Using High-resolution Species Occurrence Databases & Distribution Models To Identify Climate Refugia For Conservation Planning

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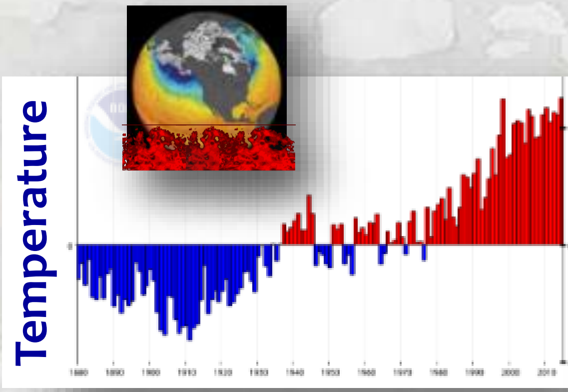
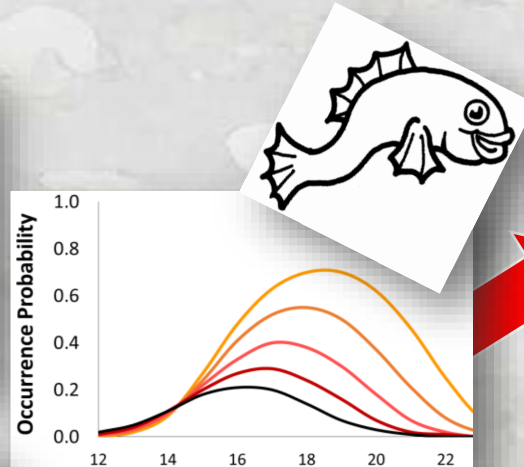
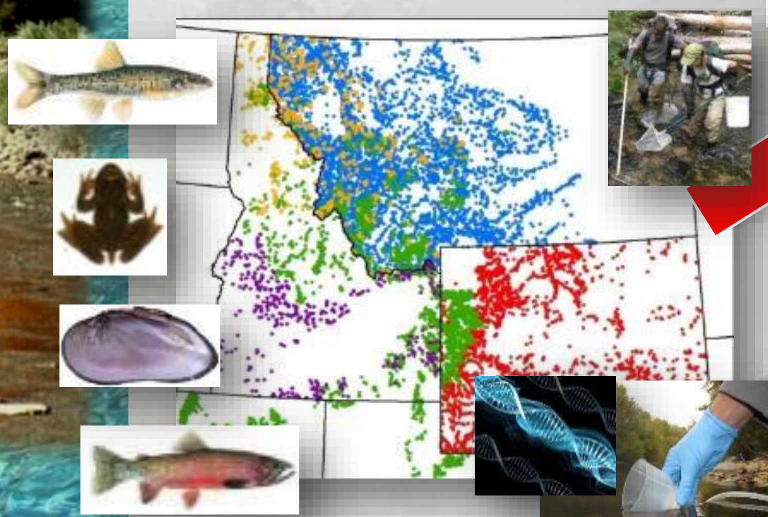
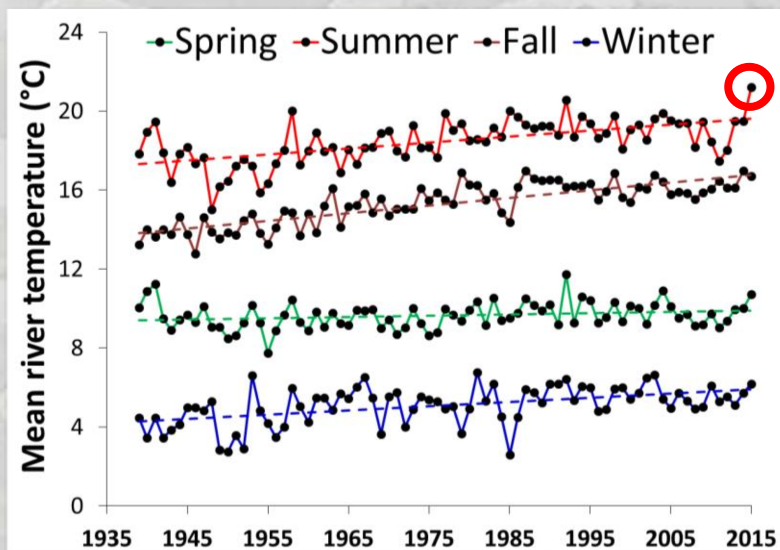




