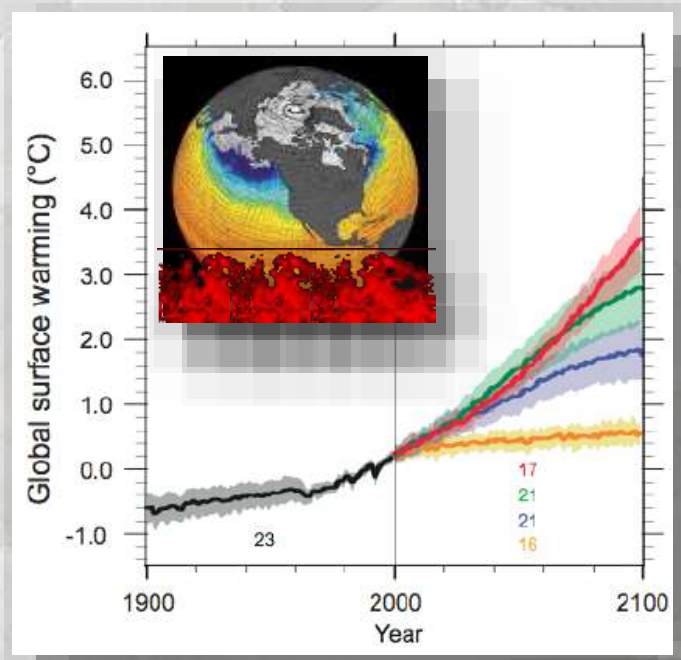
Identifying, Protecting, & Enhancing Climate Refugia for Salmonids

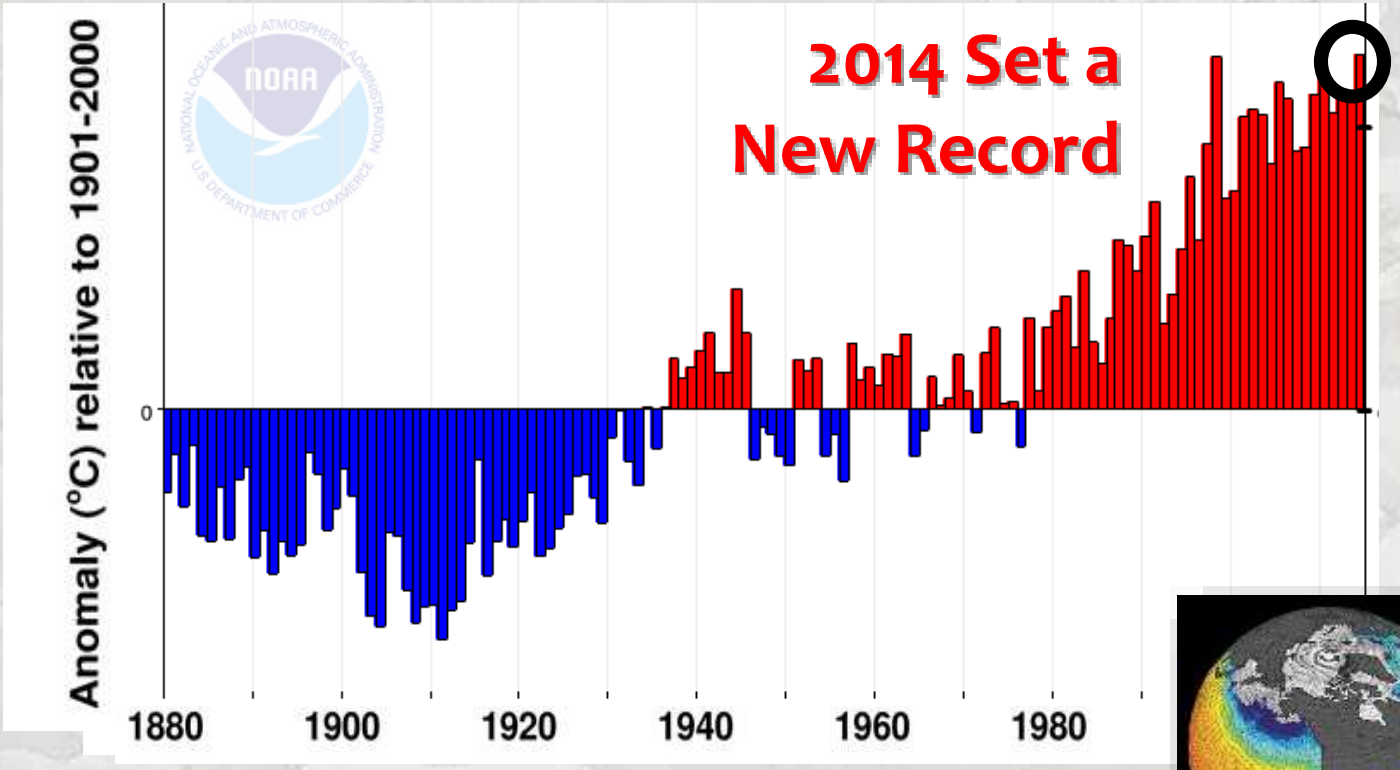
Dan Isaak & Mike Young

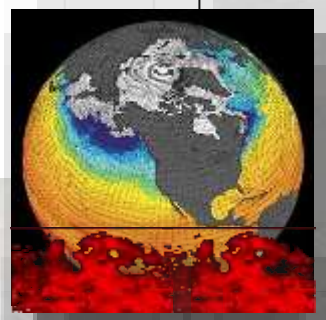
US Forest Service Research



The New Reality…

1880-2014 Global Air Temperature Trend





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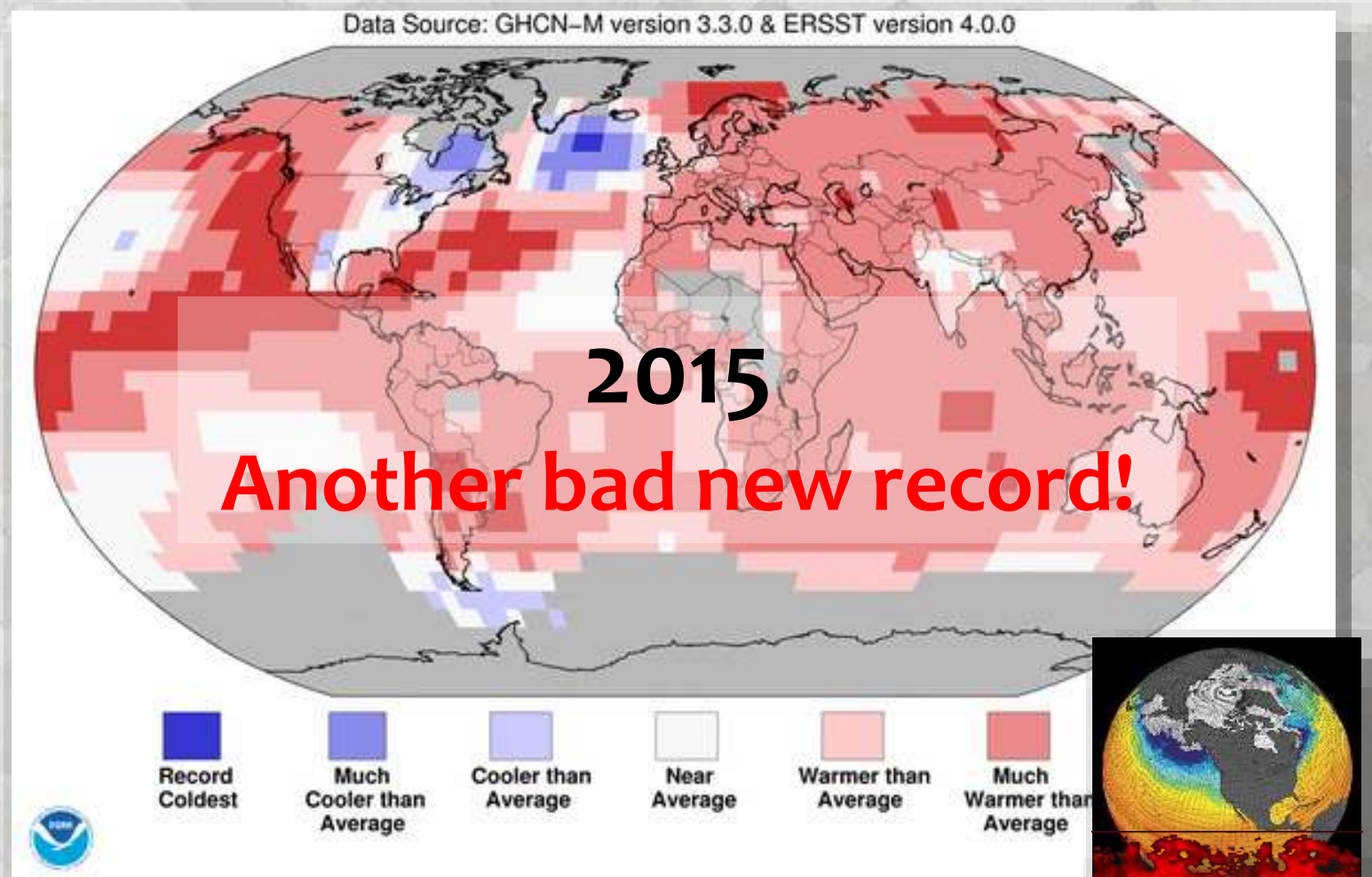
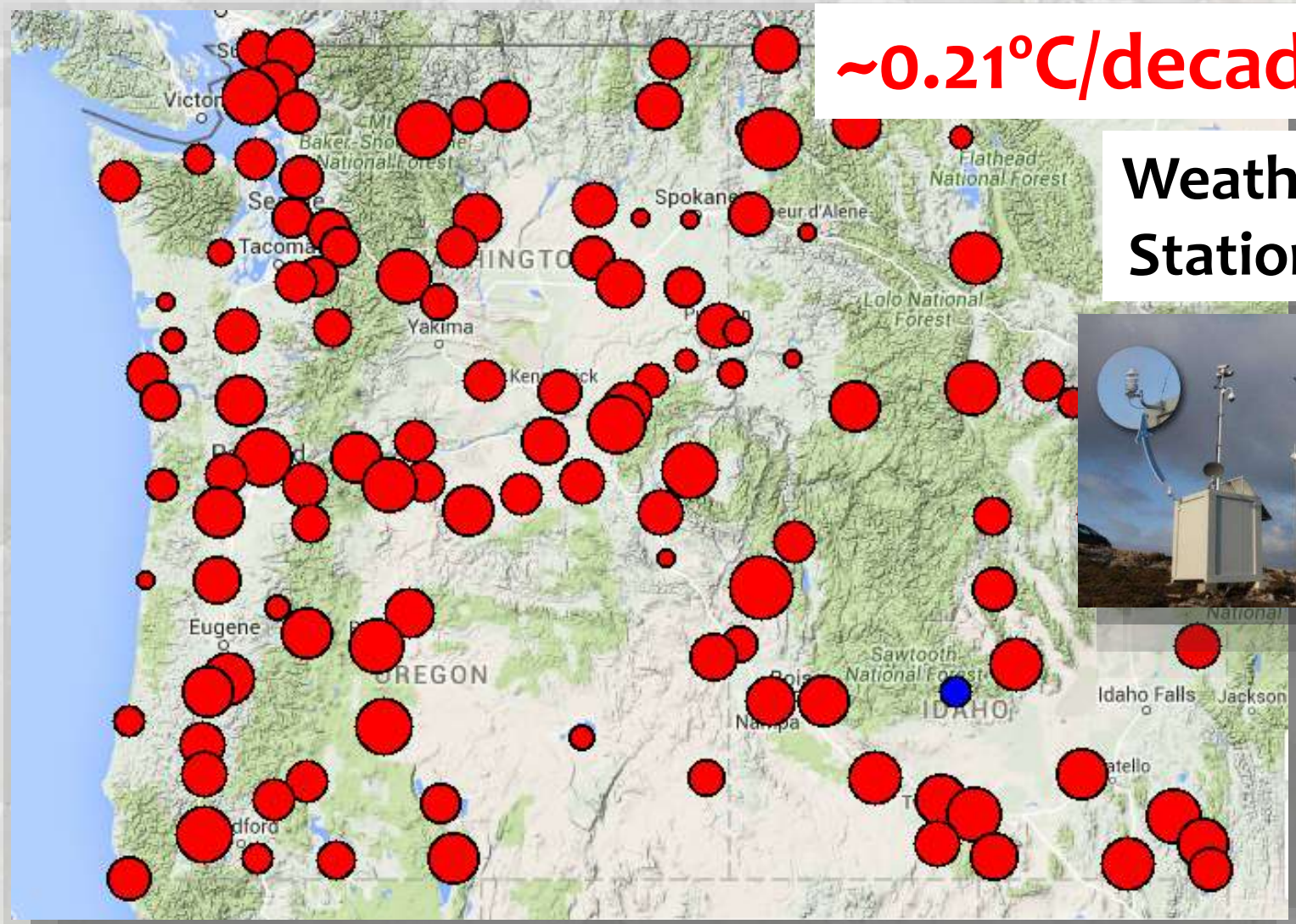


