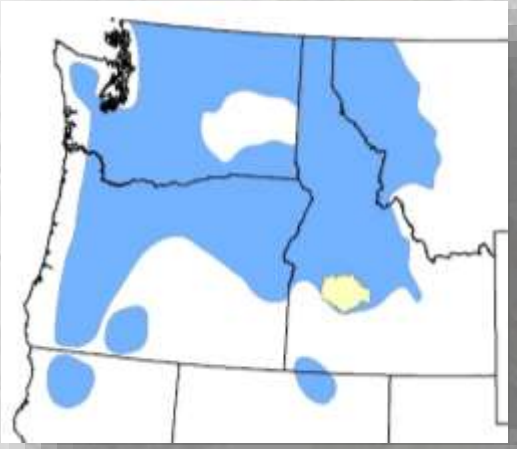
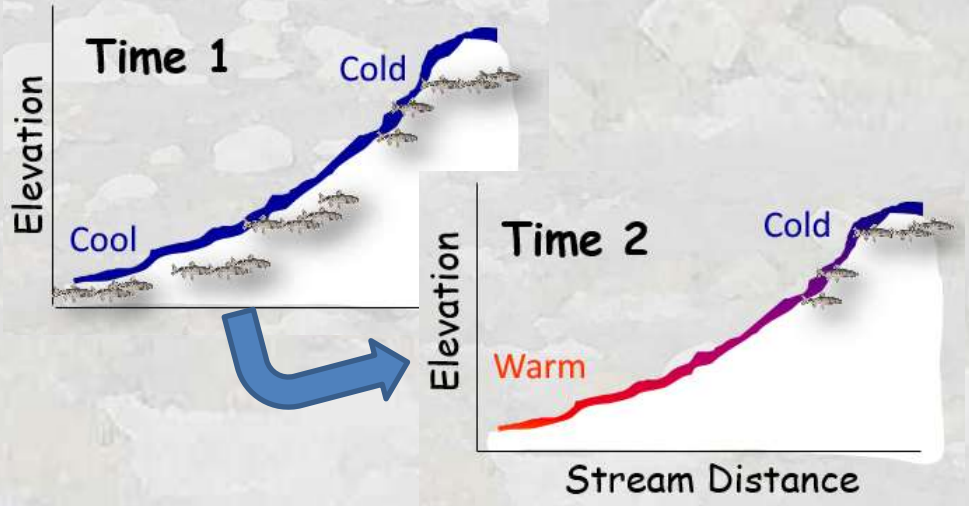
Bringing it All Together: Where to Prioritize Flow Restoration for an ESA Listed Fish?

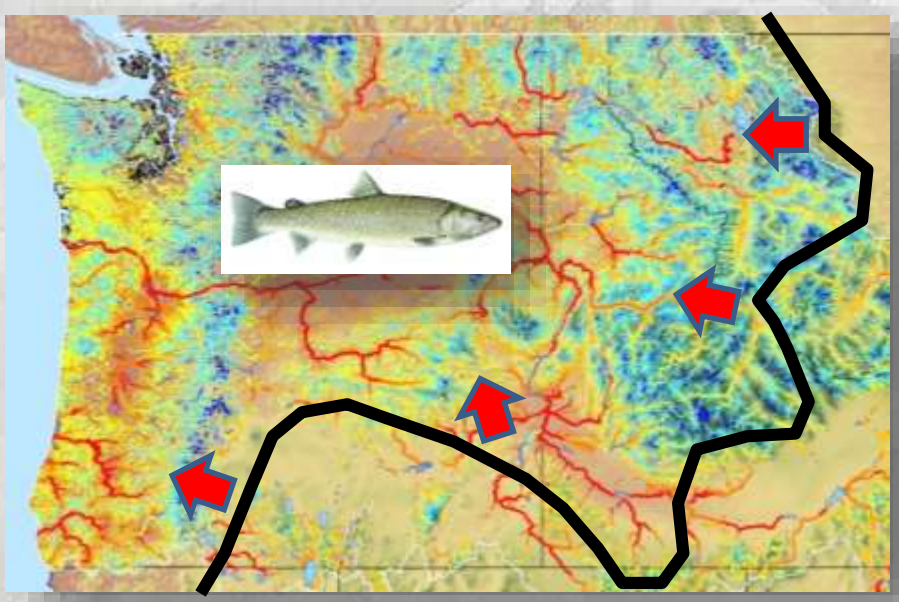


- Bull trout ESA listed as threatened in 1997
- Occurs at low densities throughout PNW
- Is climate/drought sensitive & restricted to cold headwaters
- Requires large interconnected habitat networks to persist
- Distribution is contracting as droughts & temperature increase

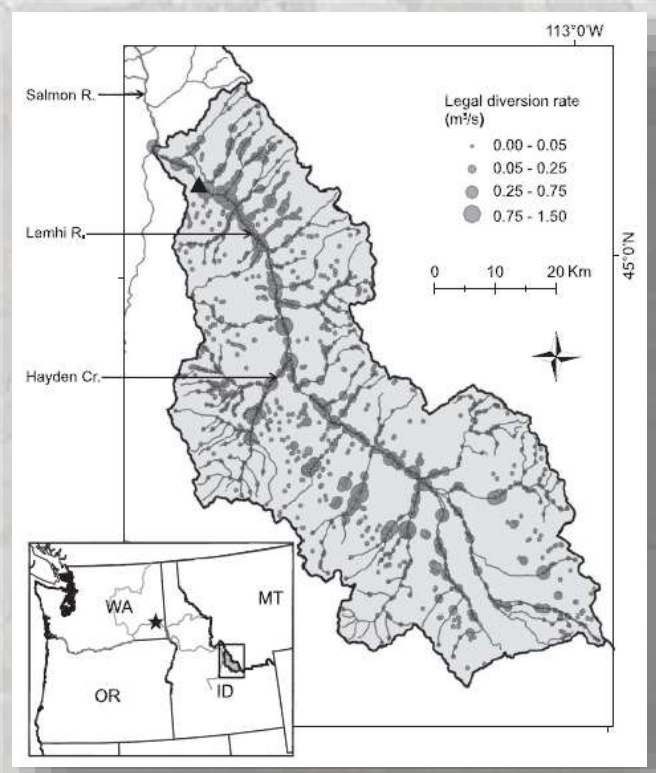


A Seemingly Overwhelming Task

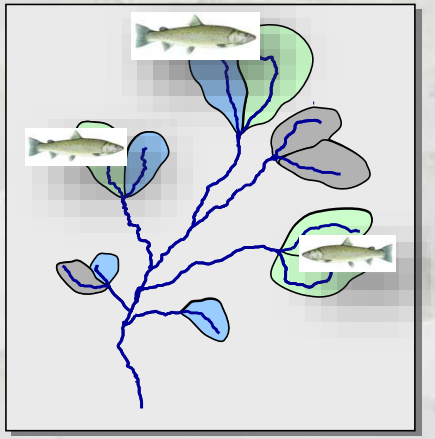
384,000 kilometer network of streams



Thousands of small water diversions



Local occurrence of bull trout often uncertain



Walters et al. 2013. *Conservation Biology* **27**:1179-1189

How to Maximize Returns on Investments

Where to invest?