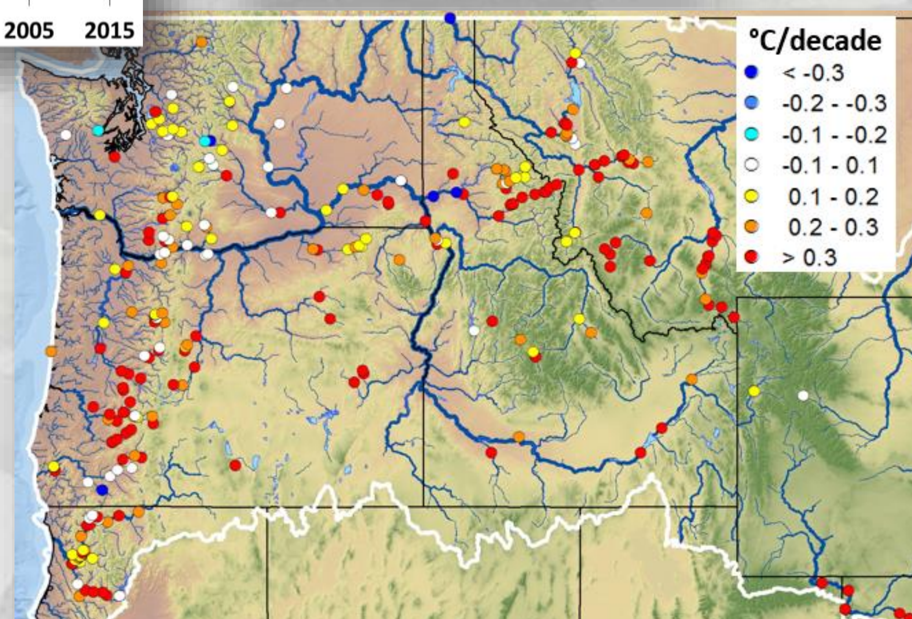
$$p = \frac{\exp(a + bx \ldots ny)}{(1 + \exp[a + bx \ldots ny])}$$

