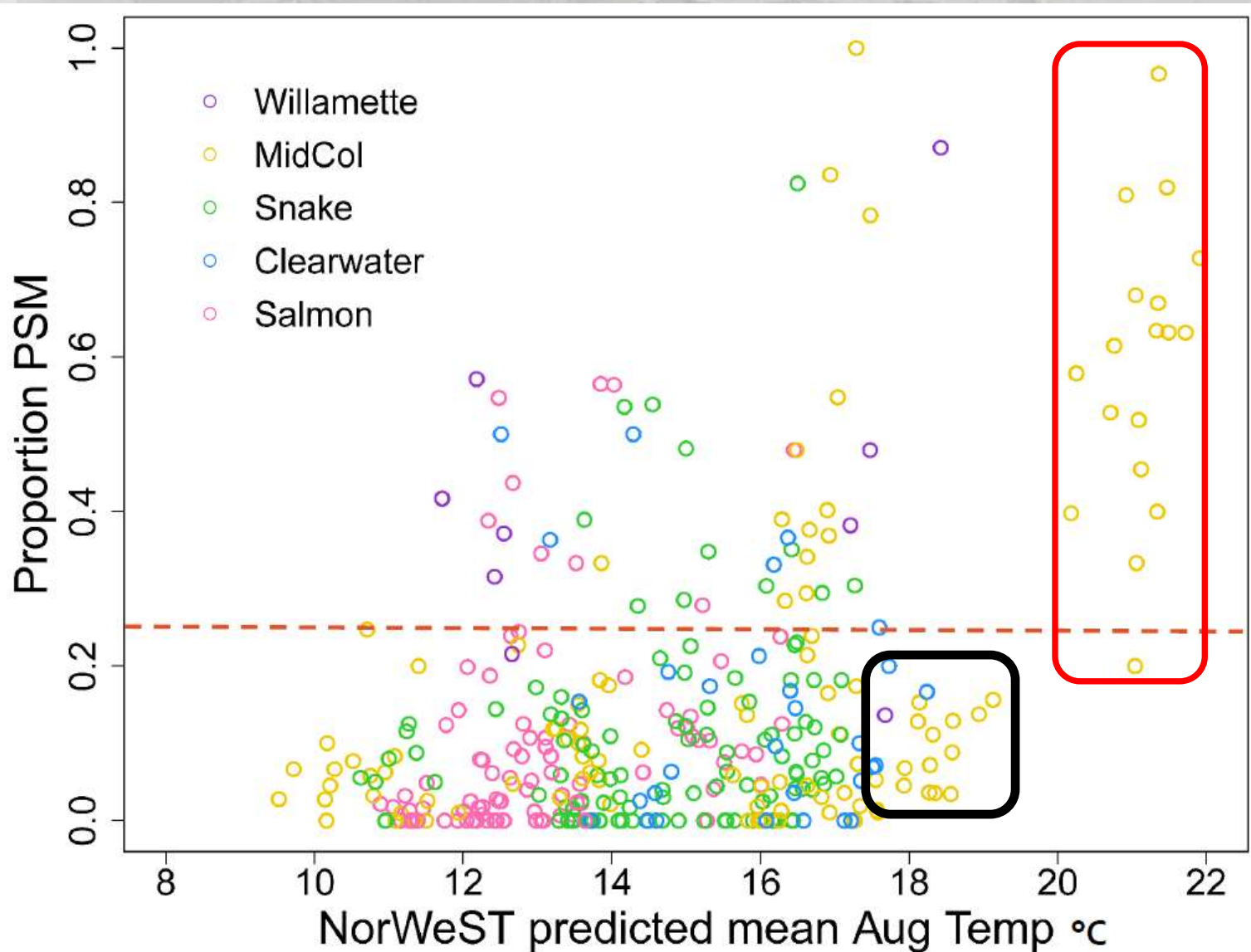


450 site years of PSM data  
8 different agencies  