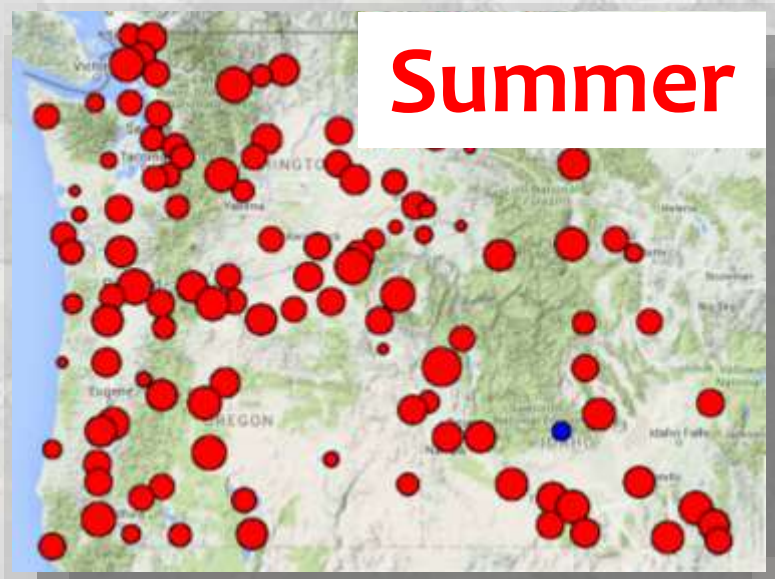
Summer Air Temp Trends (1968–2011)

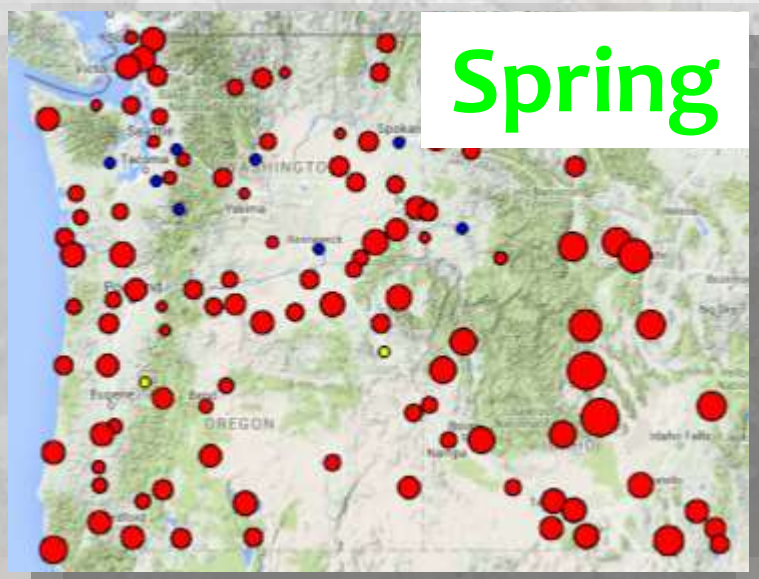


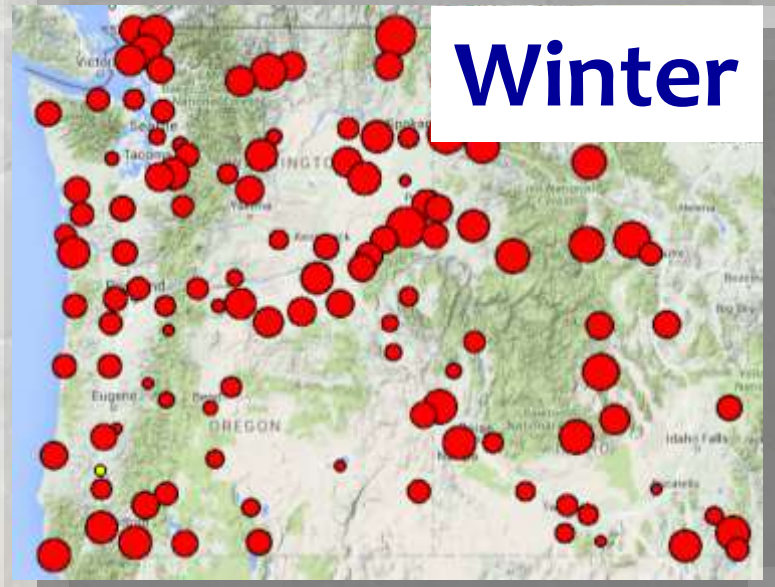
OWSC Climate Tool map

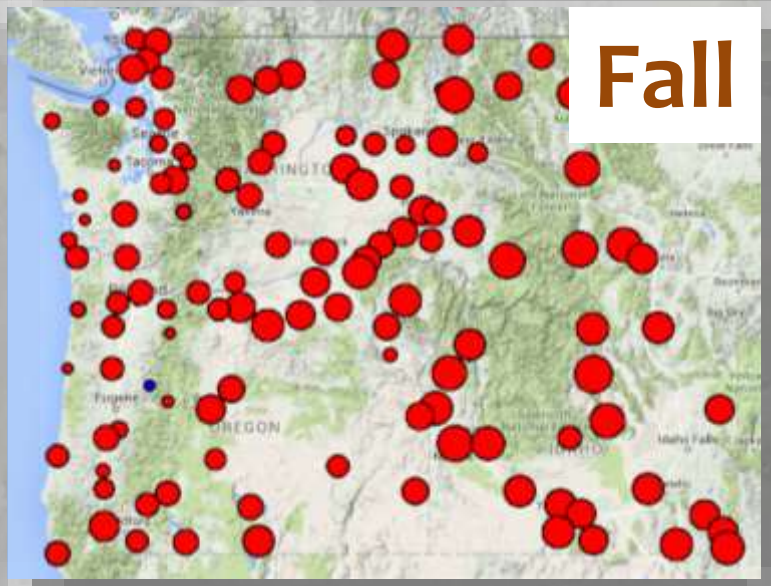
http://www.climate.washington.edu/trendanalysis/

Seasonal Air Temp Trends (1968–2011)



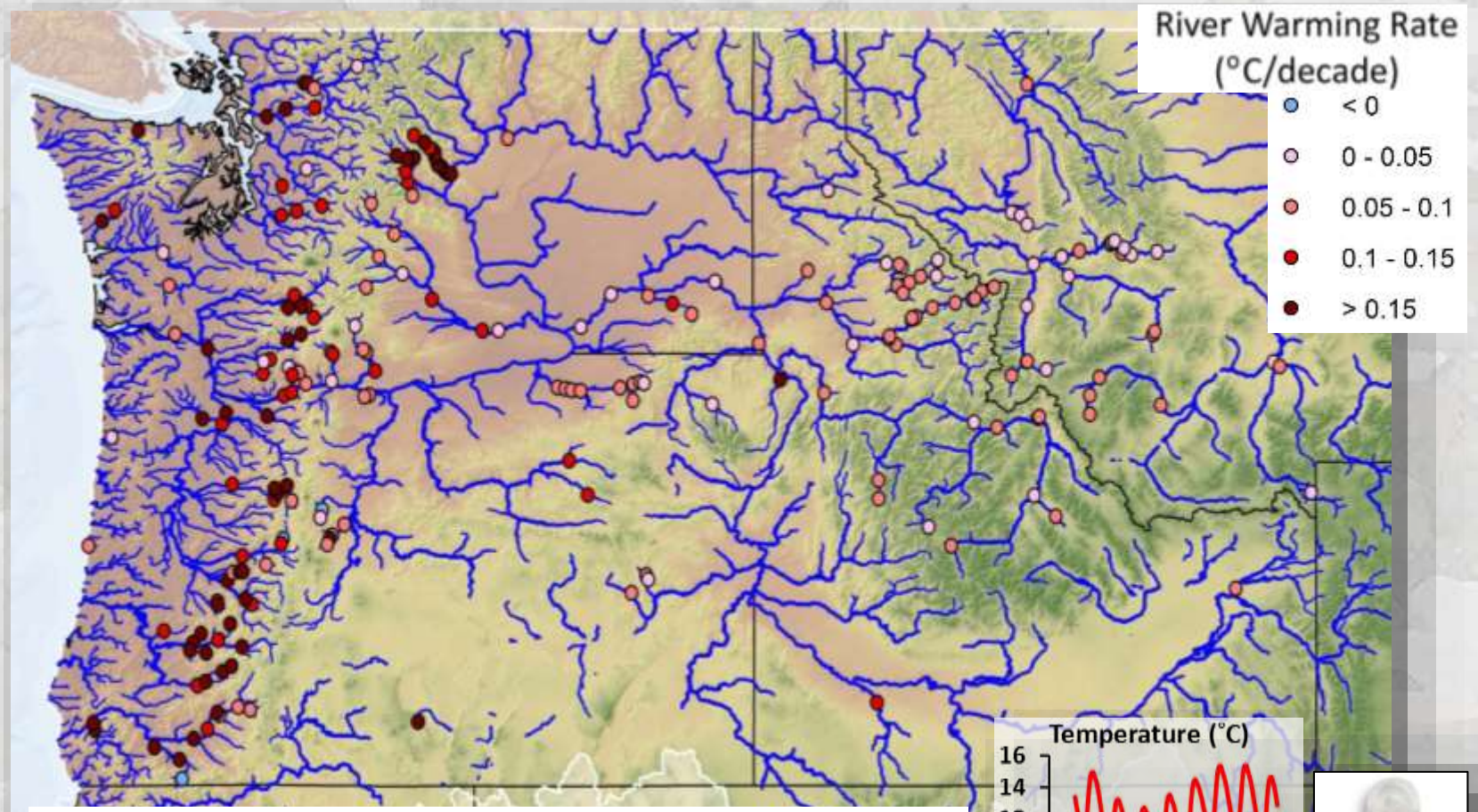






Summer River Temp Trends (1968-2011)

245 sites with >10 year monitoring records



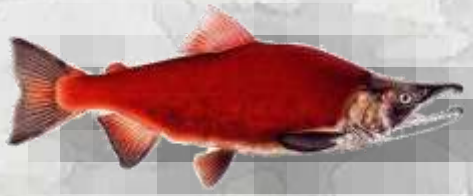
+0.11°C/decade

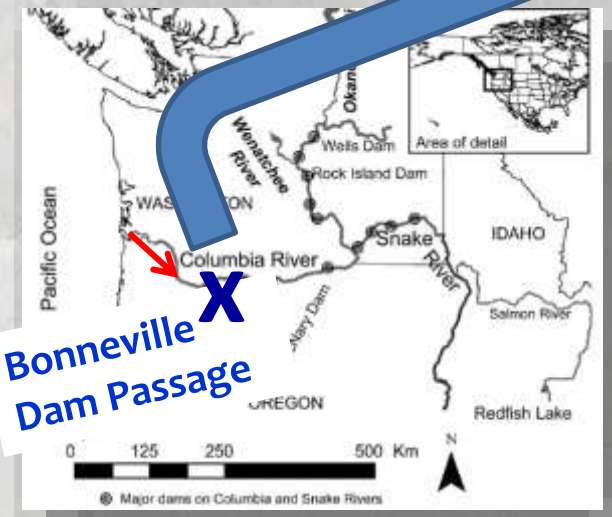
98.5% sites are warming

Isaak et al. In Prep.