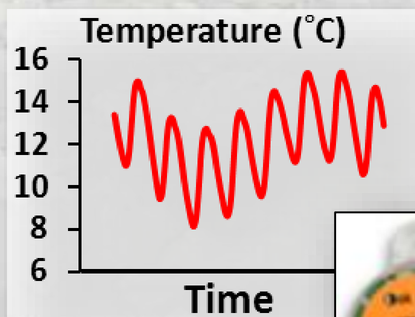


PNW Rivers are Steadily Warming



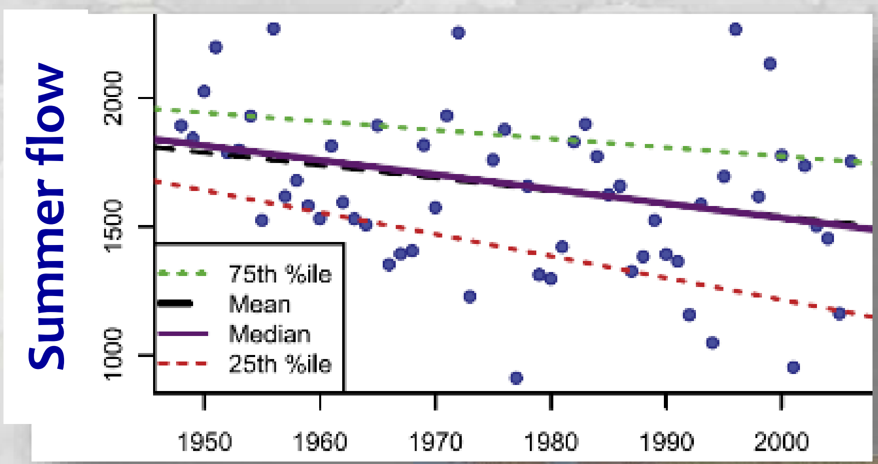
Bonneville Dam Temperature Record

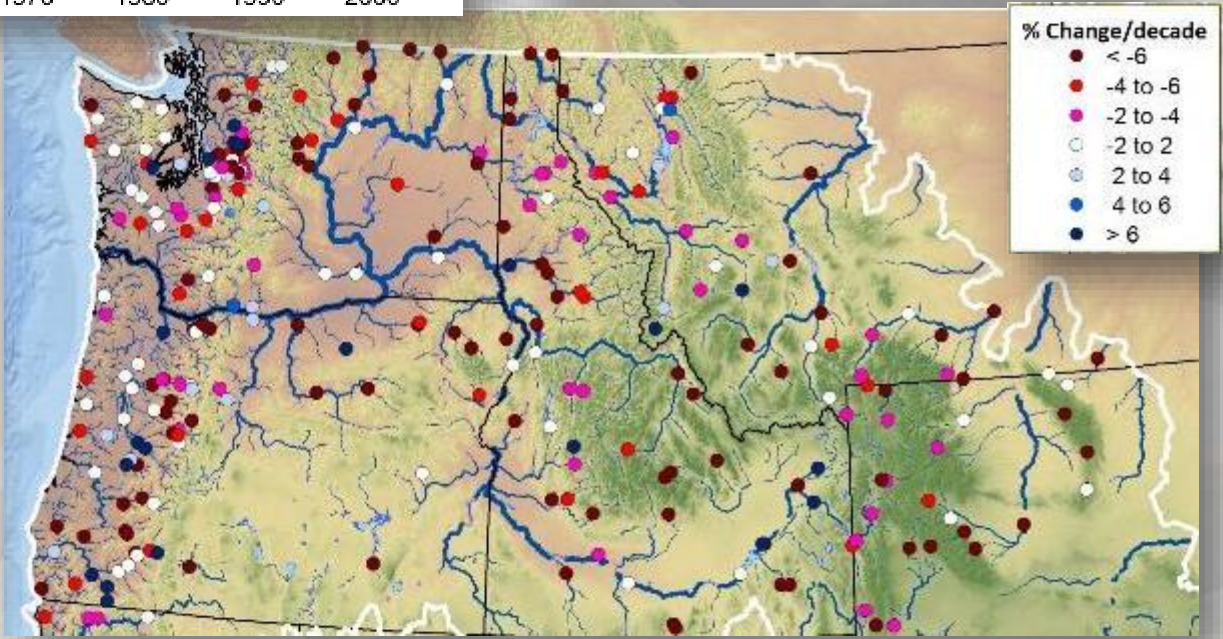




Isaak et al. 2018. Global warming of salmon and trout rivers in the Northwestern U.S. Road to ruin or path through purgatory? *Transactions of the American Fisheries Society* **147**:566.

Summer Flows are Declining (1950–2015)