3 ESUs

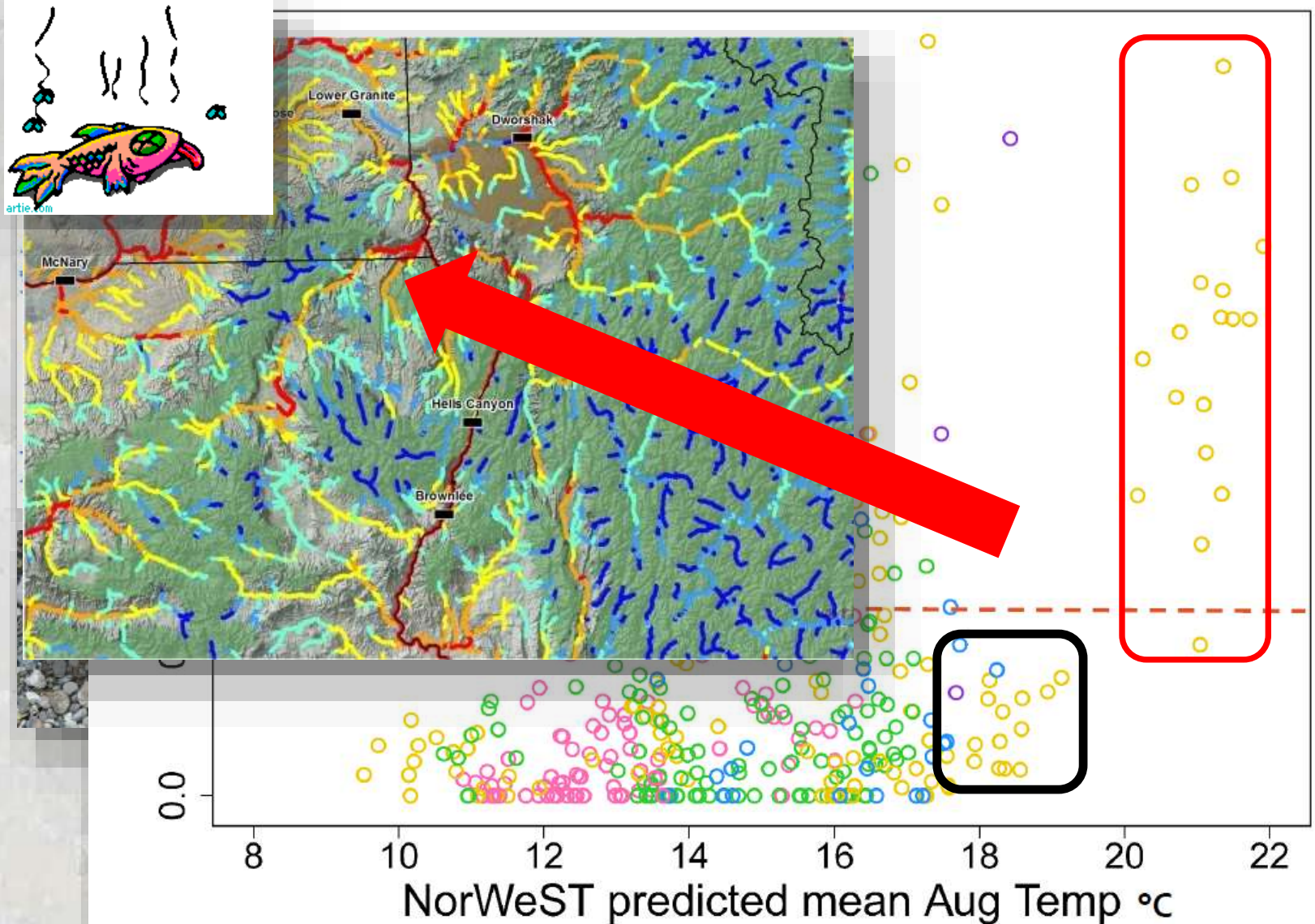


Bowerman, Keefer, & Caudill (U. Idaho)