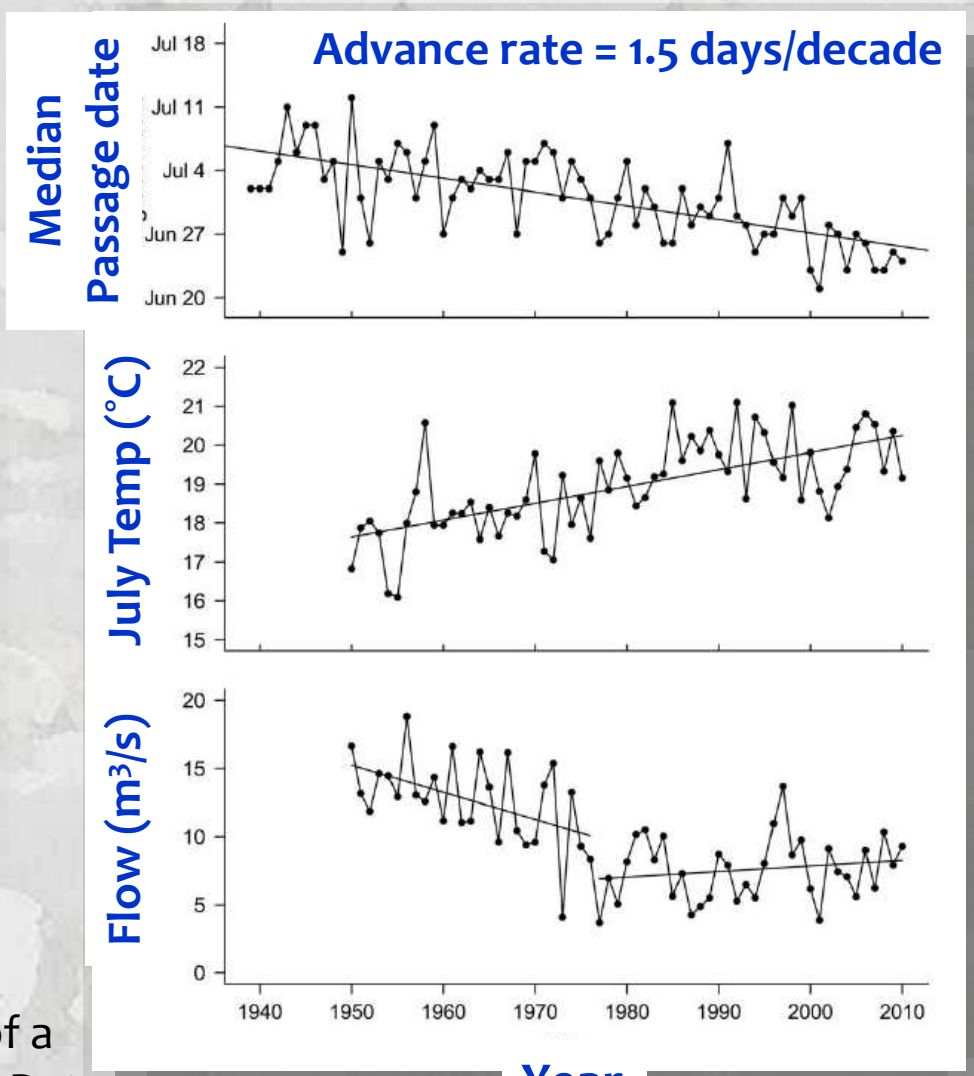
Fish are Trying to Follow Climate

Sockeye Migrations Happening Earlier…





Bonneville Dam Passage



Crozier et al. 2011. A Case Study of a Shift toward Earlier Migration Date in Sockeye Salmon. *The American Naturalist* **178**:755-773.

2015 Was a "Perfect storm"

High temps + low flows +
many fish = Many Mortalities

Summer Chinook Return Forecasted To Be Largest Since 1961; Gillnetters Raise Catch Allocation Issues
Posted on Friday, July 10, 2015 (PST)

Climate change is tilting the odds towards more perfect storms

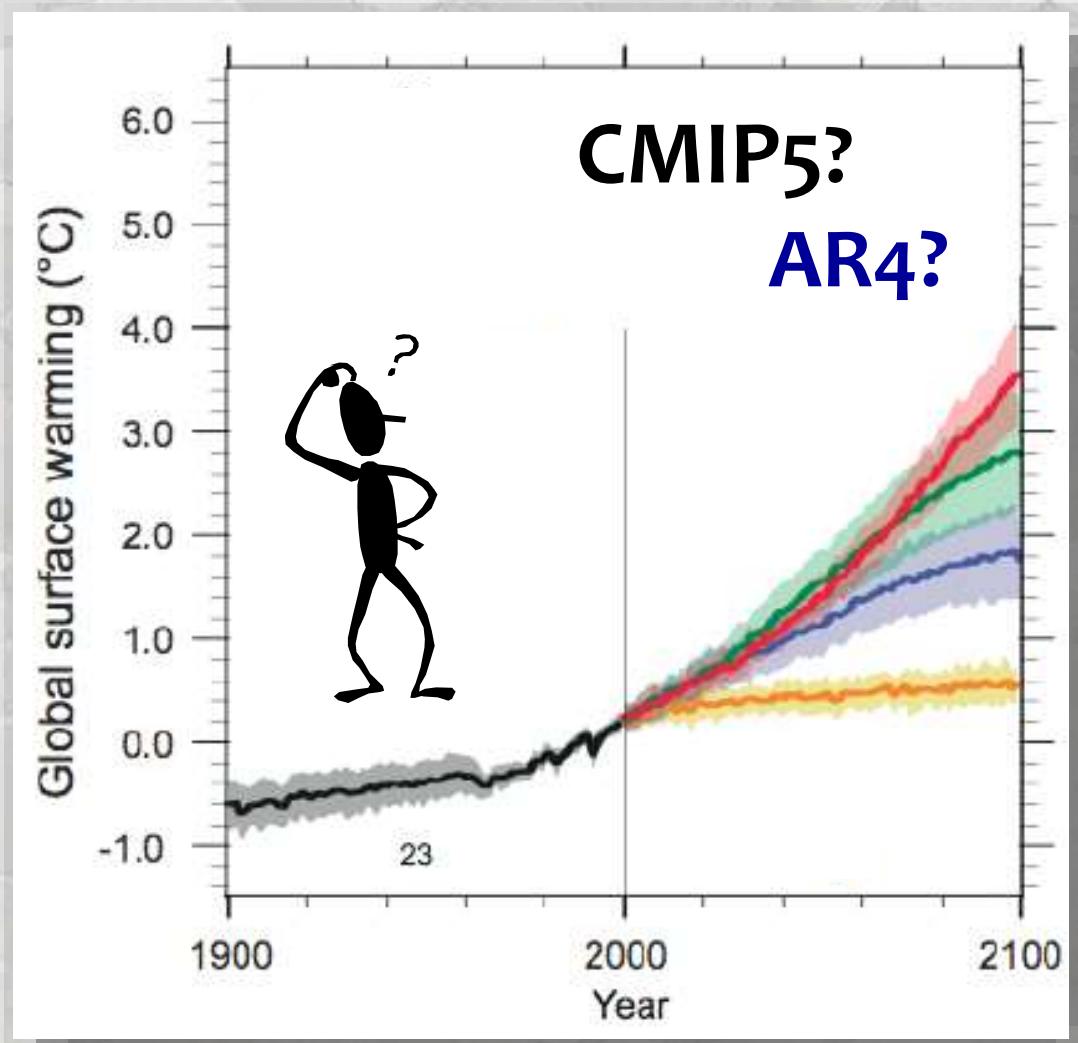
Snowpack drought has salmon dying in overheated rivers

Originally published July 25, 2015 at 5:42 pm | *Updated July 28, 2015 at 11:18 am*

The Seattle Times

How Much Warmer & When?

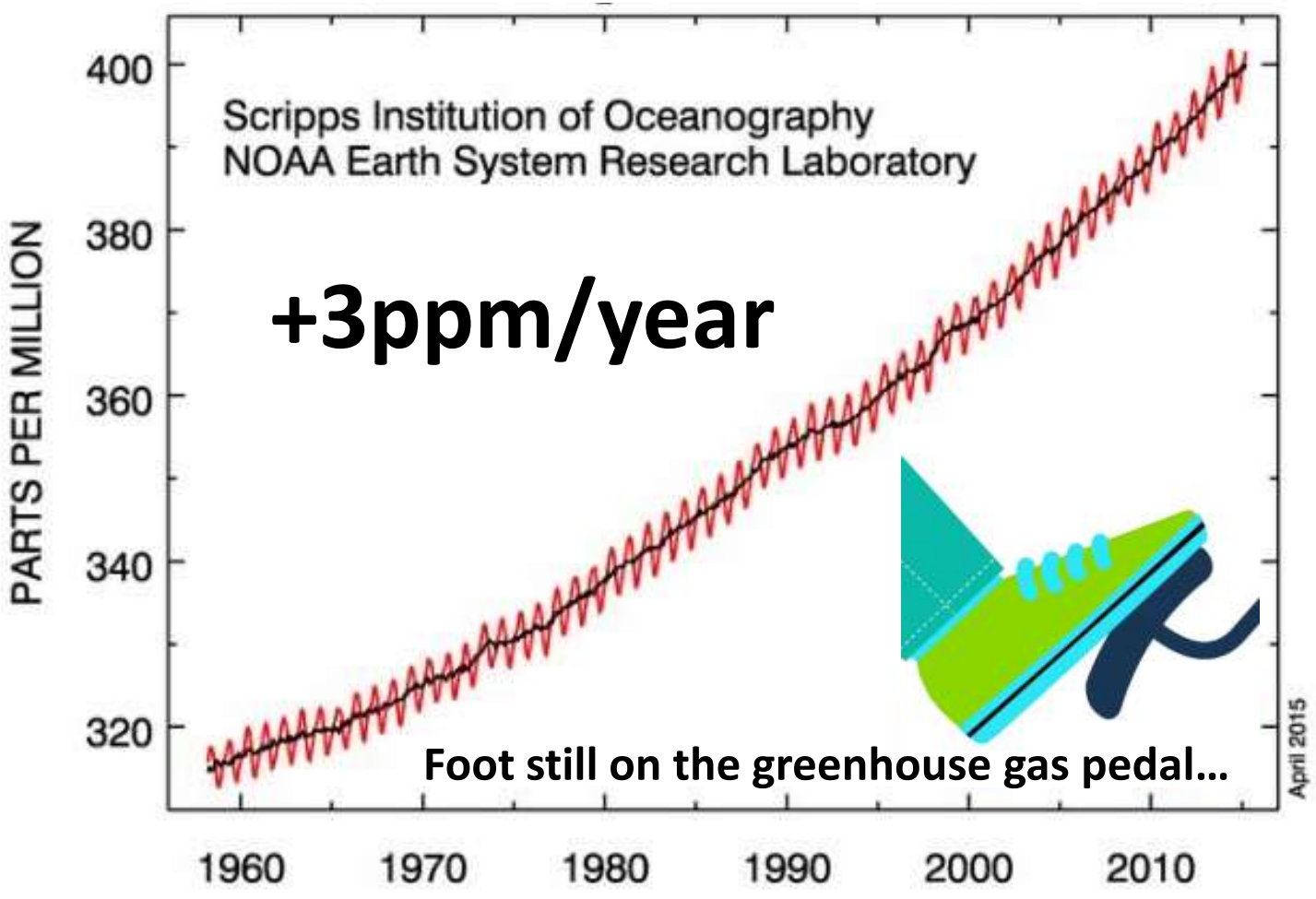
The Future is Uncertain…



The Specifics are an "Unknowable Unknown"

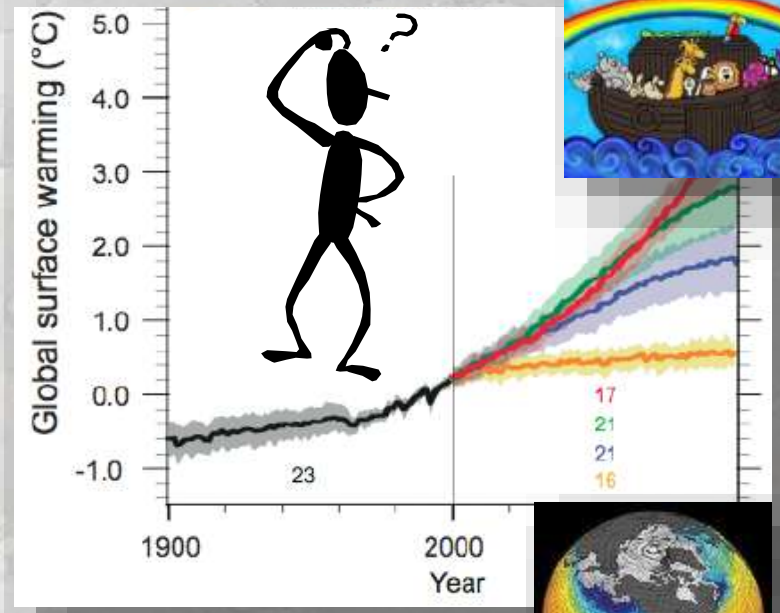
How Much Warmer & When?