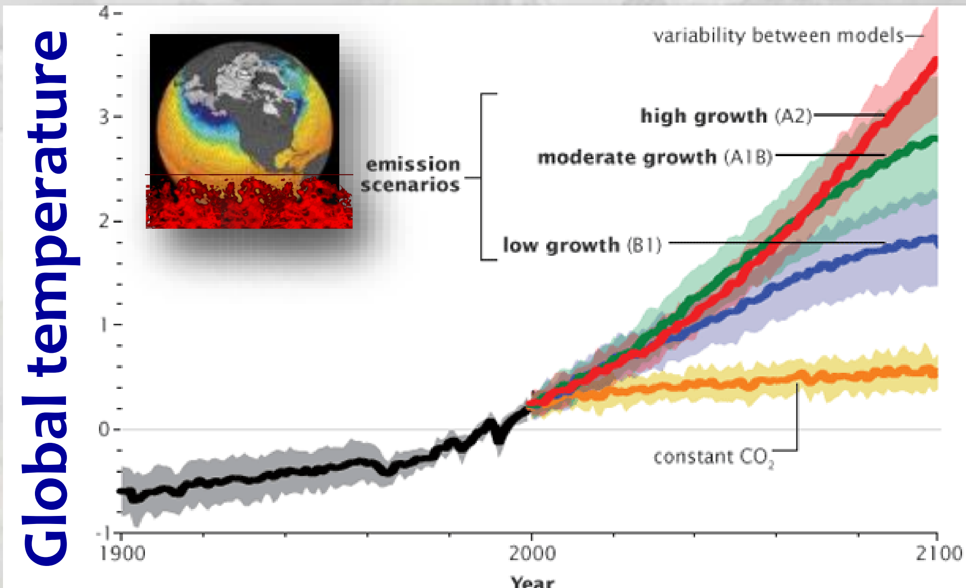




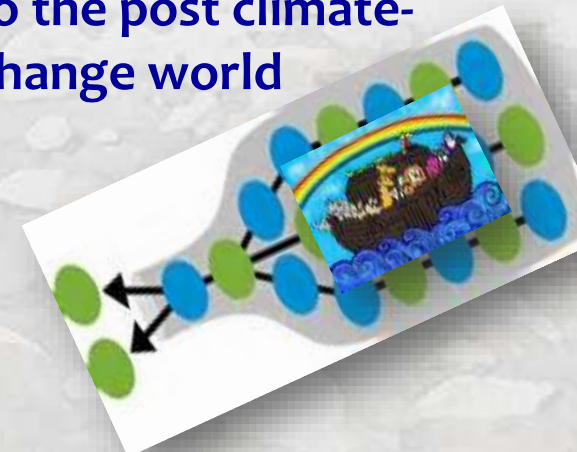
Luce and Holden 2009. Declining annual streamflow distributions in the PNW, 1948-2006. *Geophysical Research Letters* **36**: L16401.

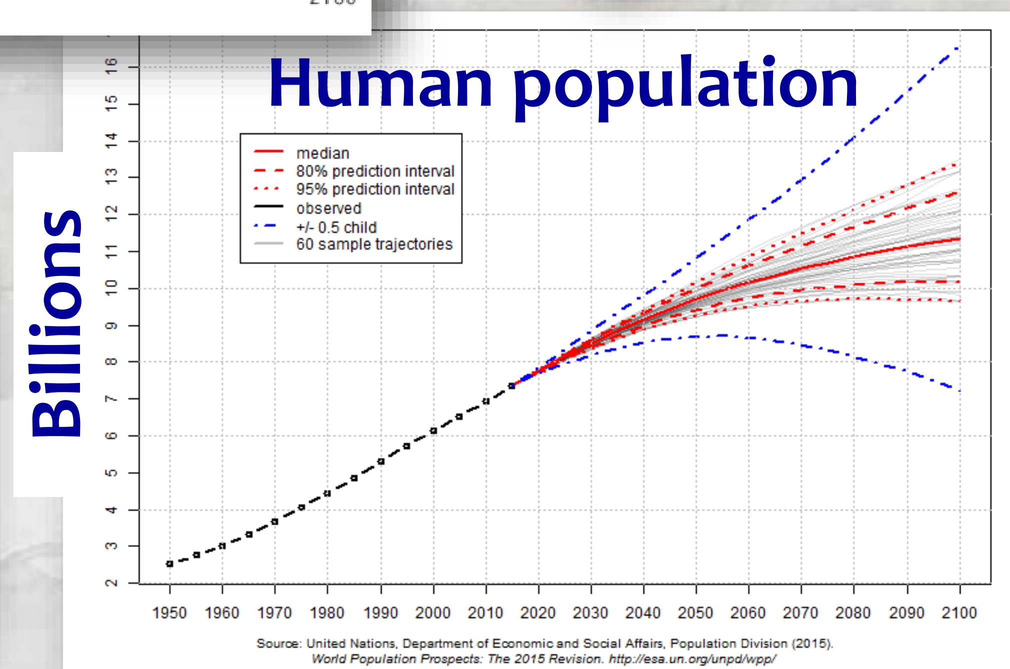
Luce et al. 2013. The missing mountain water. *Science* **342**: 1360-1364.