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

Step 1. Filter NHD to Match Species Range (i.e., define the universe)

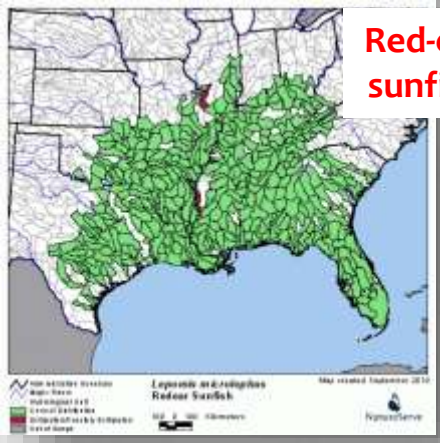
Download NHD Streamlines

- NatureServe watershed polygons
- Peer-reviewed literature
- Agency surveys

Rainbow trout

Brook trout

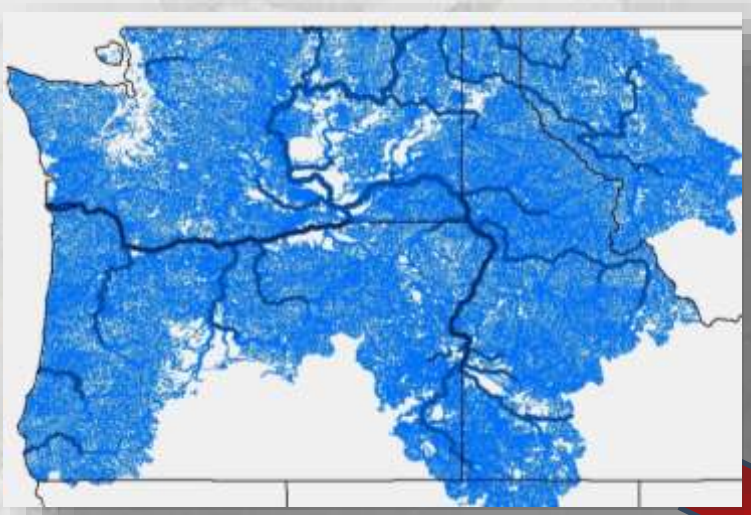
Red-ear sunfish



Well-known for popular species
Fuzzy for many others

Step 2. Filter NHD Based on Species Habitat Thresholds (i.e., refine the universe)

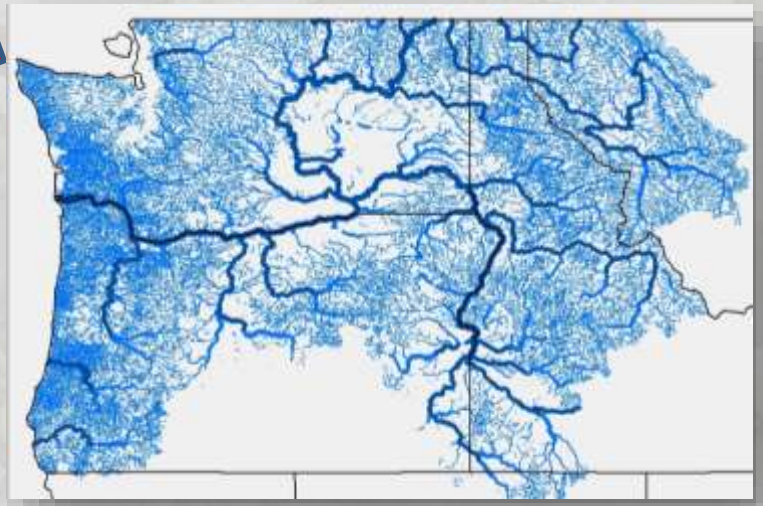
Initial network: 384,000 km of NHD streams in bull trout range



Bull trout don't occur where:

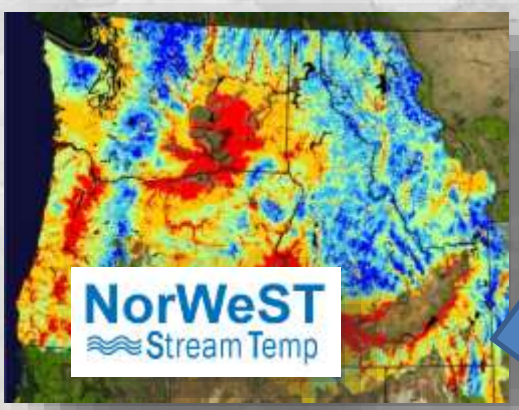
- Reach slope > 15%
- Mean flow < 1 cfs
- Flows are intermittent (NHD Fcode = 46003)

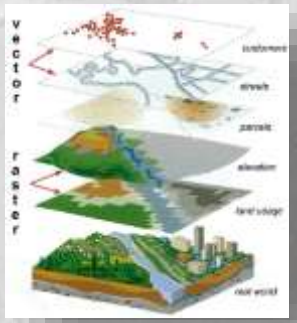
Refined network: 158,000 km of potential streams



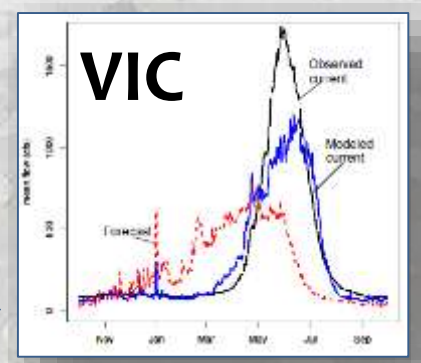
Step 3. Attribute Remaining NHD Reaches with Relevant Habitat Descriptors

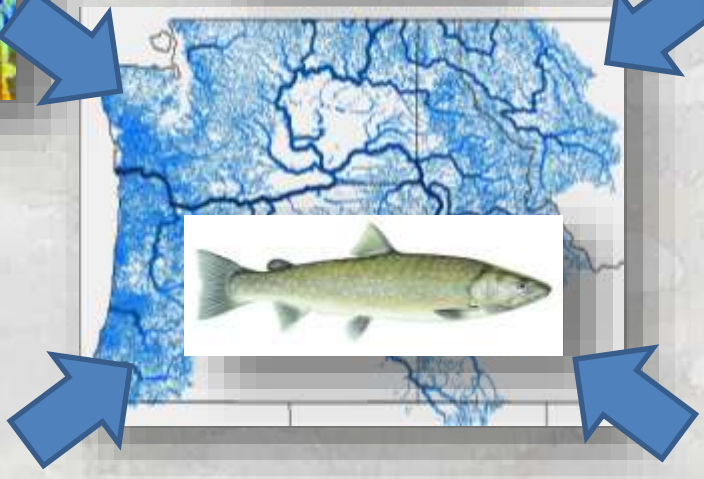
Thermal metrics





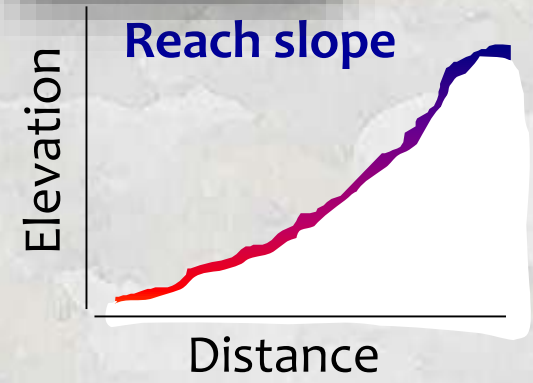
Flow metrics



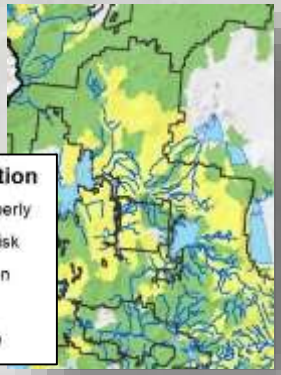


NHDPlus

Reach slope

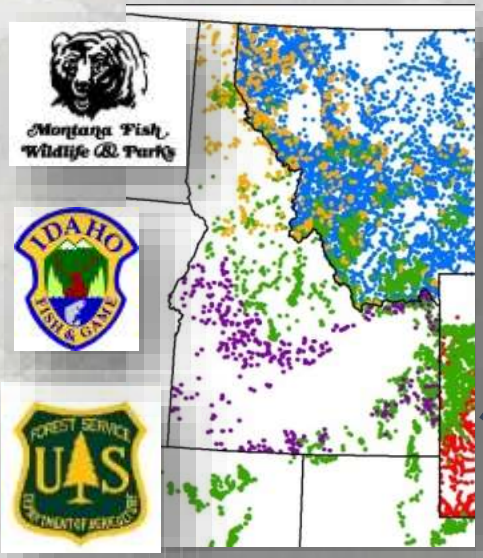


Watershed conditions (StreamCat)



Step 4. Attribute NHD Reaches With Relevant Biological Data (species occurrence/abundance)

Existing databases (MFISH, MARIS, eDNAtlas, etc.)