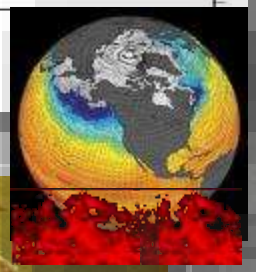
Atmospheric CO2 Concentration



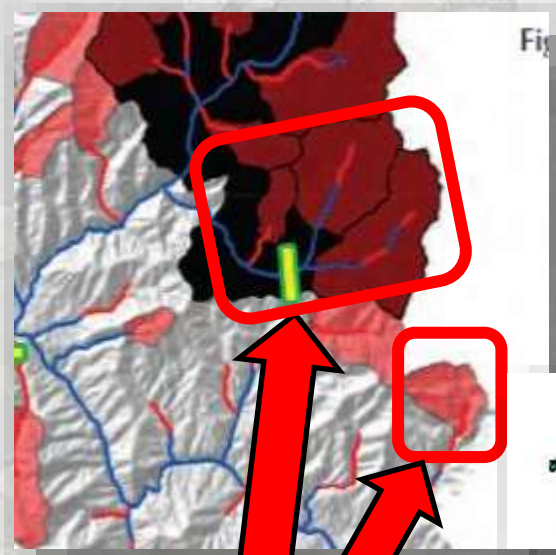
Plan on continued warming for decades…

Identifying & Protecting Climate Refugia Hedges Against Uncertainty





Strategic Context for Investment Planning



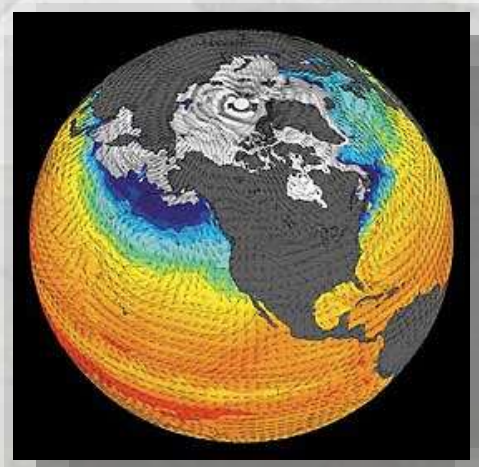
I'm going to invest here…

…not here

Resolving Refugia Requires Taking Climate Into the Water Where Fish Live

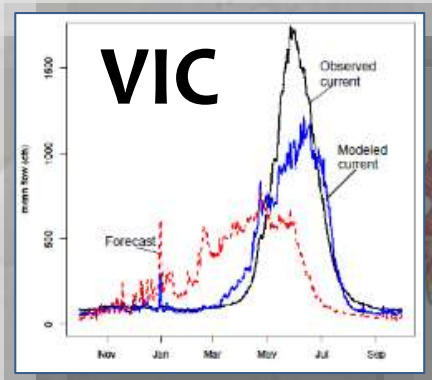
Resolving Refugia Requires Taking Climate Into the Water Where Fish Live

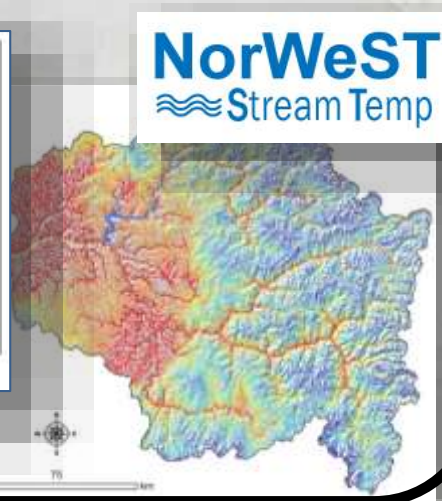
Climate model (air temp & precip)



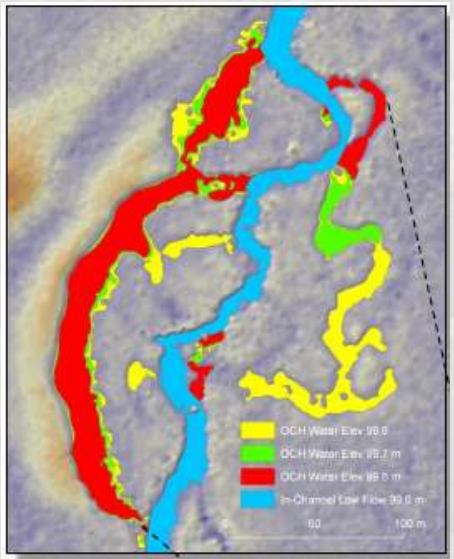
Regional patterns

Stream temperatures & flow



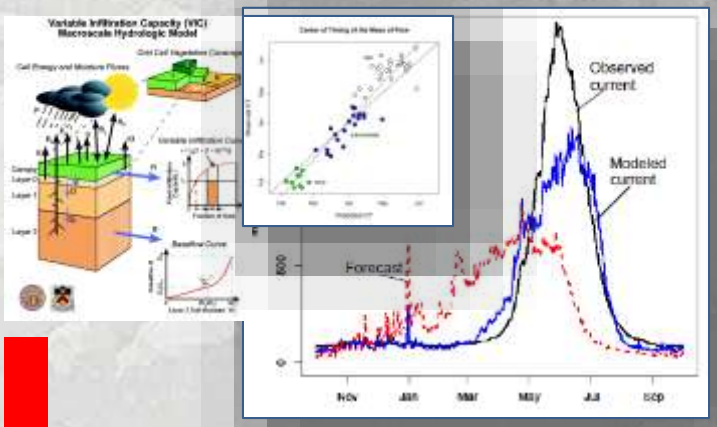


Stream reach patterns

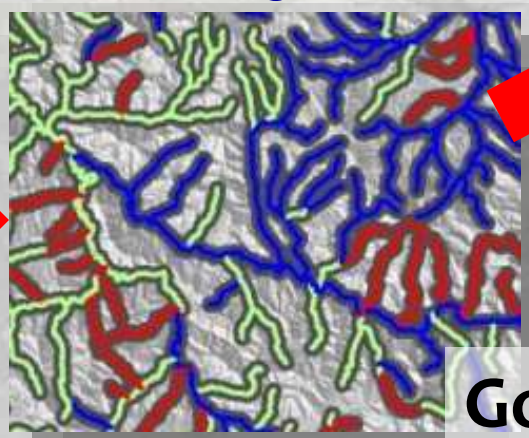


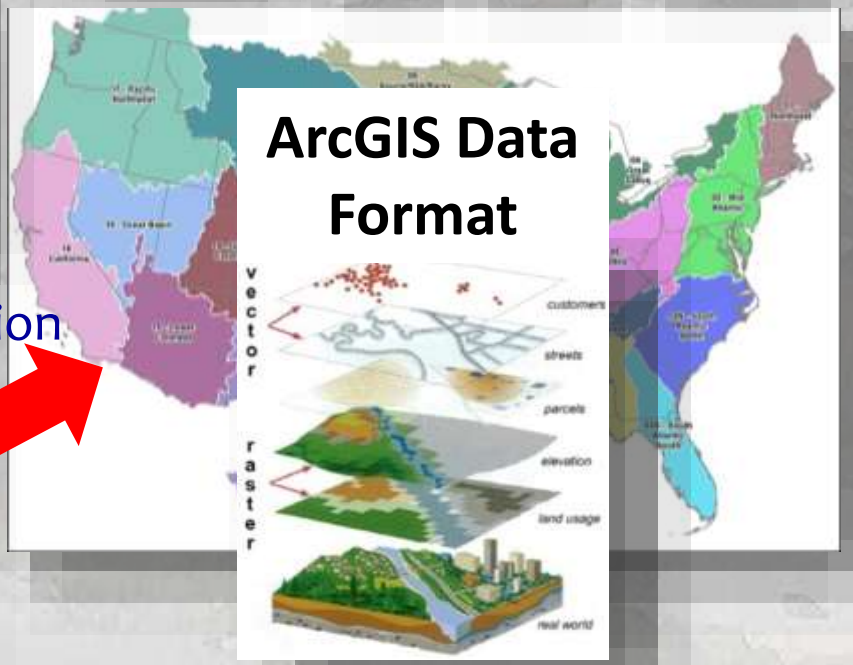
Website: VIC Streamflow Scenarios

Ecological Flow Metrics



NHD+ stream segment resolution



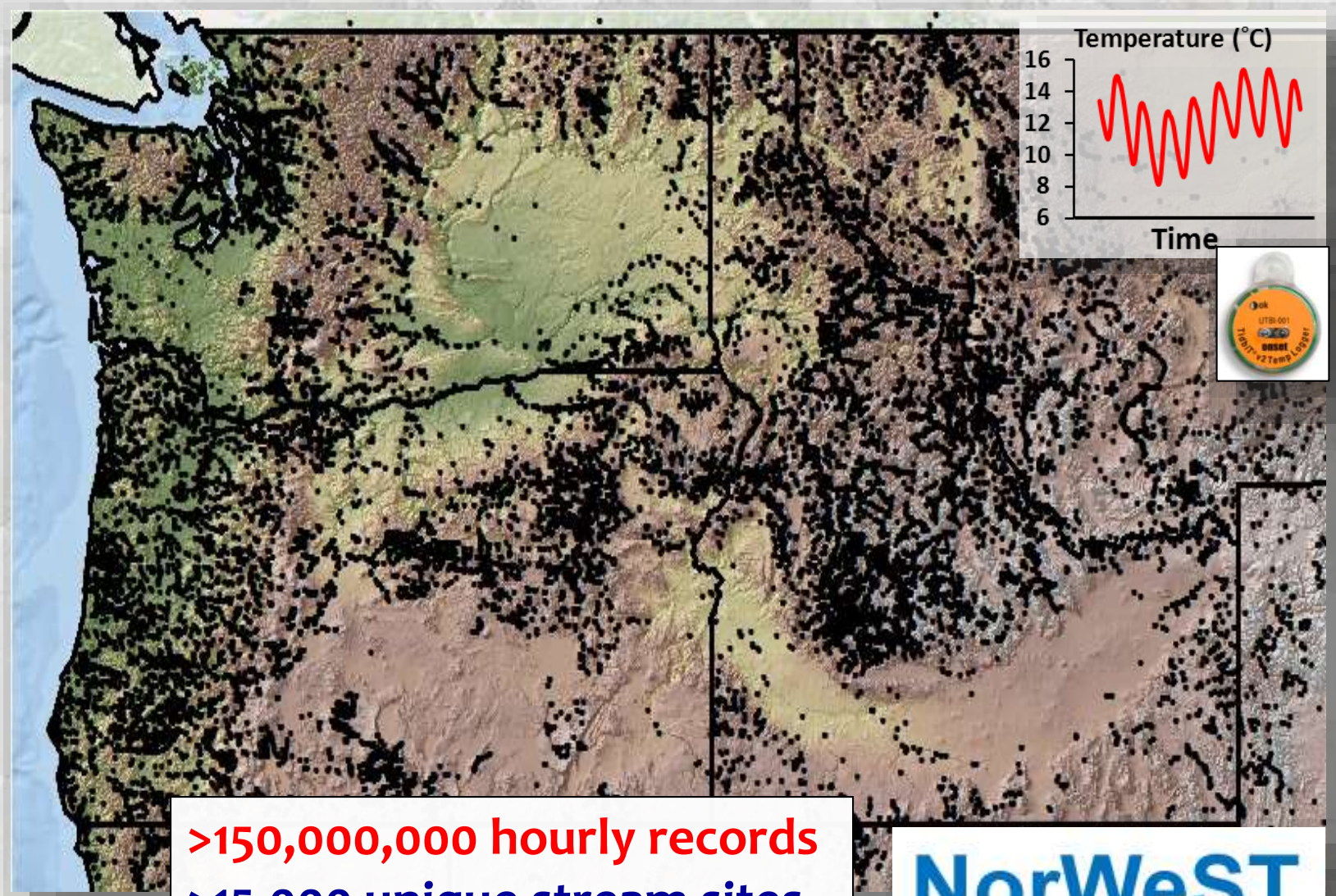


Google "Stream flow Metrics"