21st Century Will Be a Bottleneck



Refugia help navigate to the post climate-change world

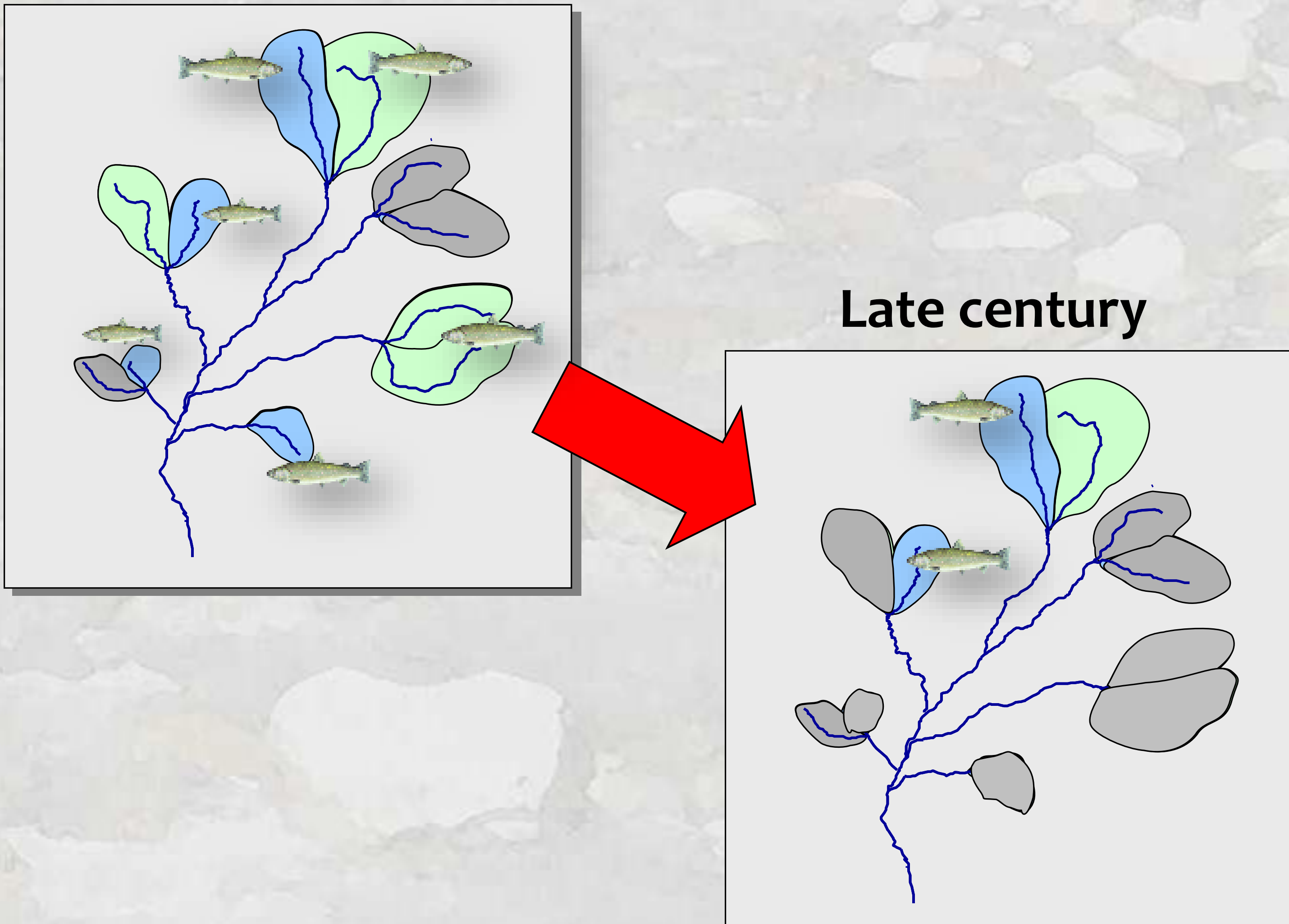




What is a Climate Refugium?