4,500 reach samples

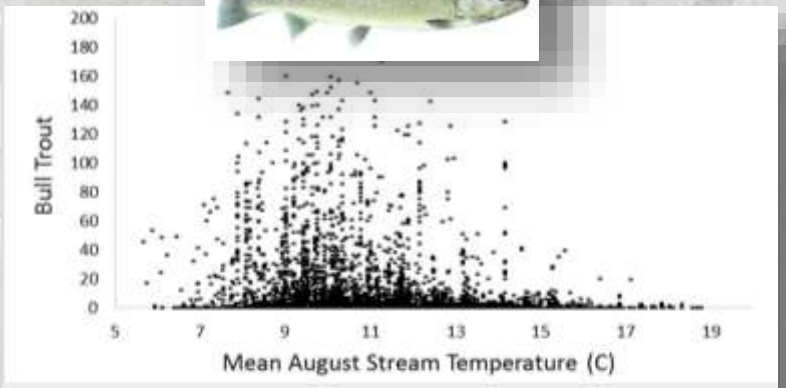
512 streams

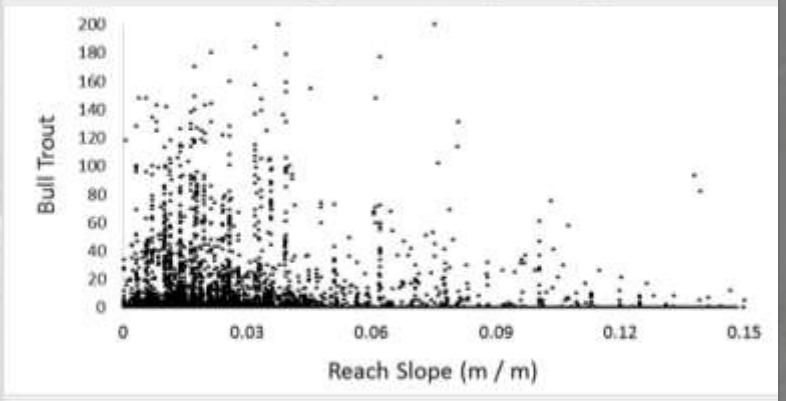
Target species

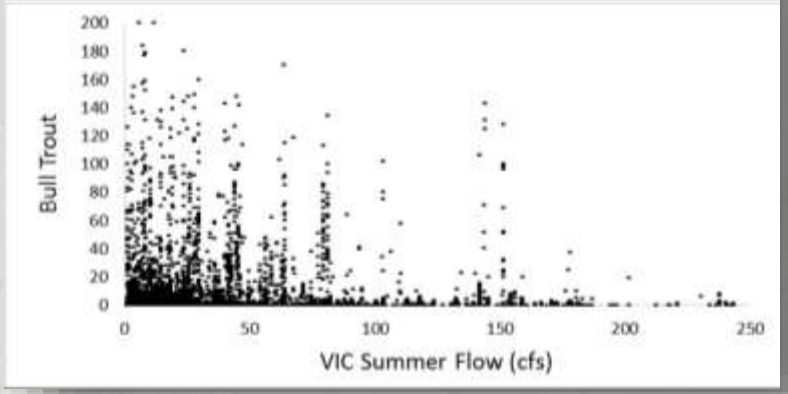
But also invasive species / competitors

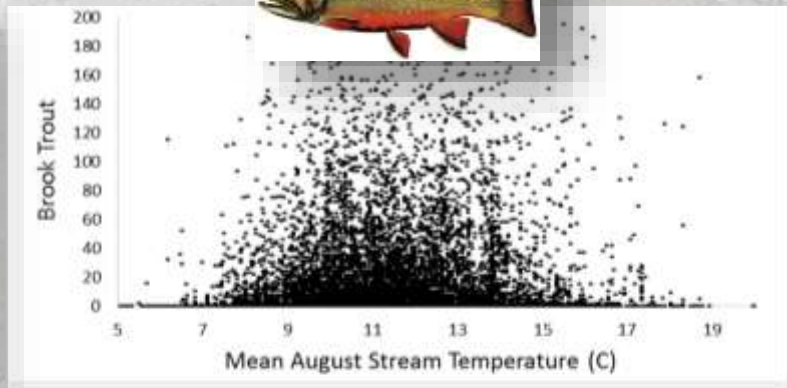
eDNA sampling campaign to collect new data

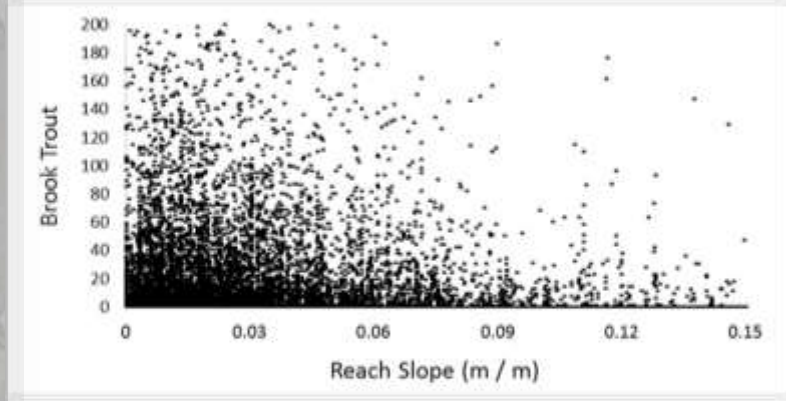
Step 5. Data Summaries and Visualization

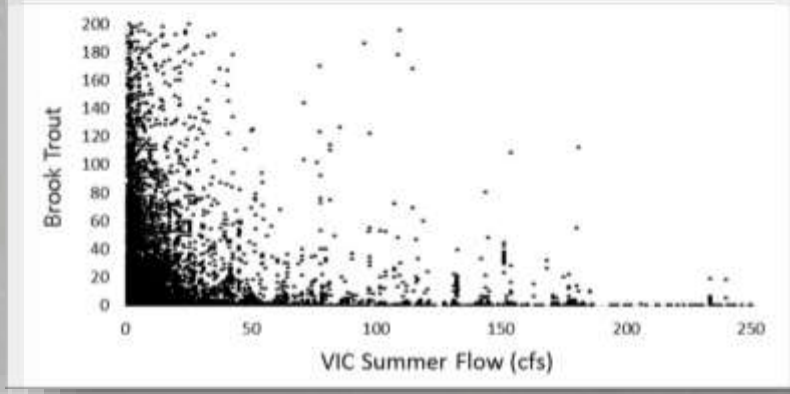






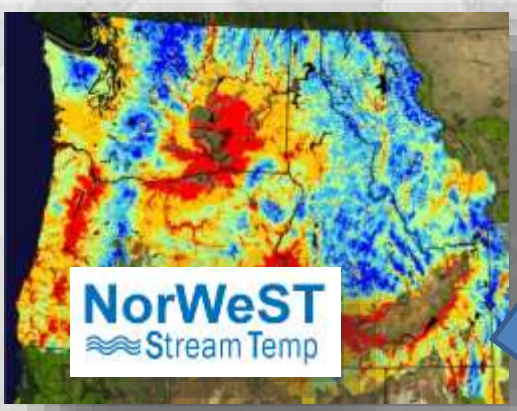






Step 6. Model Building to Assess Covariate Effects and Develop Predictive Relationships

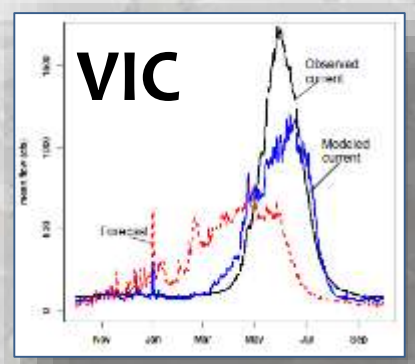
Thermal metrics



Models types:

- SSNs
- MaxEnt
- GLMM
- GLM
- Random forests

Flow metrics

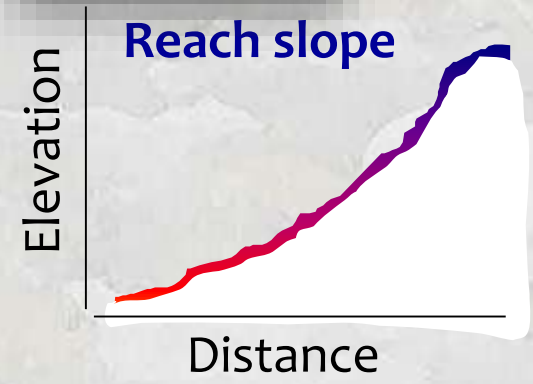


$$p = \frac{\exp(a + bx \ldots ny)}{(1 + \exp[a + bx \ldots ny])}$$

Watershed conditions (StreamCat)

NHDPlus

Reach slope



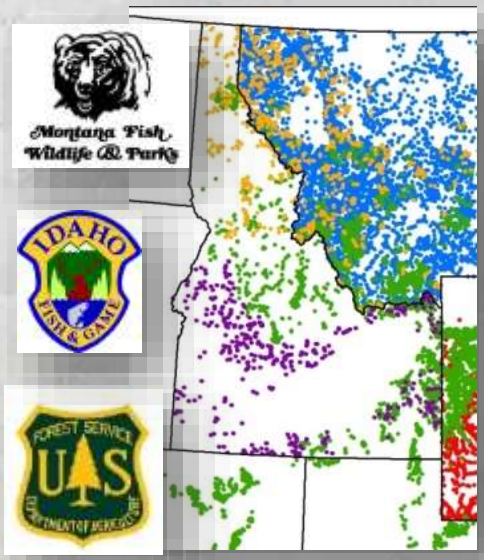
Step 7. Model Response Curves Describe Relationships & Enable Sensitivity Analysis

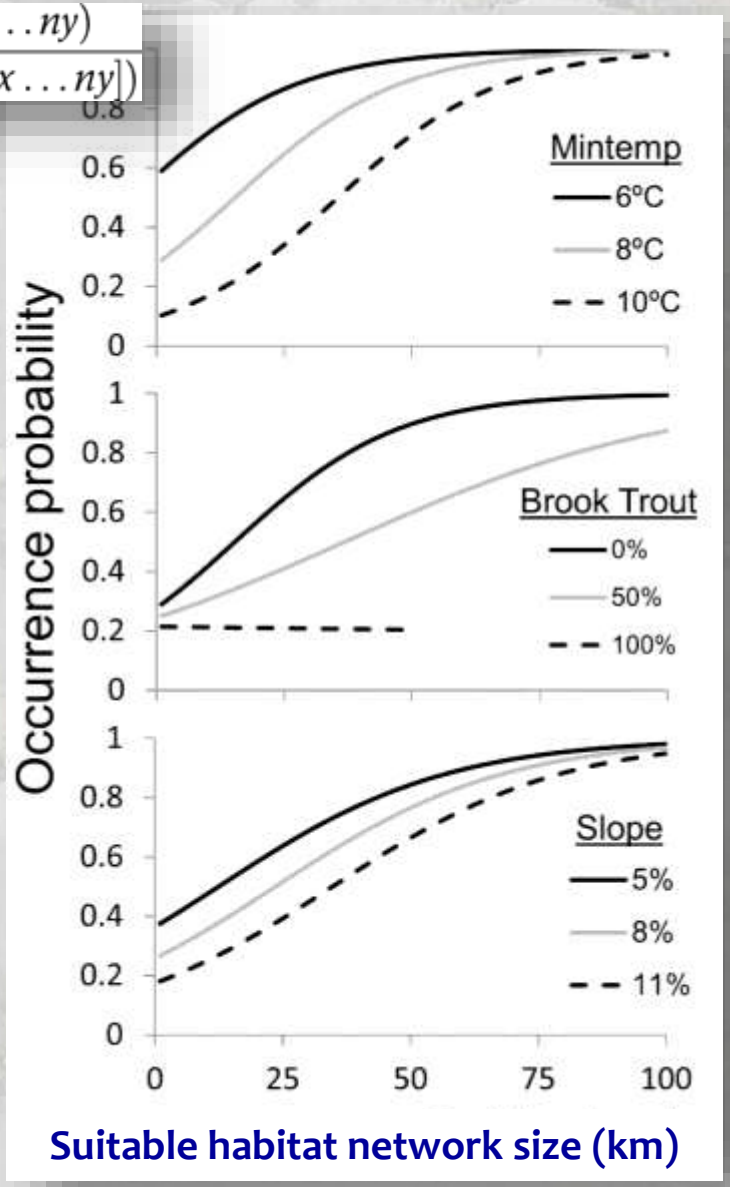
$$p = \frac{\exp(a + bx \ldots ny)}{(1 + \exp[a + bx \ldots ny])}$$