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

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

Stream & River Temperature Data



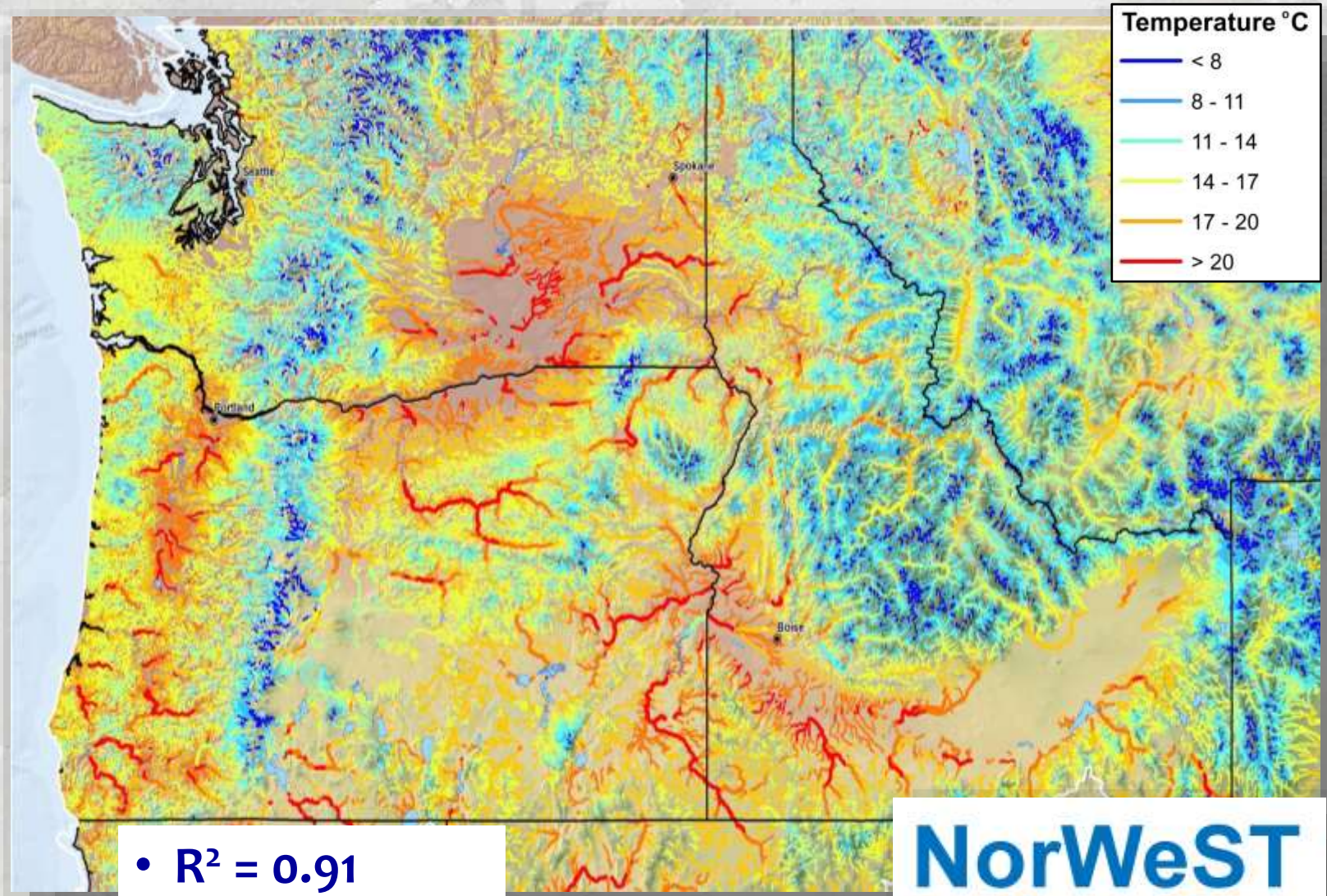
>150,000,000 hourly records

>15,000 unique stream sites

>100 resource agencies

NorWeST Stream Temp

High-Resolution Stream Scenarios

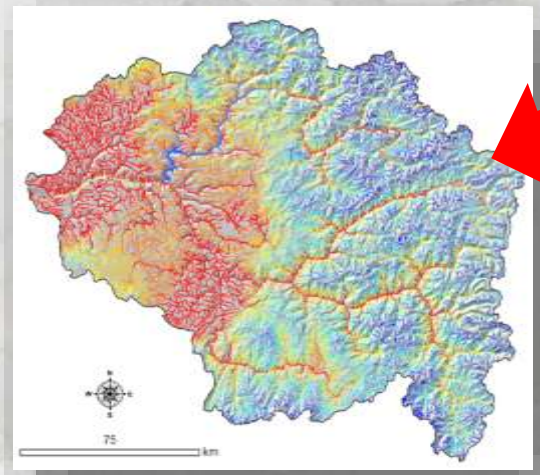


- R^2 = 0.91
- RMSE = 1.0°C

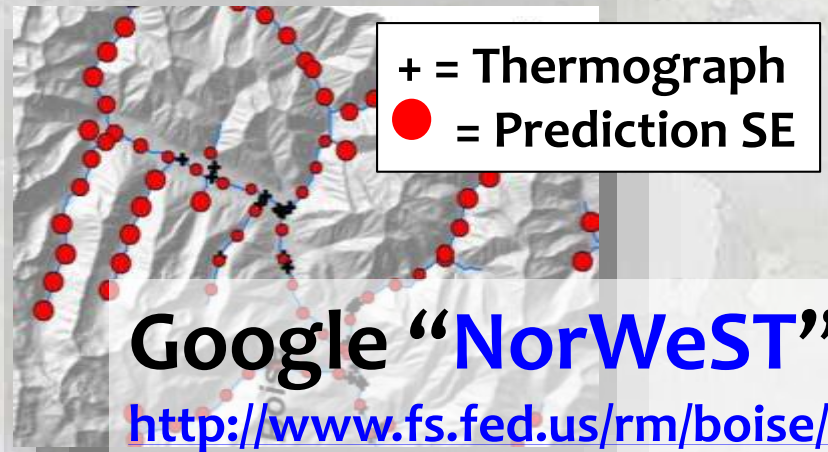
NorWeST Stream Temp

Website: Temperature Scenarios & Data in User-Friendly Formats

1) GIS shapefiles of stream temperature scenarios



2) GIS shapefiles of stream temperature model prediction precision



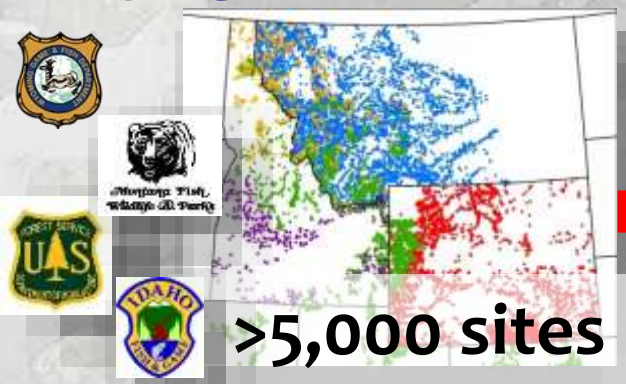
3) Temperature data summaries

Google "NorWeST" or go here...

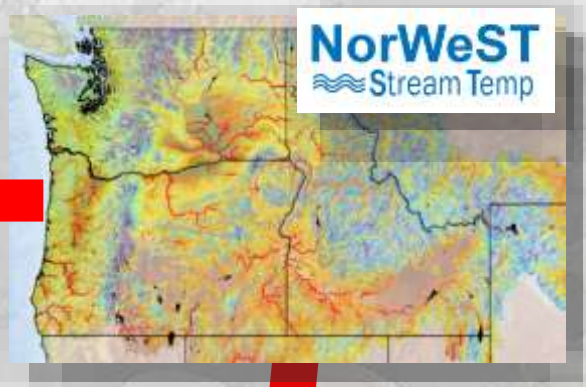
http://www.fs.fed.us/rm/boise/AWAE/projects/NorWeST.shtml

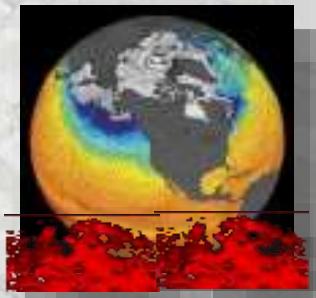
Stream Scenarios Enable Accurate Fish Distribution Models