# NorWeST Temperature & Prespawn Mortality in Salmon



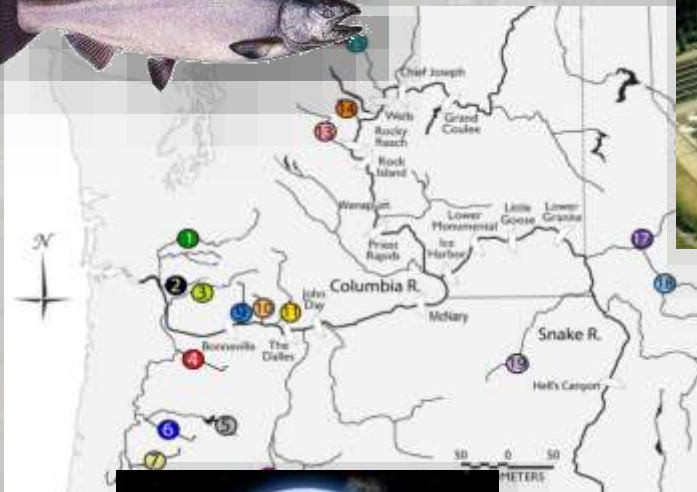
# NorWeST Temperature & Prespawn Mortality in Salmon



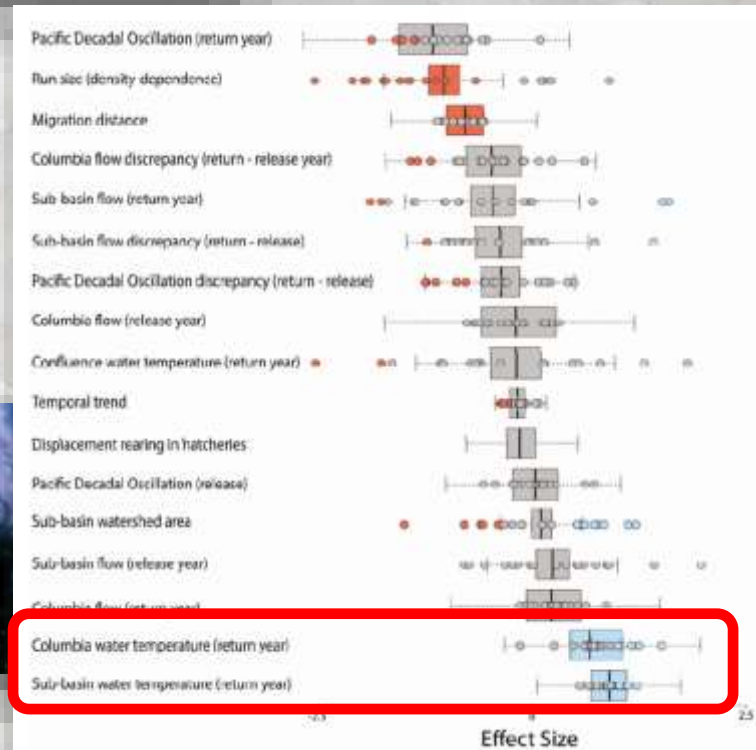
# NorWeST Temperature & Salmon Hatchery Straying Rates

1993-2011

Environmental Predictors



**E.T. Go Home**  
**Not in Hot Years**



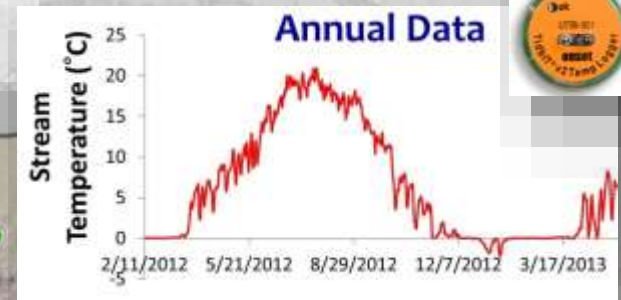
Westley et al. 2015. Signals of climate, conspecific density, and watershed features in patterns of Pacific salmon straying. *Ecology* doi.org/10.1890/14-1630.1