78% stream classification accuracy

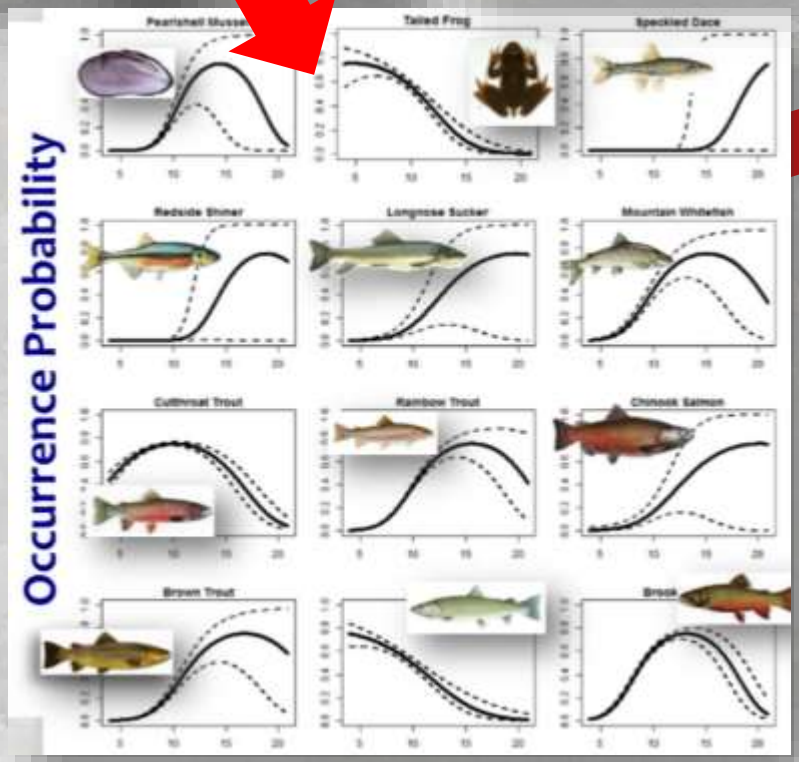
4,500 reach samples

512 streams





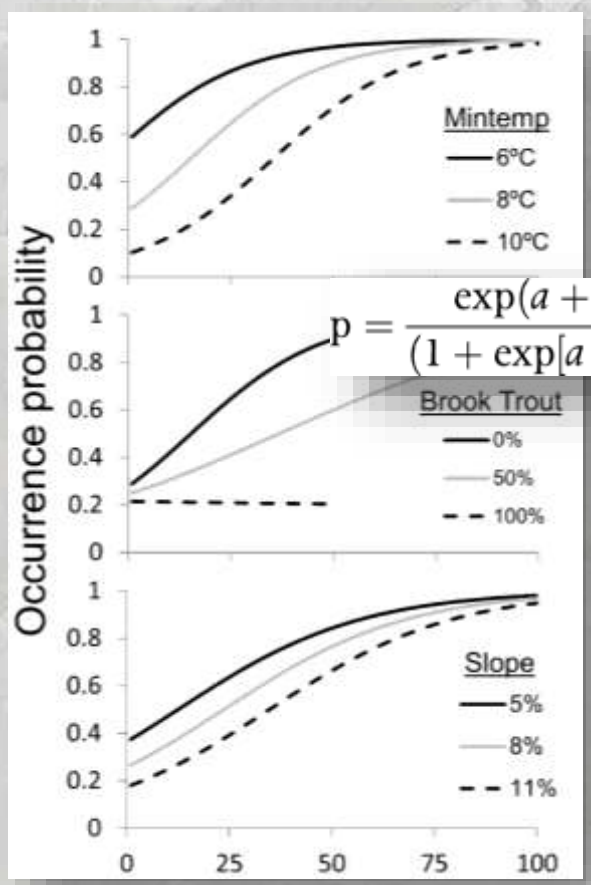
Process is Repeatable With Many Species



Species and model	AUC	ΔAIC
Longnose dace		
Simple	0.86	37
Multivariate	0.87	0
Speckled dace		
Simple	0.92	8
Multivariate	0.93	0
Redside shiner		
Simple	0.91	33
Multivariate	0.93	0
Longnose sucker		
Simple	0.81	65
Multivariate	0.86	0
Mountain whitefish		
Simple	0.76	380
Multivariate	0.90	0
Cutthroat trout		
Simple	0.56	37
Multivariate	0.56	0
Rainbow trout		
Simple	0.75	243
Multivariate	0.83	0
Chinook salmon		
Simple	0.62	63
Multivariate	0.73	0
Brown trout		
Simple	0.69	158
Multivariate	0.73	0
Bull trout		
Simple	0.60	474
Multivariate	0.75	0
Brook trout		
Simple	0.57	191
Multivariate	0.63	0
Slimy sculpin		
Simple	0.67	17
Multivariate	0.73	0
Rocky Mountain tailed frog		
Simple	0.65	4
Multivariate	0.65	0
Columbia spotted frog		
Simple	0.63	0
Multivariate	0.64	3

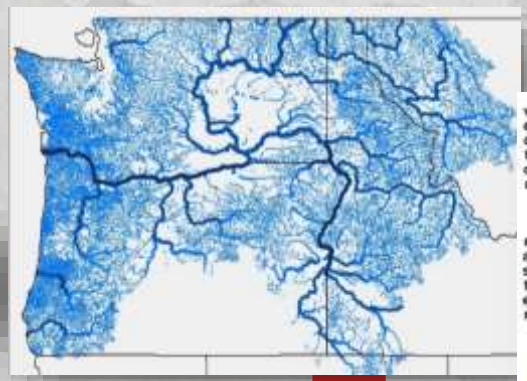
Isaak et al. 2017. Big biology meets microclimatology. *Ecological Applications.* **27**:977-990.

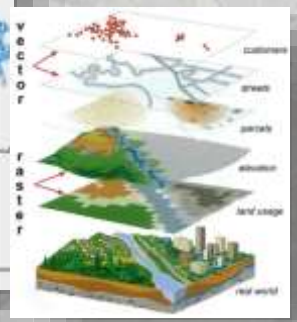
Step 8. Map Species Occurrence Probabilities Back to Stream Network

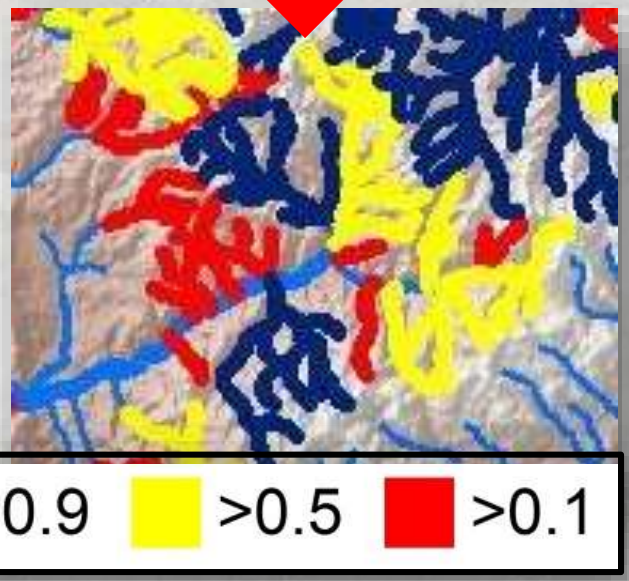


$$p = \frac{\exp(a + bx \ldots ny)}{(1 + \exp[a + bx \ldots ny])}$$

Habitat descriptors are geospatial





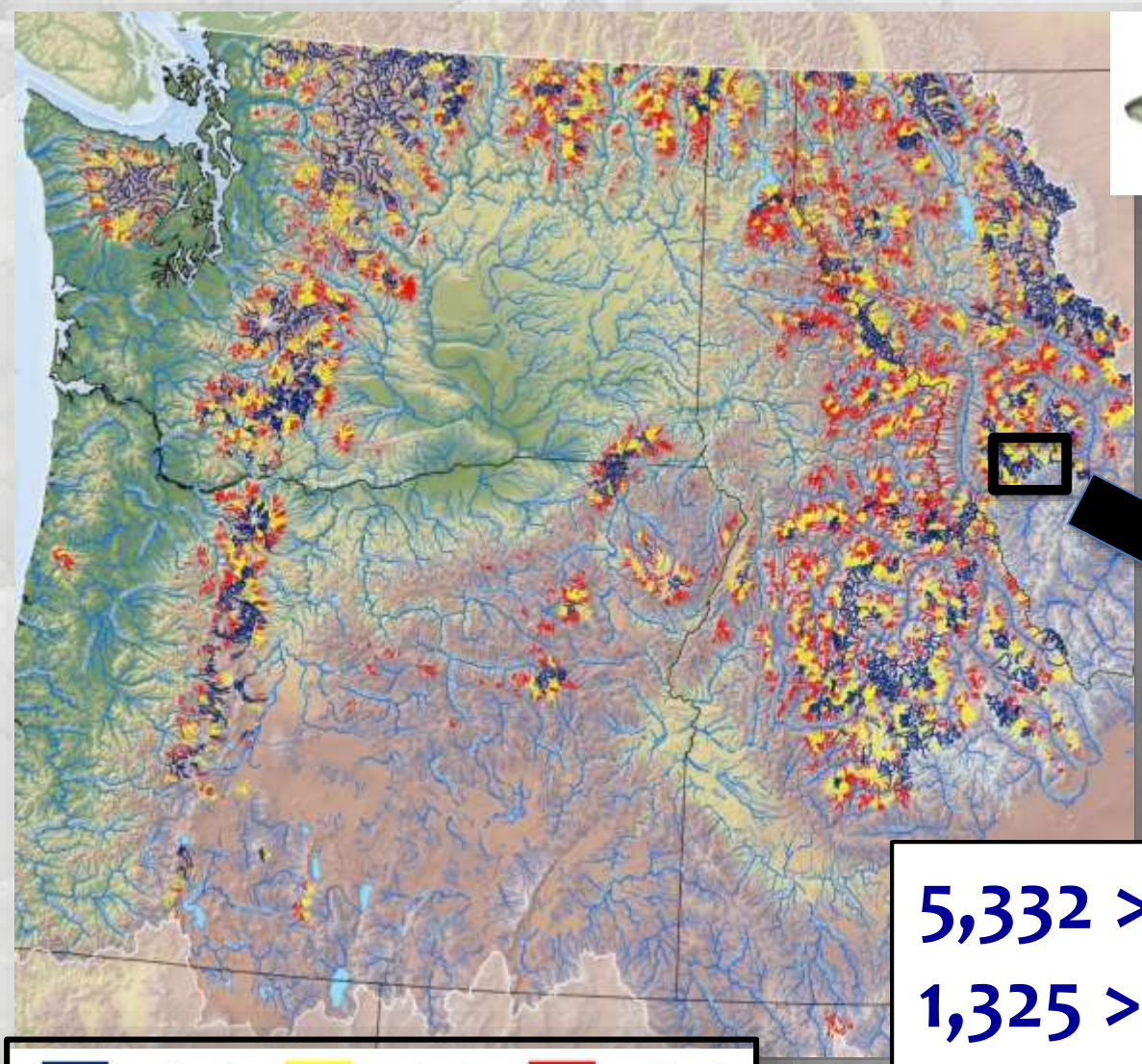


Isaak et al. 2015. The cold-water climate shield: Delineating refugia for preserving native trout through the 21st Century. *Global Change Biology* **21:** 2540-2553