BIG FISH DATA

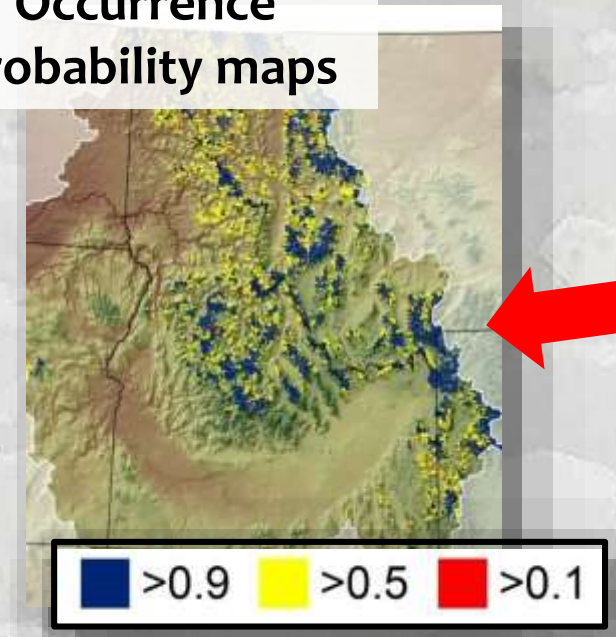


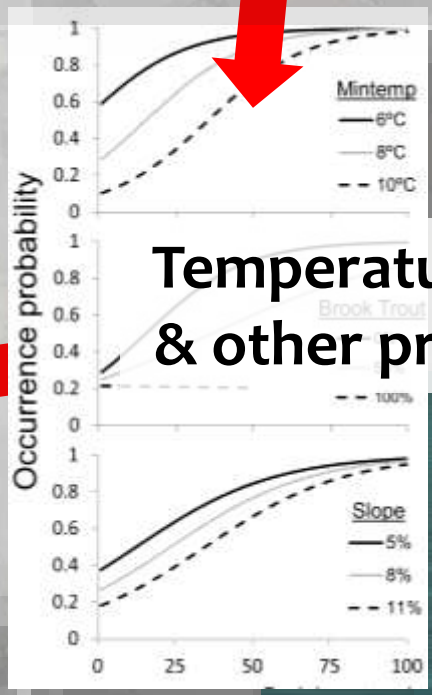
>5,000 sites





Occurrence probability maps





Climate Shield

Temperature, flow & other predictors

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

Bull Trout Climate Probability Map 1980s

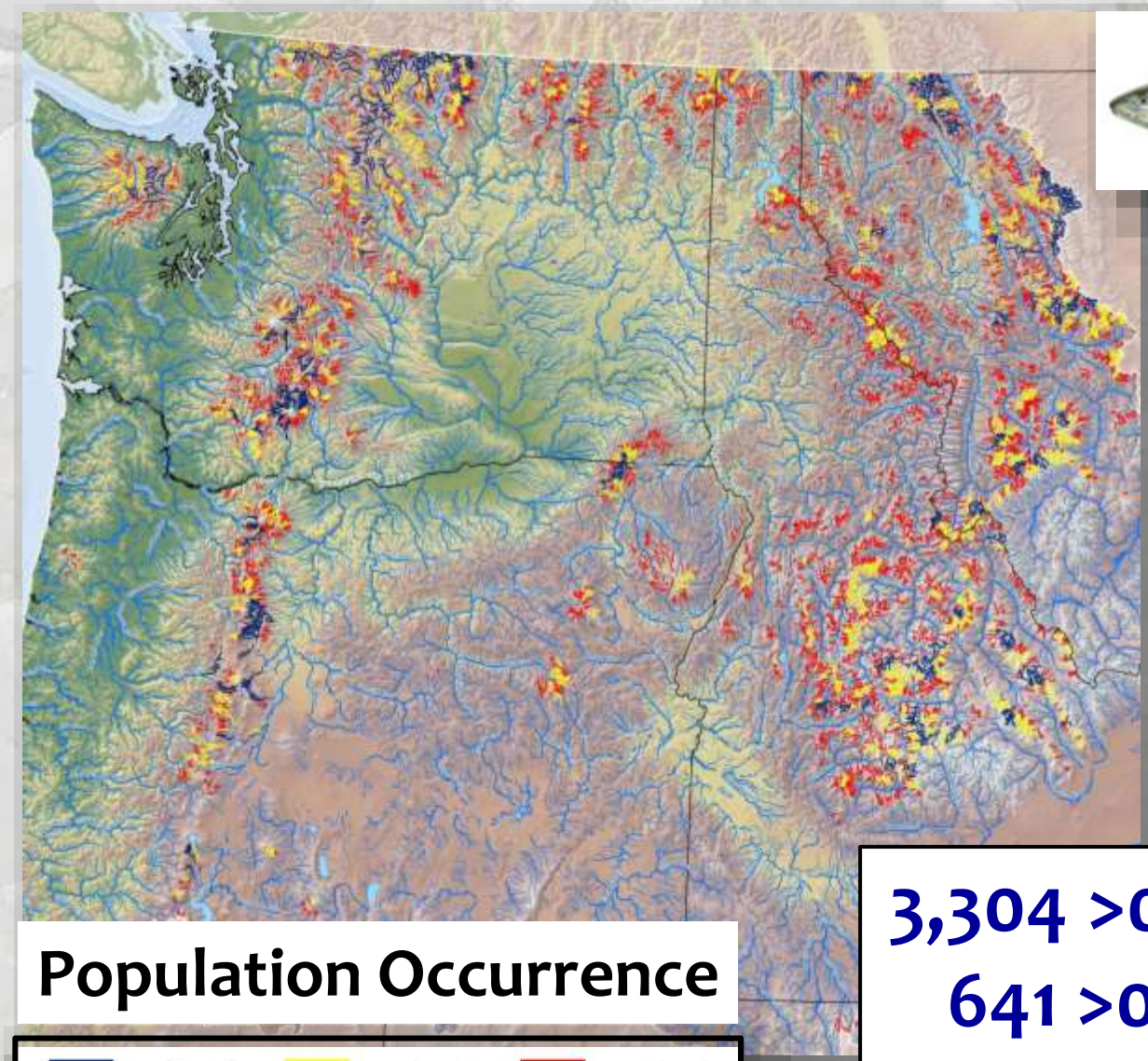
Stream population scale predictions

Population Occurrence

>0.9 >0.5 >0.1

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

Bull Trout Climate Probability Map 2040s

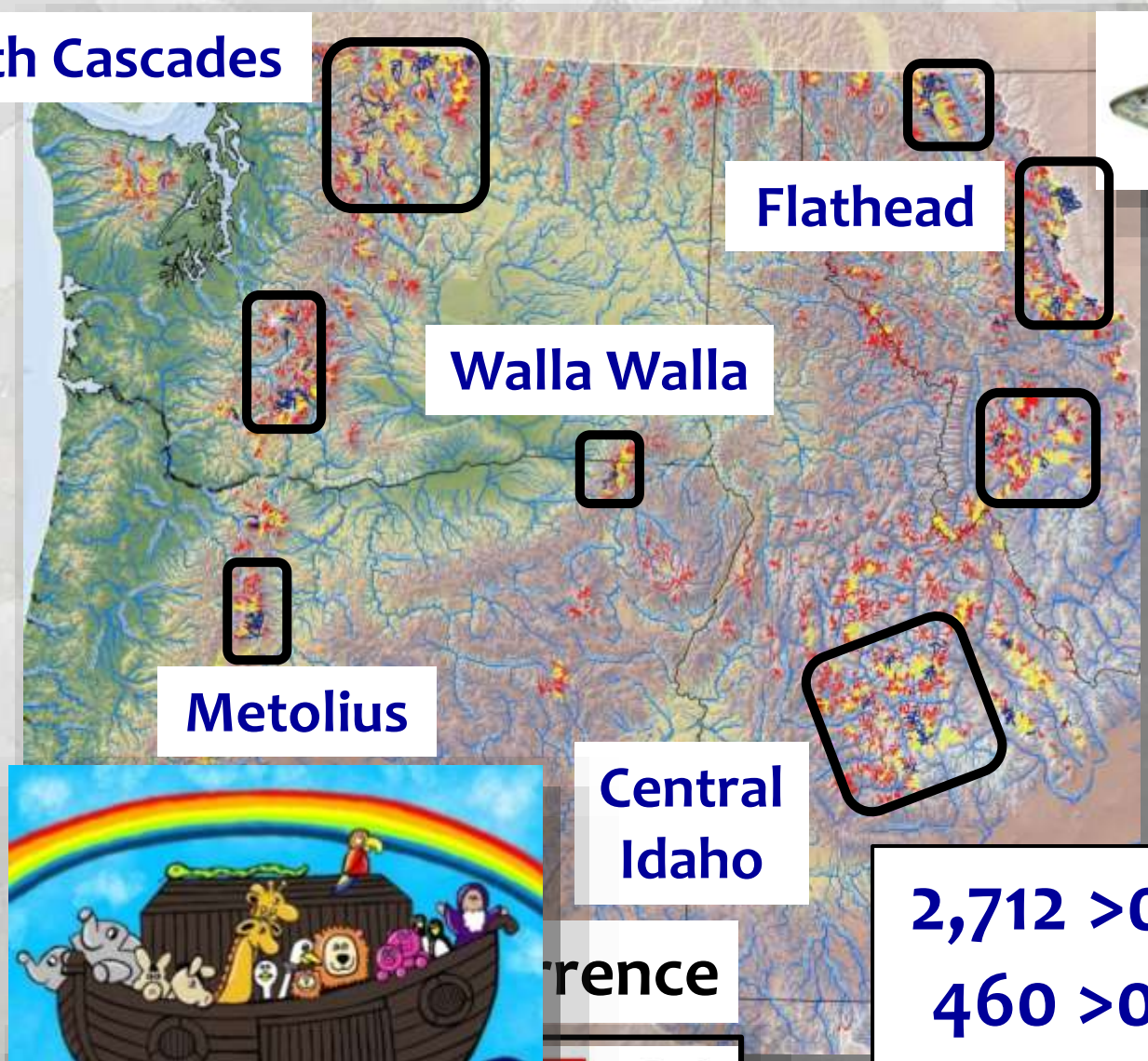


Population Occurrence

>0.9 >0.5 >0.1

3,304 >0.1 habitats
641 >0.5 habitats
130 >0.9 habitats

Bull Trout Climate Probability Map 2080s

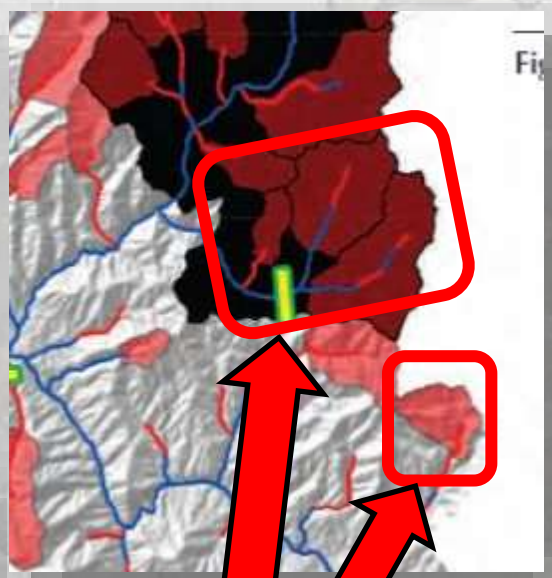


Extreme Change Scenario!

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

Many Conservation Investment Options Once we Know "Where"

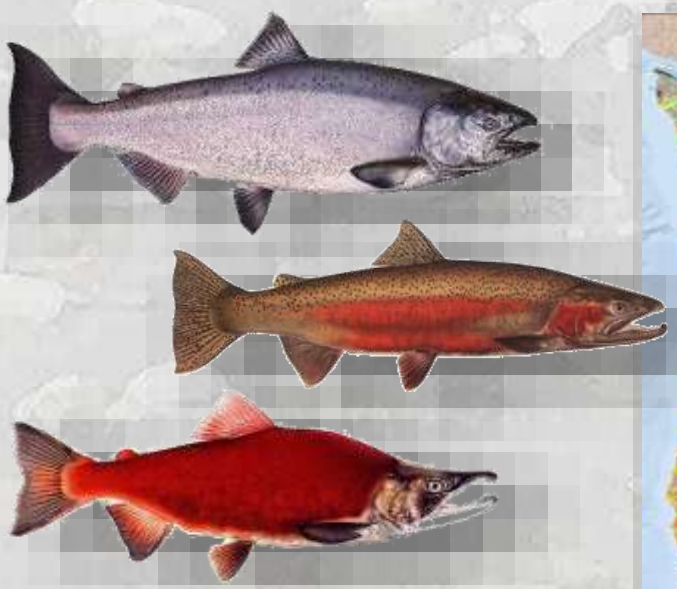
- Maintaining/restoring flow…
- Maintaining/restoring riparian…
- Restoring channel form/function…
- Prescribed burns limit wildfire risks…
- Non-native species control…
- Improve/impede fish passage…

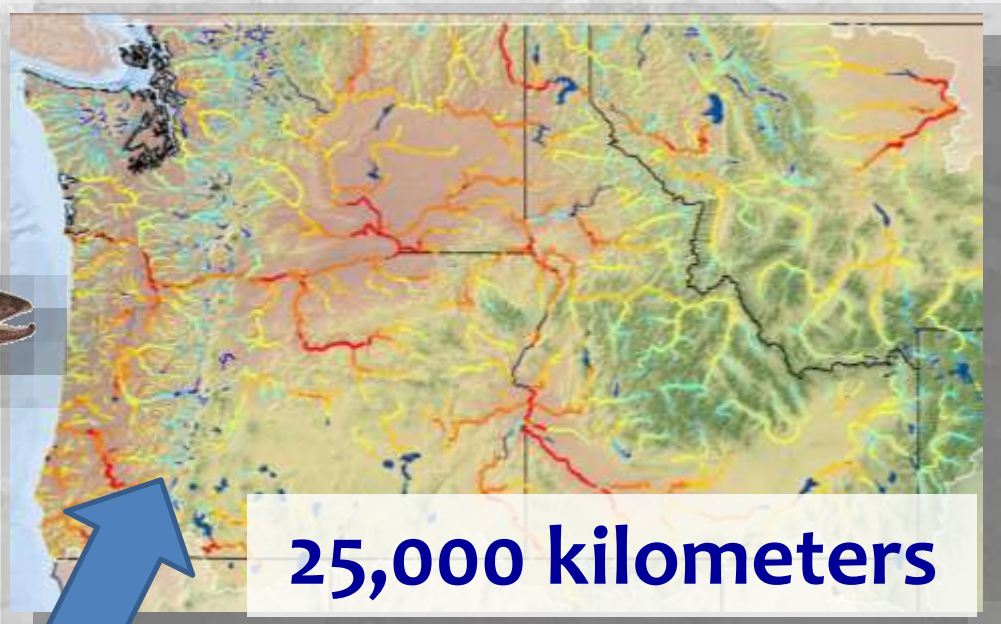


I'm going to invest here…

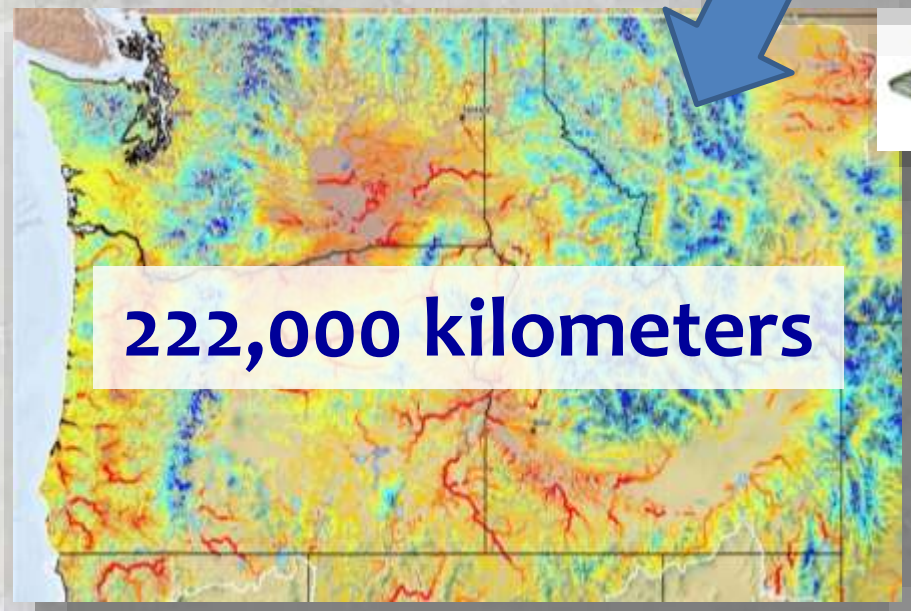
…not here

Refuge Concept for Big Fish in Big Rivers





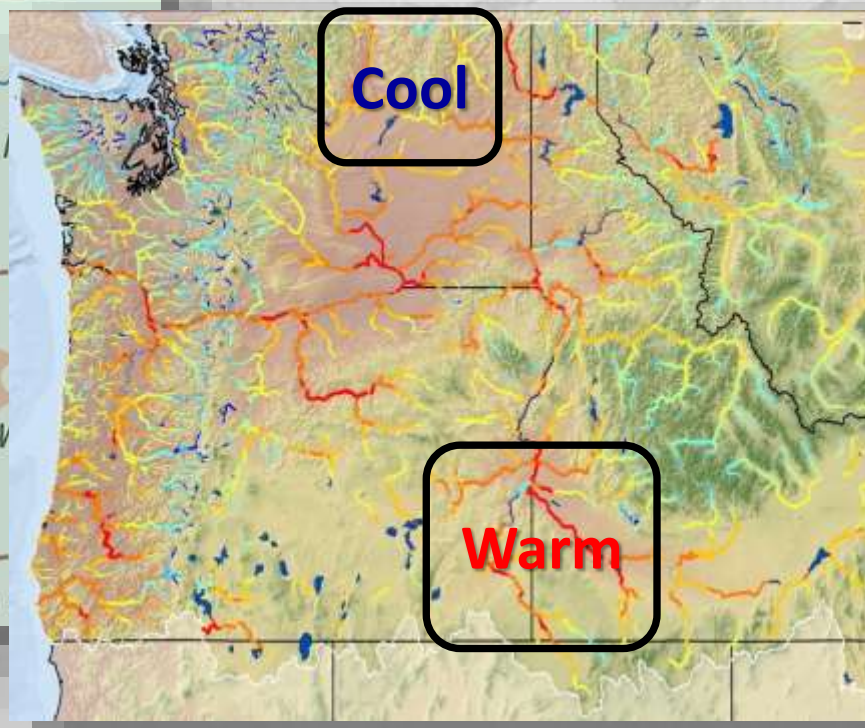
25,000 kilometers



222,000 kilometers

- Abundant high elevation refuges
- Body size not limiting
- Life cycle includes small areas

Large Scale: Some Cool Salmon Rivers Blocked



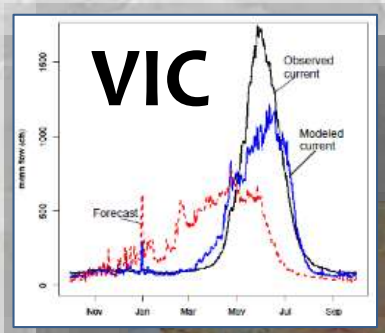
Small scale: Cold Micro-refugia are Migration Waypoints Why Not Map Them all in PNW Rivers?