"…habitat that supports a locally reproducing population [or key life history stage] and has a high probability of doing so late this century"

Late century

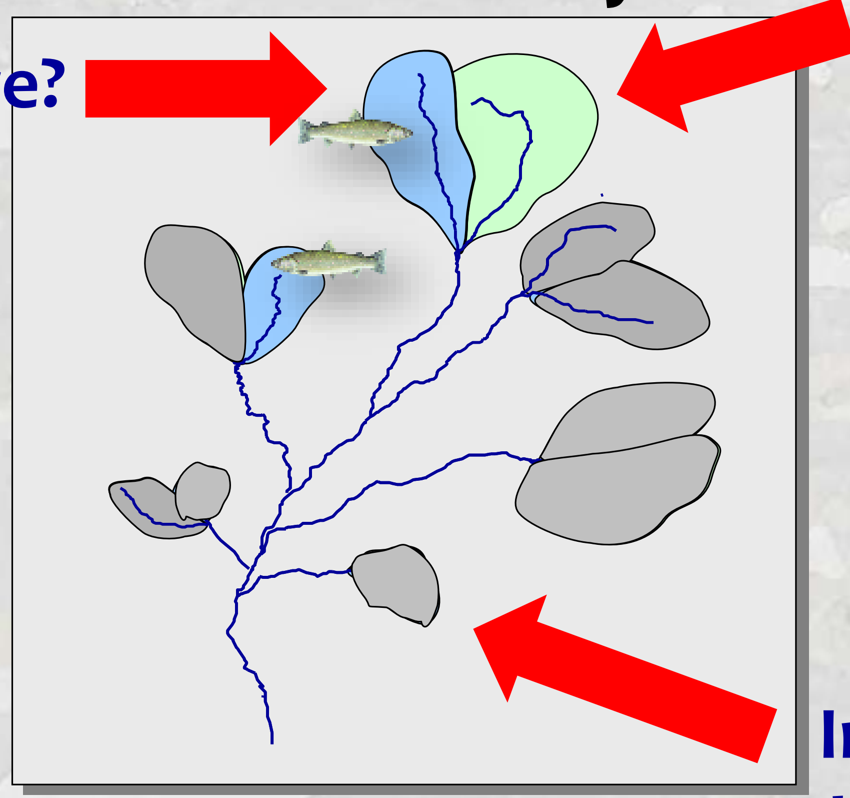


Identifying Refugia Facilitates Climate-Smart Planning & Conservation Investing

Late century

Invest here?

Or here?