High-Resolution Maps at Broad Scales Provide BioClimatic Context

2000s

Stream population scale predictions



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

High-Resolution Maps at Broad Scales Provide BioClimatic Context

2040s

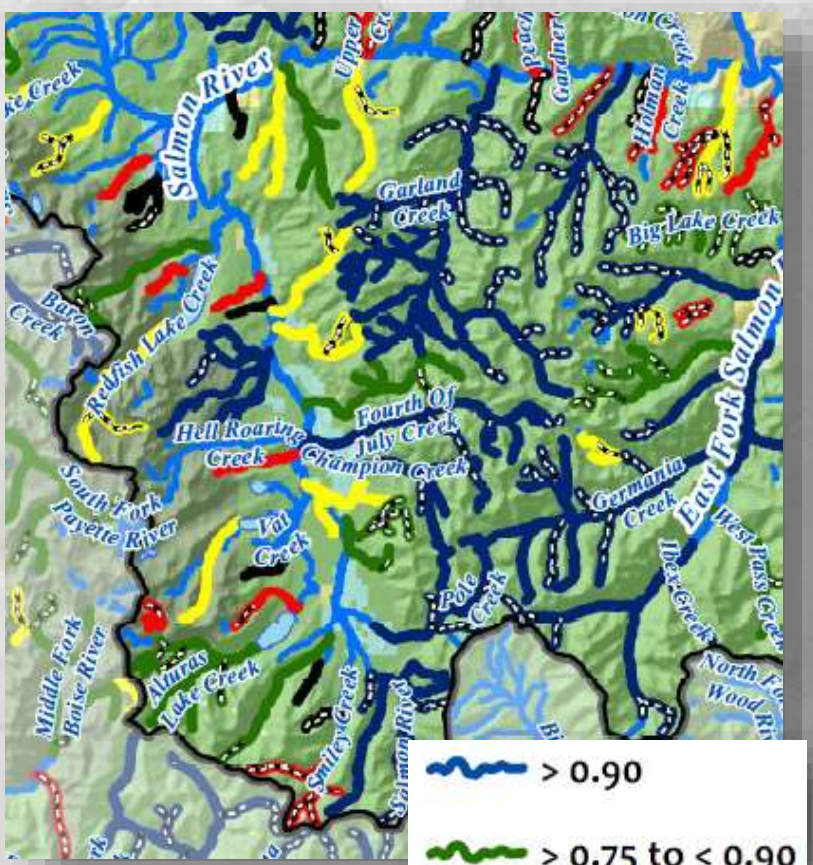
Future "Drought"
Flows 20-30% lower
Temps 1–2 °C warmer

>0.9 >0.5 >0.1

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

Step 9. Conduct Local Drought Sensitivity Analysis

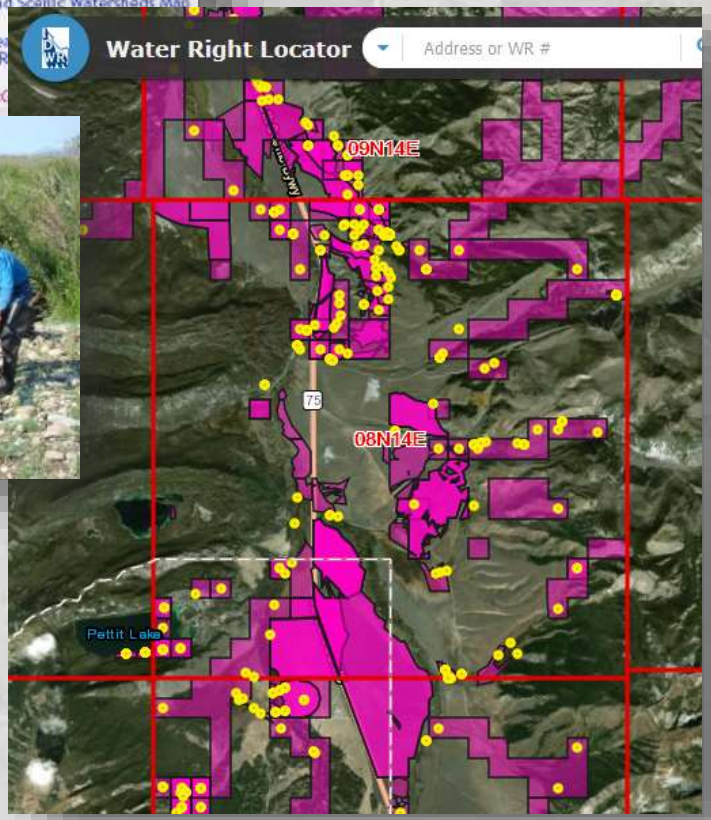
2000s



Where does it make sense to invest?

2040s: Warmer & drier

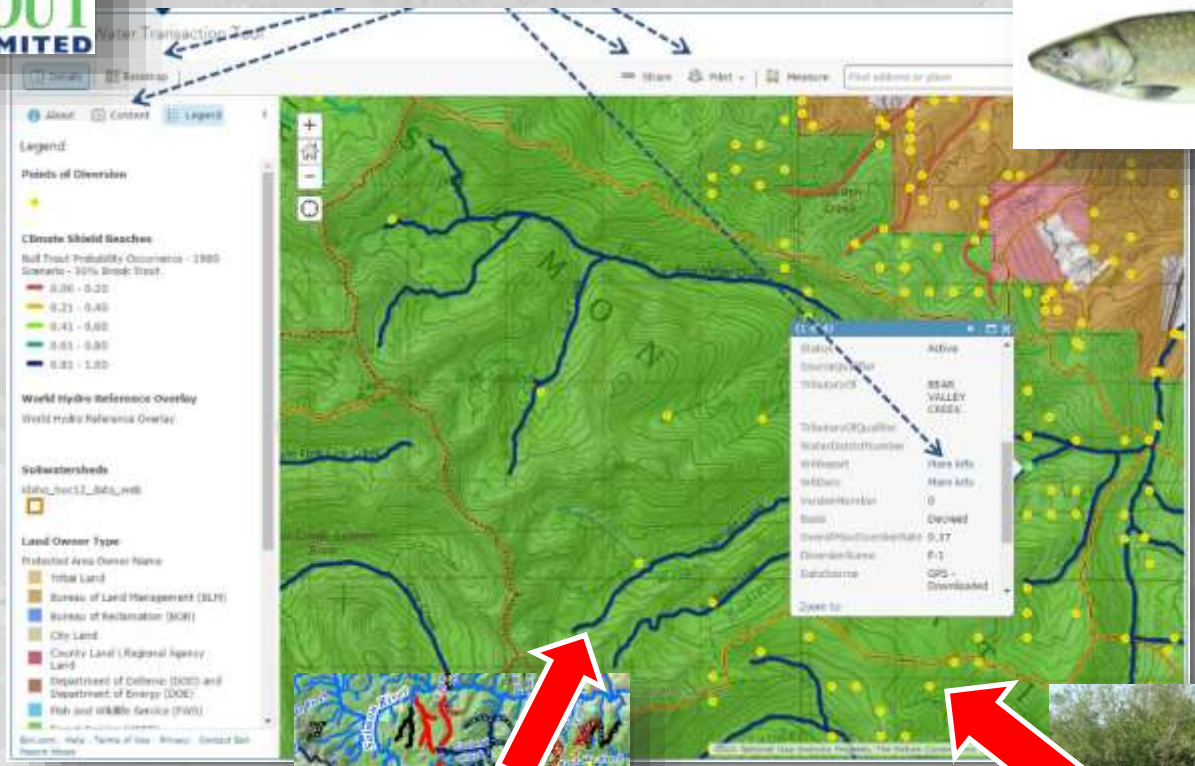
Water rights and points of diversion database



Step 10. Interface Water Diversion Infrastructure With Bull Trout Distribution Maps