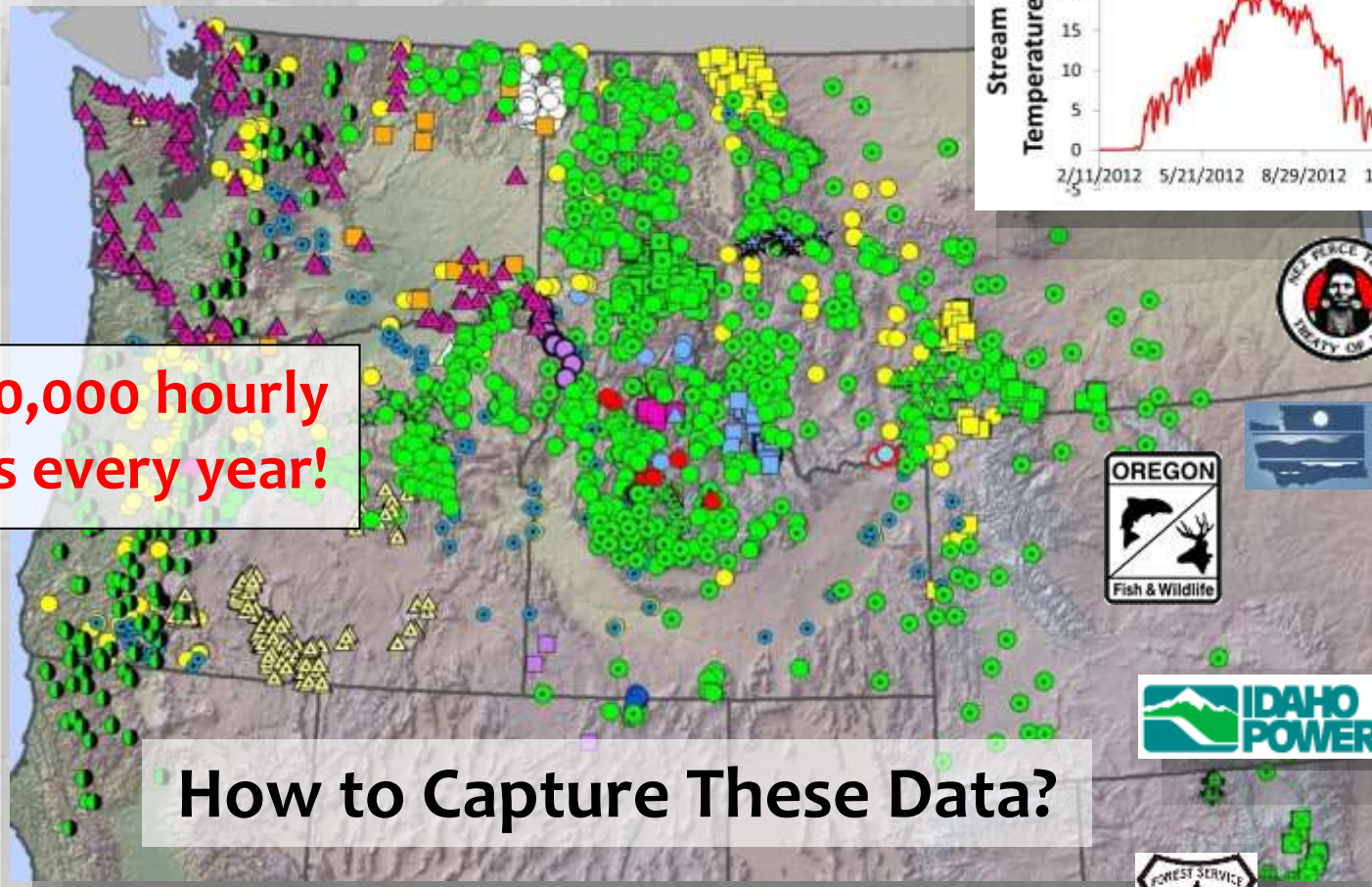
# Data Acquisition Rate is Overwhelming

>3,000 annual sites in Pacific Northwest

>200 new sites last year



~30,000,000 hourly records every year!



How to Capture These Data?



# Additional Significant Uses



- EPA/OR-DEQ salmon climate refuge project in PNW
- NorWeST north of the border – Canadians replicating in BC & NWT
- USFWS bull trout recovery plan
- FS Climate Adaptation Partnerships (BMAP, NRAP, SCOAP, SWAP, IAP...)
- FS Forest Plan revisions (~80 national forests)
- NOAA Pacific Coast salmon climate vulnerability assessment



## Key Points...

- Warming likely to continue for decades
- Summer low flows likely to trend lower
- Precise information about when & where climate factors cause significant stress for anadromous fishes is needed for planning
- Response options include:
  - a) habitat restoration,
  - b) assisted evolution & migration,
  - c) decrease stocking densities,
  - d) do nothing
- Strategic prioritization is required







The End