Technology exists & is becoming cheaper…

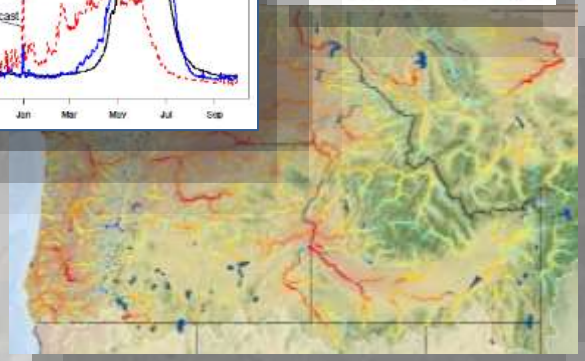
Drone mounted cameras

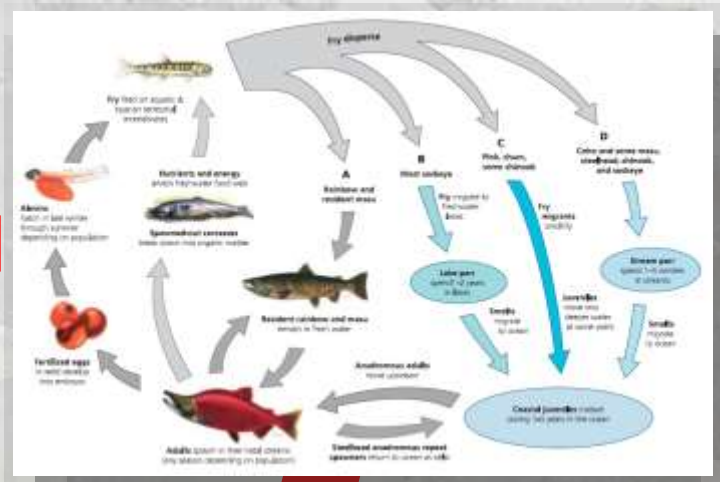
Torgersen et al. 1999; 2012

Integrate Salmon Models & Data with Stream Climate Scenarios



NorWeST Stream Temp



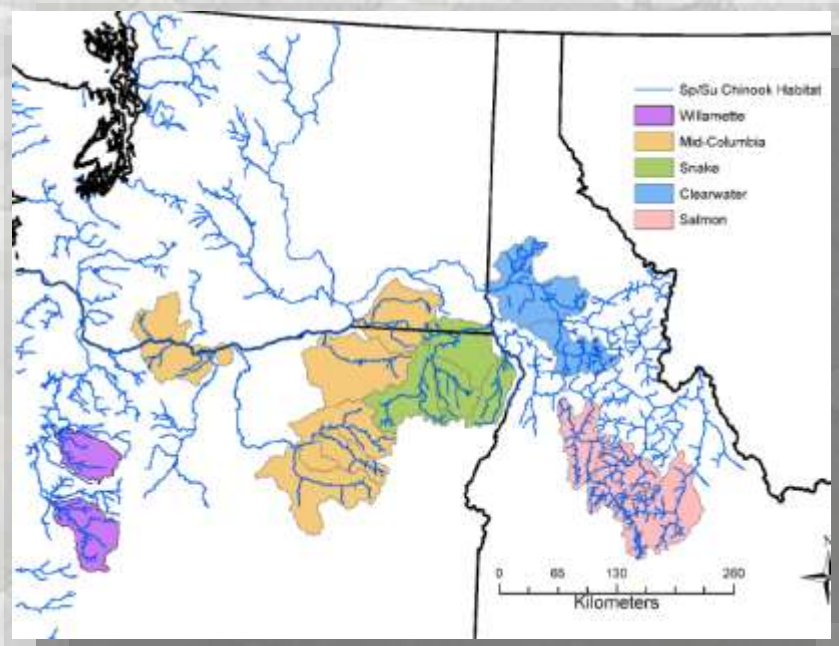


Yes

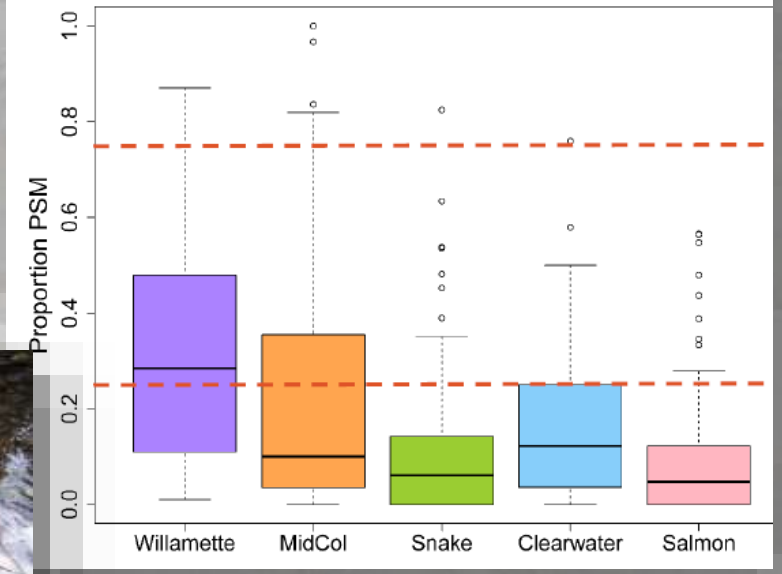
NO

Spatially explicit predictions for investment planning…

An Example Pre-Spawn Mortality

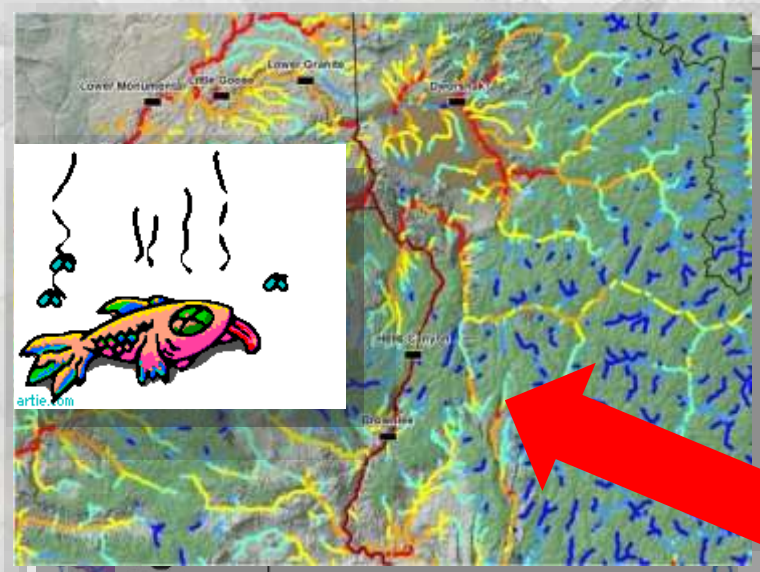


450 site years of PSM data
8 different agencies
3 ESUs



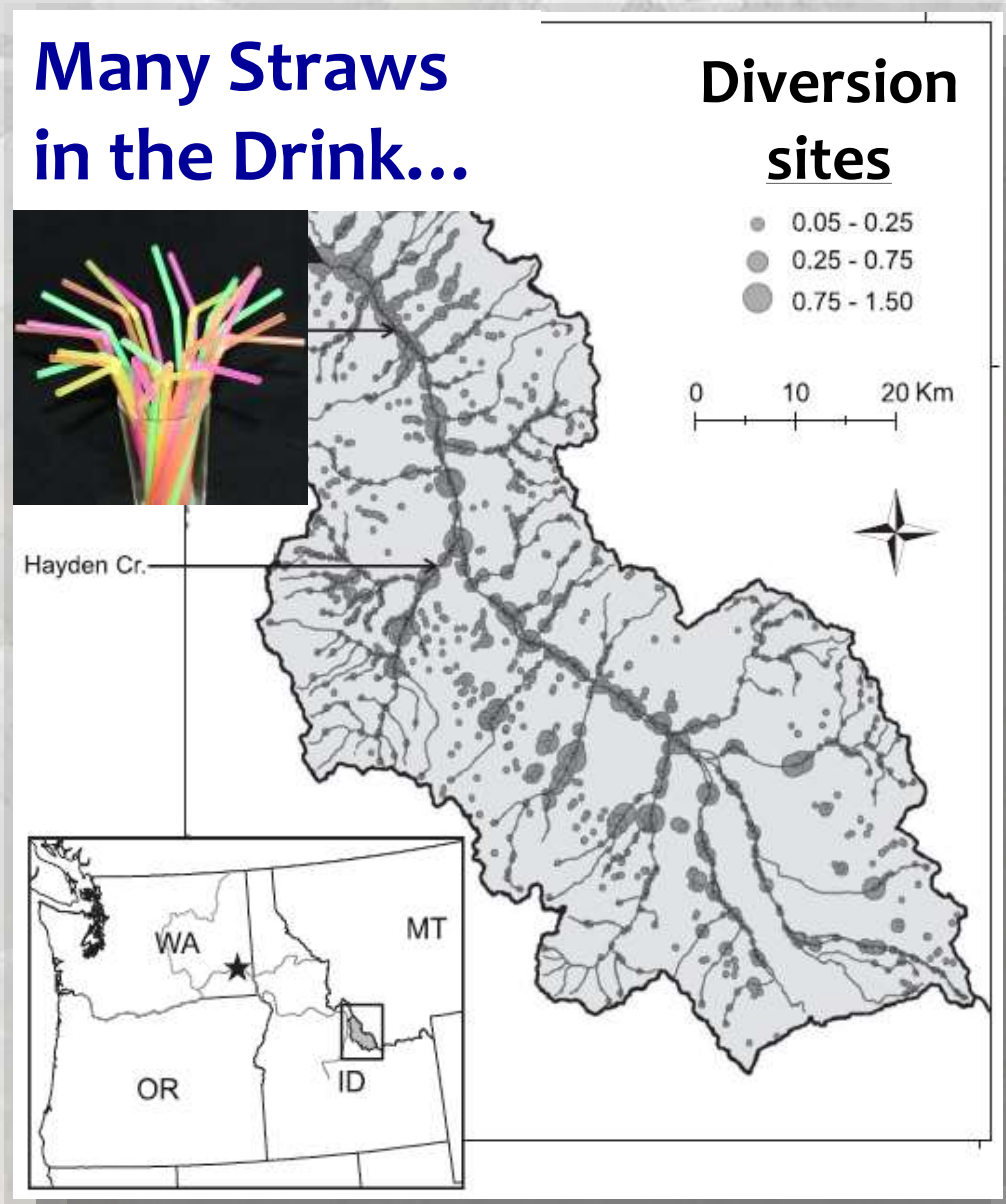
Bowerman, Keefer, & Caudill (U. Idaho)