TROUT UNLIMITED

Water Transaction Tool

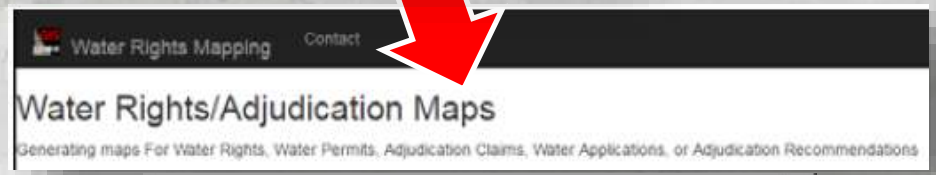


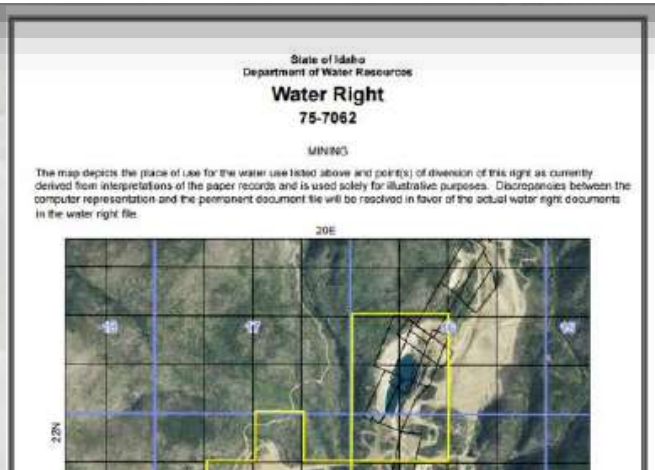
IDWR

Step 10. Interface Water Diversion Infrastructure With Bull Trout Distribution Maps

TROUT UNLIMITED

Water Transaction Tool





State of Idaho
Department of Water Resources

Water Right
75-7062

MINING

The map depicts the place of use for the water use listed above and point(s) of diversion of this right as currently derived from interpretations of the paper records and is used solely for illustrative purposes. Discrepancies between the computer representation and the permanent document file will be resolved in favor of the actual water right documents in the water right file.

20E

22N

Close

IDAHO DEPARTMENT OF WATER RESOURCES
Water Right Report

4/21/2016

WATER RIGHT NO 75-7062

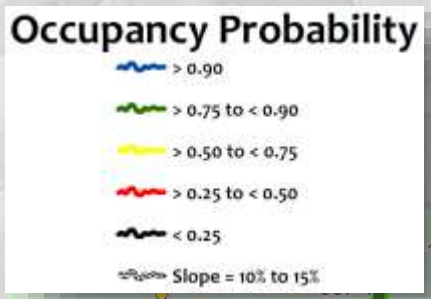
Owner Type	Name and Address
Current Owner	MERIDIAN BEARTRACK CO PO BOX 749 SALMON, ID 83467 (208)756-6300
Attorney	HOLLAND & HART LLP 101 SOUTH CAPITOL BLVD STE 1400 BOISE, ID 83702-7714 (208)342-5000
Original Owner	HARRY I JOHNSON 3380 HANDLY AVE IDAHO FALLS, ID 83401

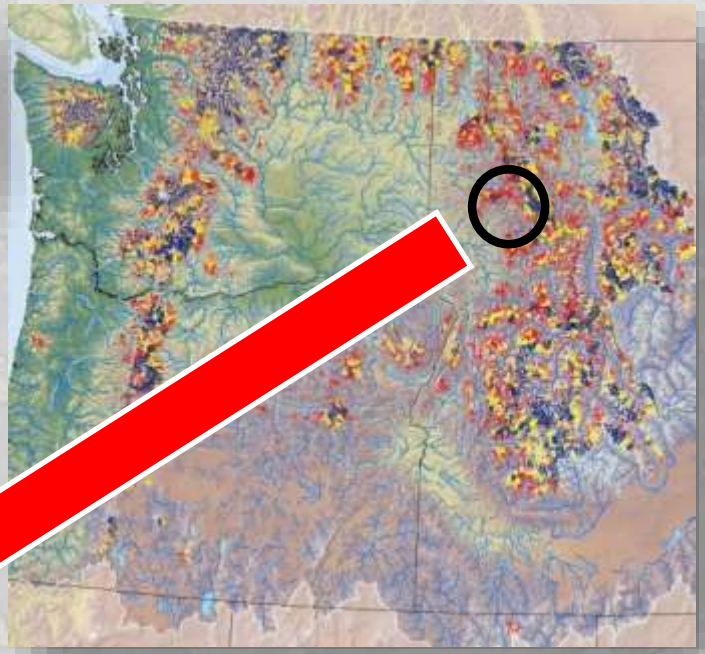
Priority Date: 05/30/1975
Basis: Decreed
Status: Active

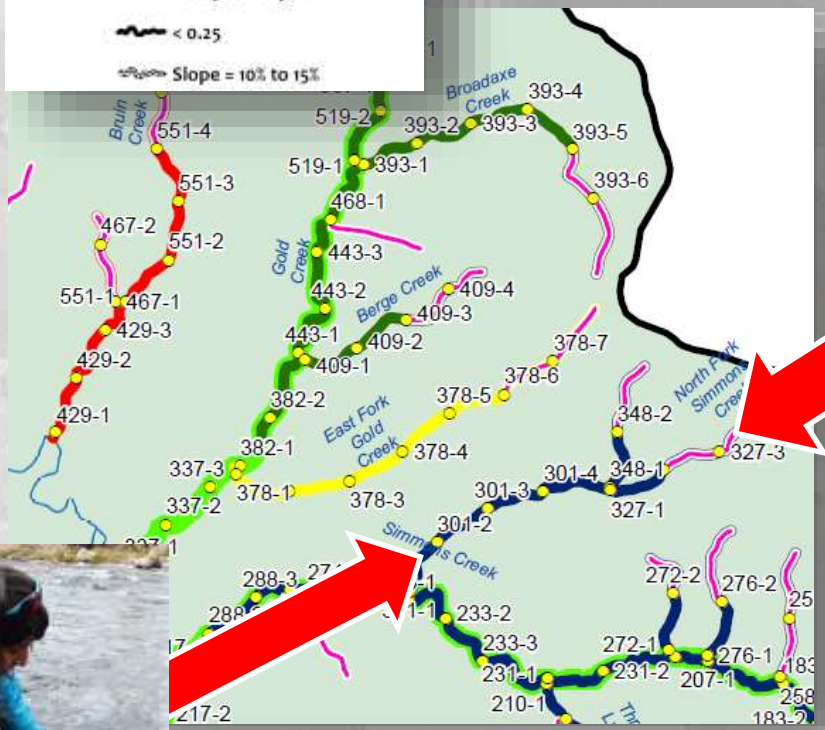
Source	Tributary
NAPIAS CREEK	PANTHER CREEK

Beneficial Use	From	To	Diversion Rate	Volume
MINING	03/15	12/01	1.58 CFS	408.9 AFA
Total Diversion			1.58 CFS	

Framework Can be Updated with New Data

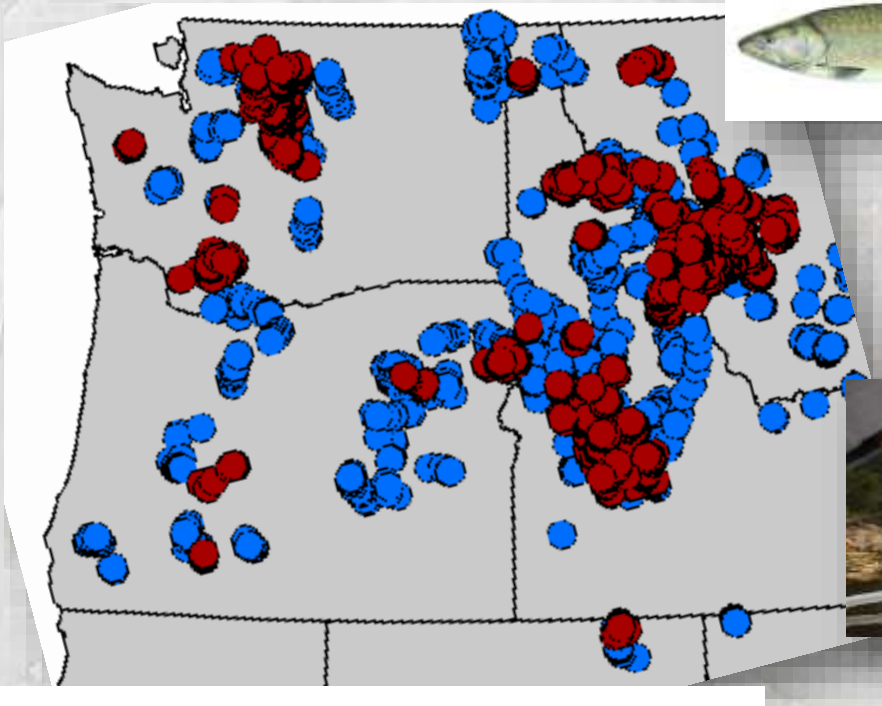






- New sampling can be precisely targeted to refine distribution maps & refine habitat relationships

Crowd-Sourced Rangewide Bull Trout eDNA Project



USDA Forest Service
National Genomics
Center for Wildlife
and Fish Conservation

Project partners sampled…

2016: 3,000 stream sites surveyed

2017: 2,000 stream sites surveyed

>2018: ? additional sites surveyed

NOAA Fisheries

King County

IDAHO

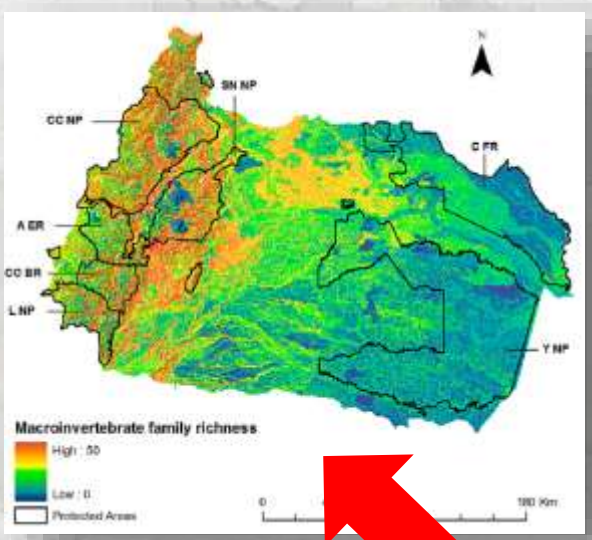
OREGON
Fish & Wildlife

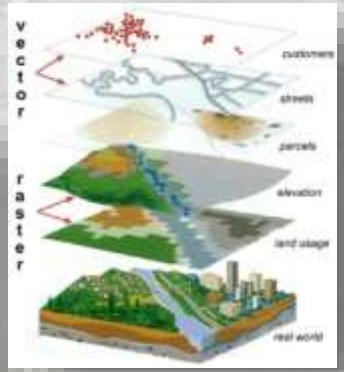
IDAHO POWER
An IDACORP Company

DEPARTMENT OF ECOLOGY
State of Washington

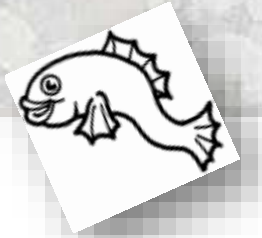
Future: Multispecies Datasets and Map Capabilities to Enable Community/Biodiversity Based Assessments

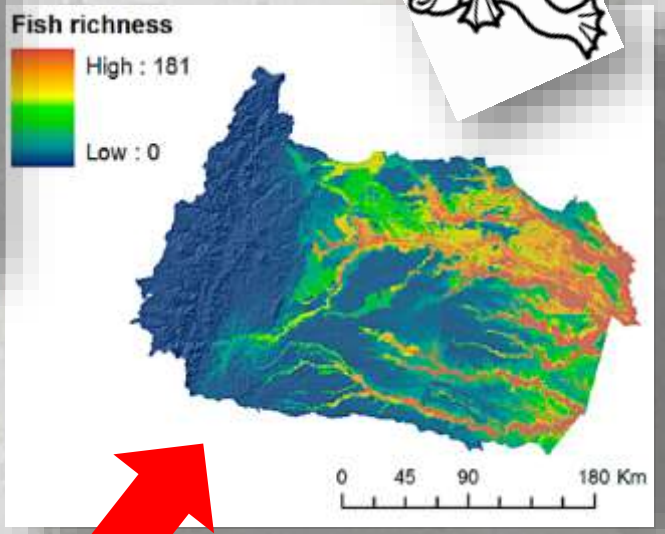
Macroinvertebrates





Fish





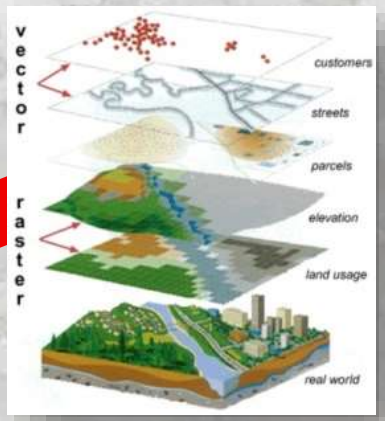
Aquatic biodiversity maps

Lessmann et al. 2016. Freshwater vertebrate and invertebrate diversity patterns in an Andean-Amazon basin: implications for conservation efforts. *Neotropical Biodiversity* **2:** 99-114.

Challenges: Teams of People With Complementary Skillsets are Essential

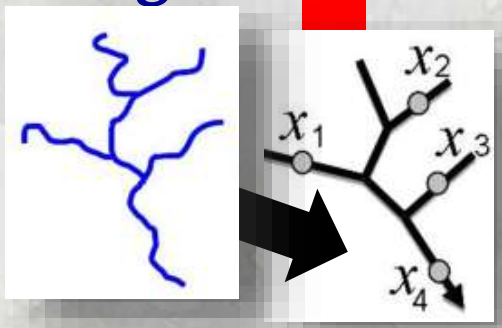
Managers

GIS analysts

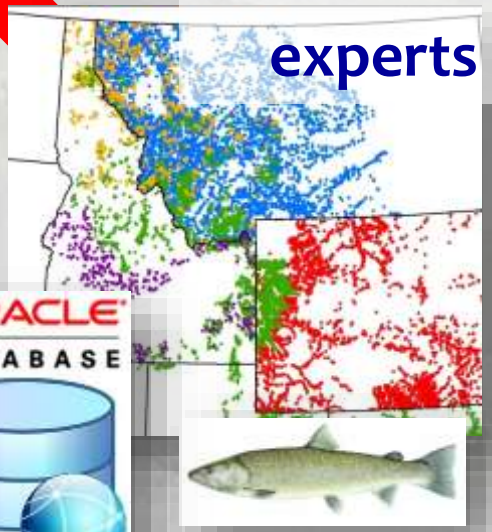


Scientists

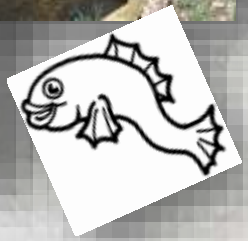
Ecological Modelers



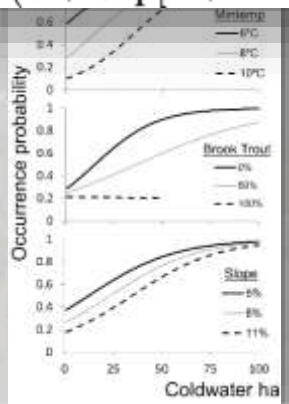
Database experts

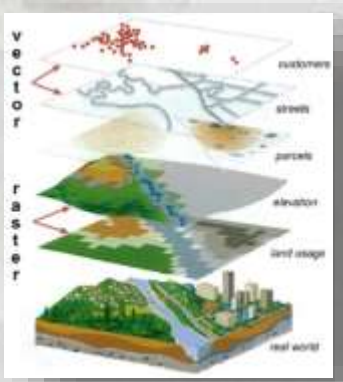


Trajectory is Clear: NHD, New Sensing Technologies, and Precise Datasets Can Reduce Uncertainty & Increase Restoration Efficiency



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






The End