An Example Pre-Spawn Mortality



More Summer Water Keeps Streams Cooler

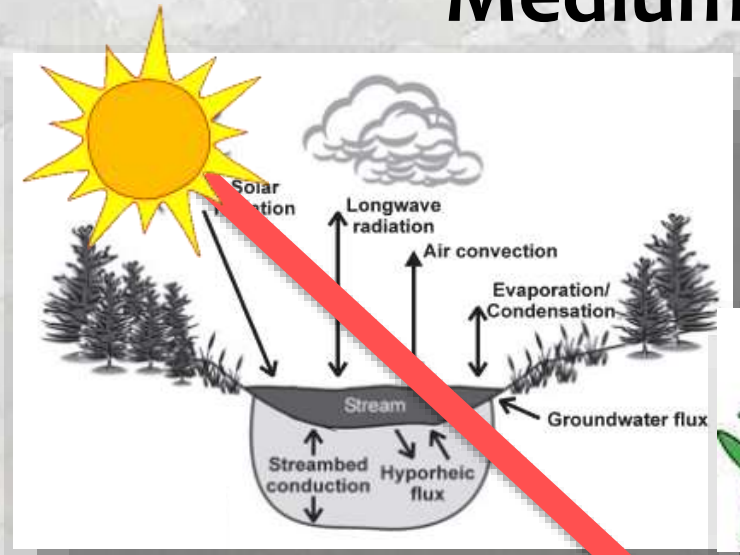
Many Straws in the Drink…



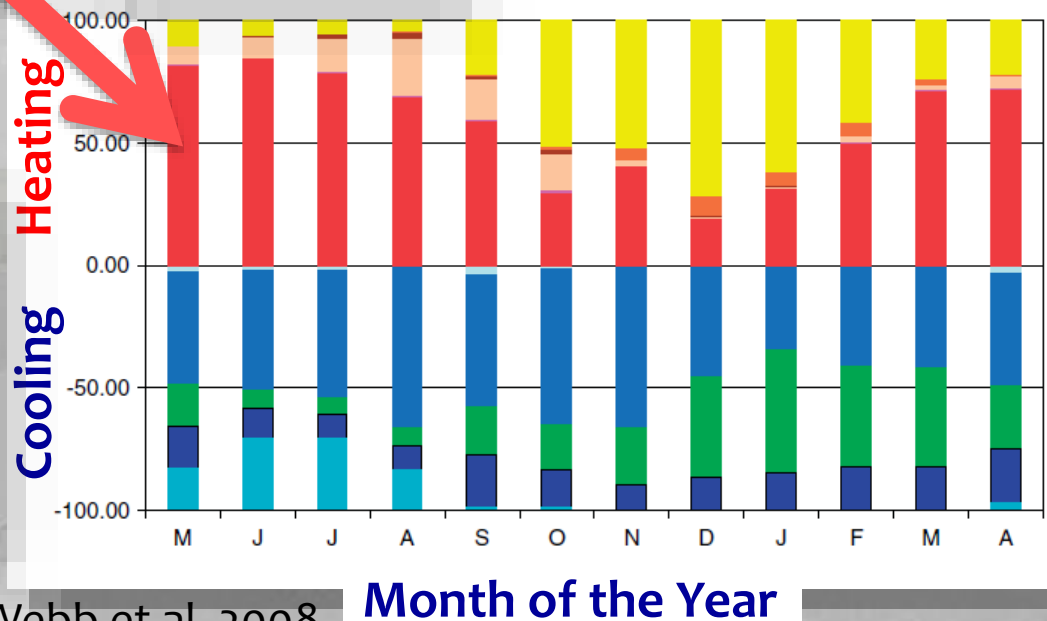
Modernize Water Systems…

Purchase Water Rights

Riparian Restoration to Cool Small & Medium Sized Salmon Rivers

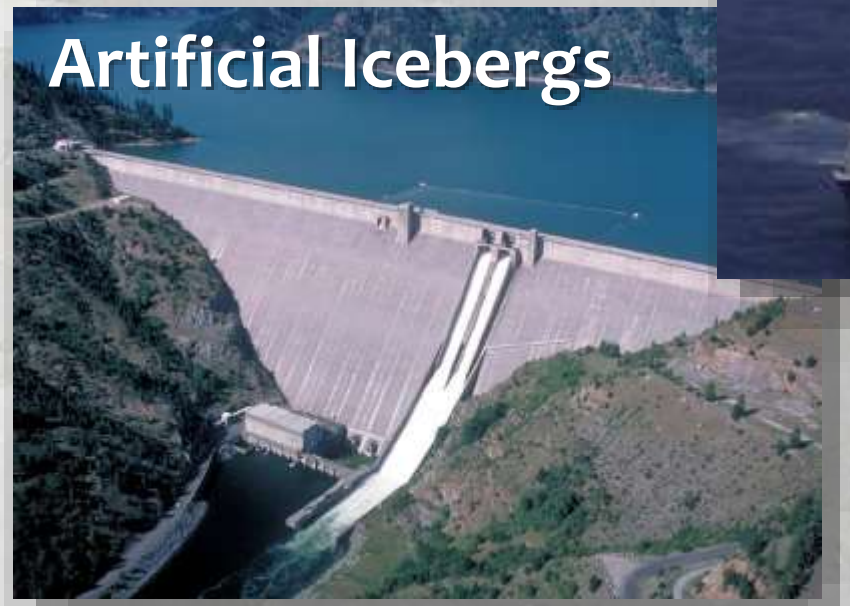


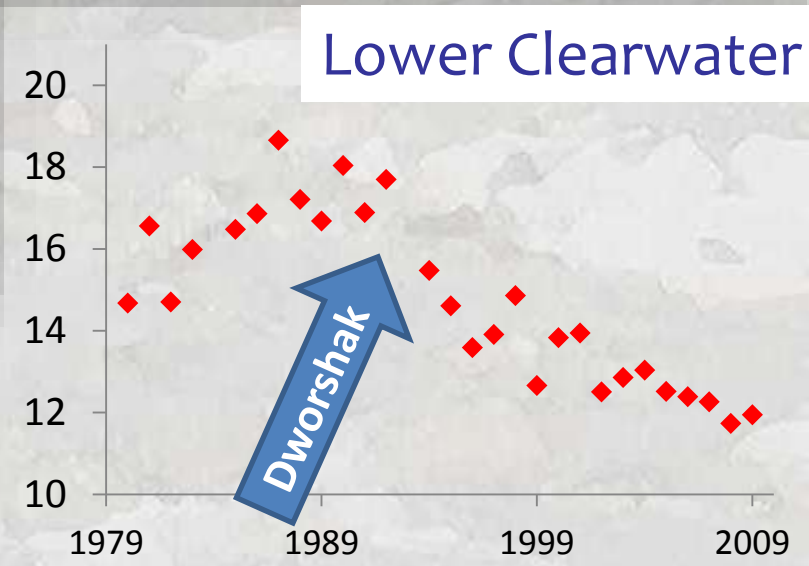
Shading is THE most important factor…



Webb et al. 2008

Options for Cooling Largest Rivers are Limited…

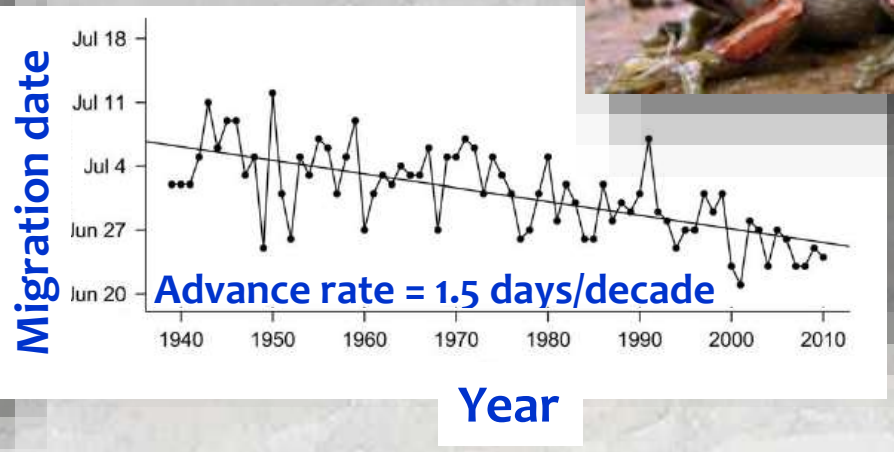




- Deep reservoir needed for cold water creation

Accelerate Evolution?

Hatchery selection of migration timing

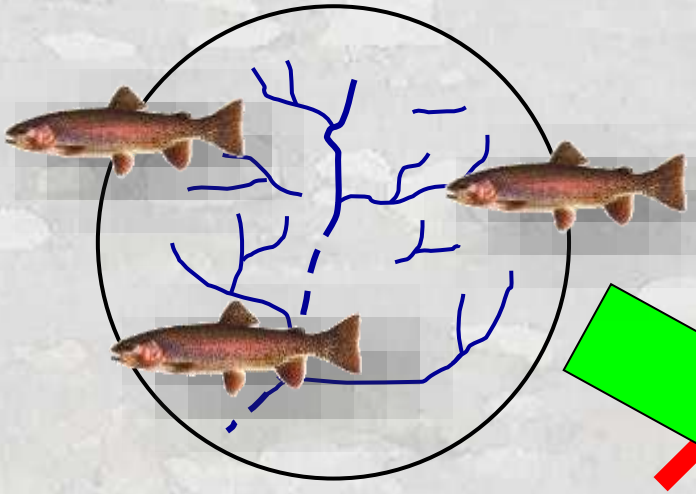


Trait	Evolutionary Potential
Heat tolerance	Low
Disease resistance	Low to moderate
Upstream migration timing	High
Spawning date	High
Emergence date	Low
Juvenile growth	Low
Downstream migration timing	?
Ocean residence	?

Crozier et al. 2008

Adjust our Mindset…

We can't save everything, everywhere

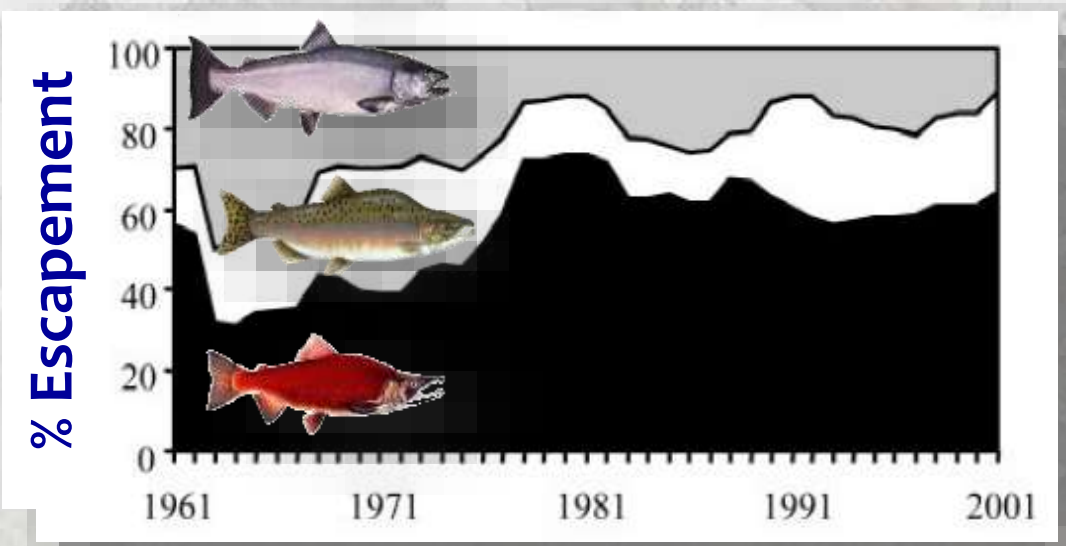


Sorry Charlie

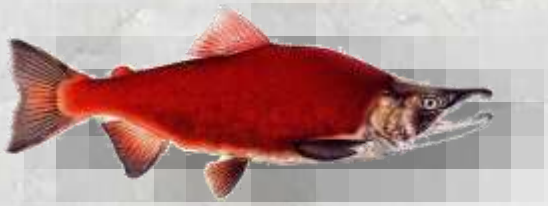
Don't feed the zombies

Biocomplexity Will Provide a Buffer

Extinction is unlikely…



…But some species (or runs) may experience long-term declines



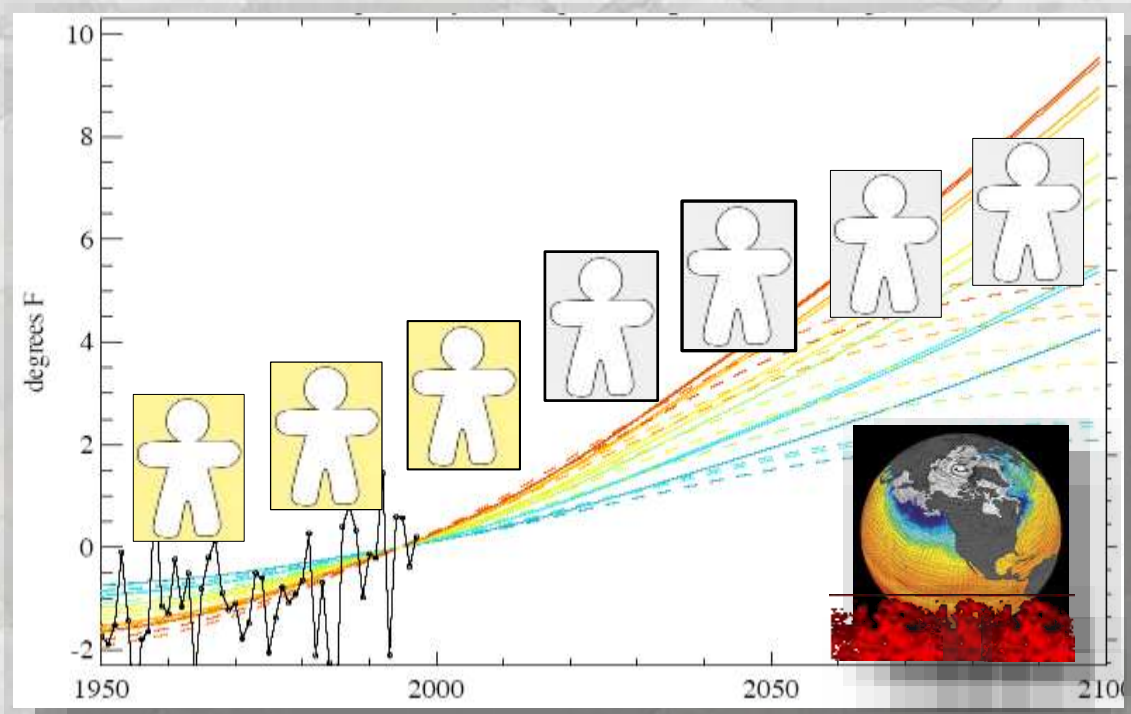
Summer runs

Fall/winter runs

Inter-Agency, Collaborative Spirit will Be Needed…

PNW is a World Leader

Inter-Generational Commitment



This can be our Finest Century