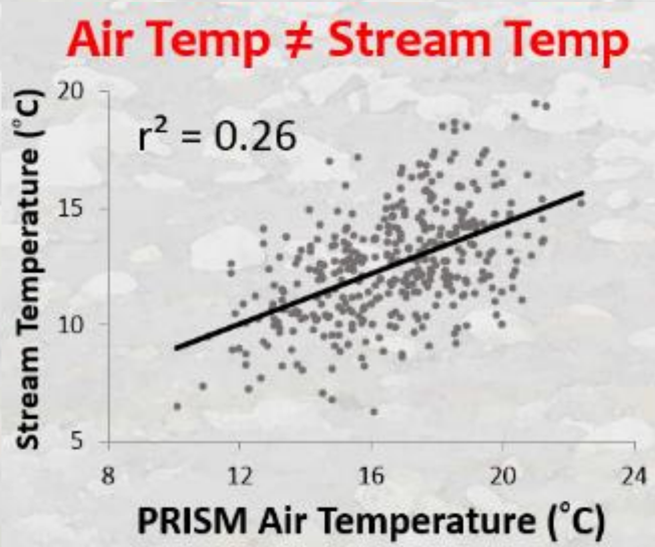


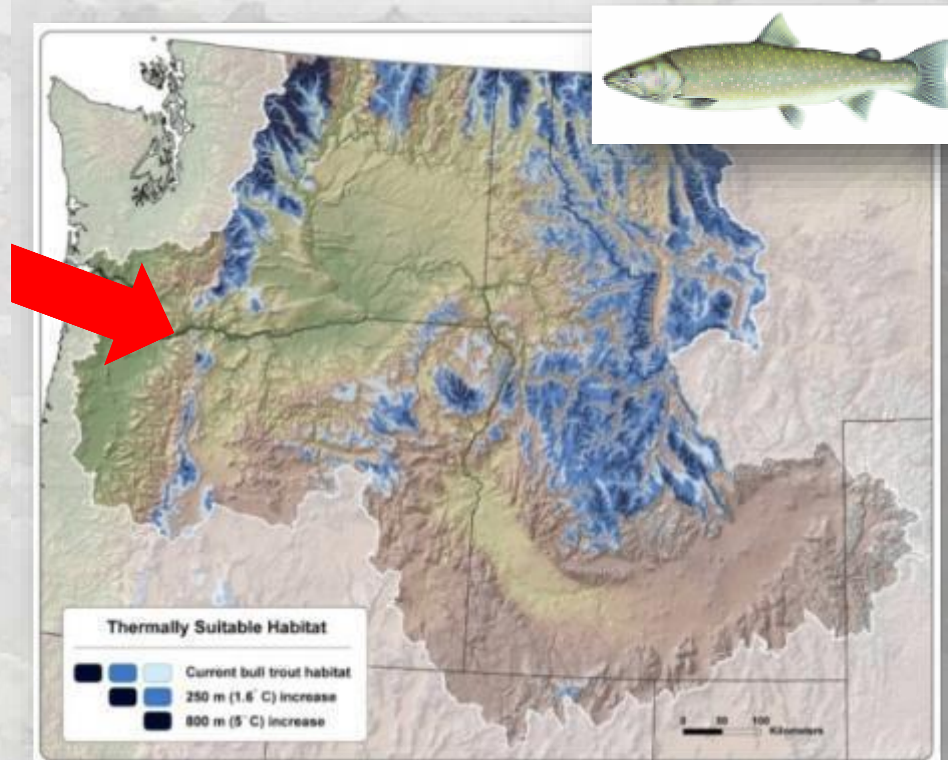
Invest here?

Identifying refugia also allays fears of species extinction

Precise Information Needed Across Broad Areas:

1st Generation Species Distribution Models Are Imprecise

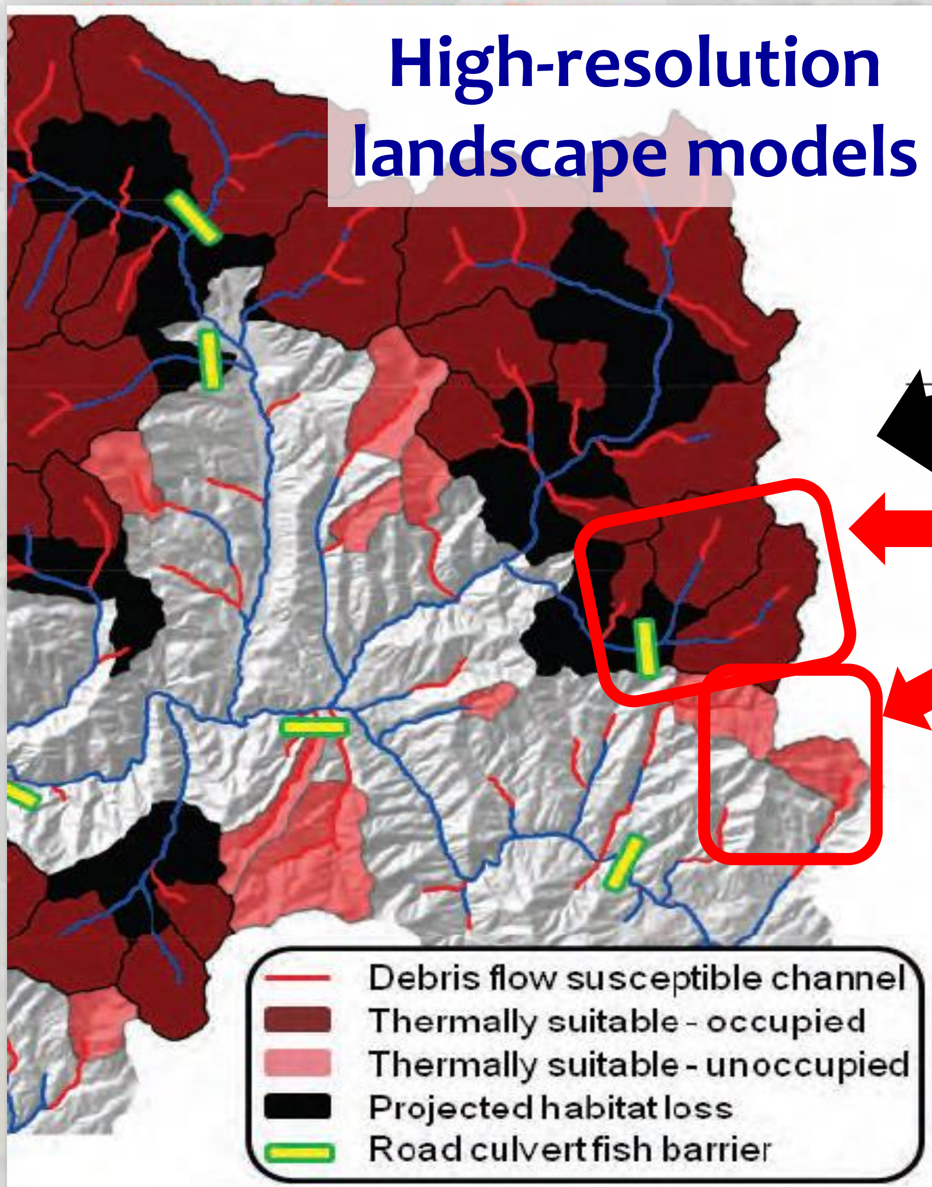




Rieman et al. 2007. Anticipated Climate Warming Effects on Bull Trout Habitats and Populations Across the Interior Columbia River Basin. *TAFS* **136**:1552-1565.

Precise Information Needed Across Broad Areas:

1st Generation Species Distribution Models Are Imprecise

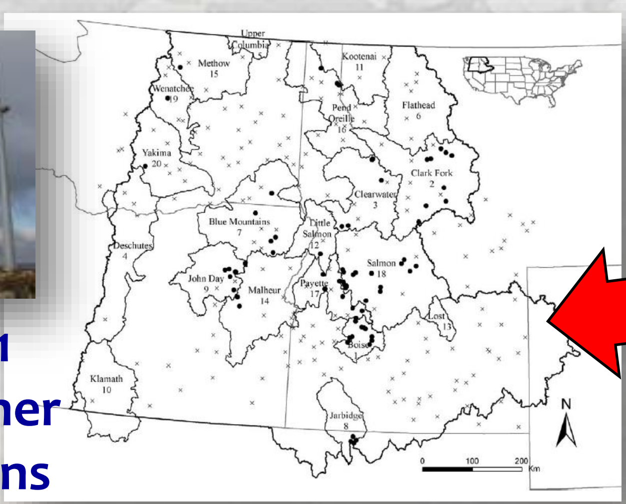


I'm going to invest here…

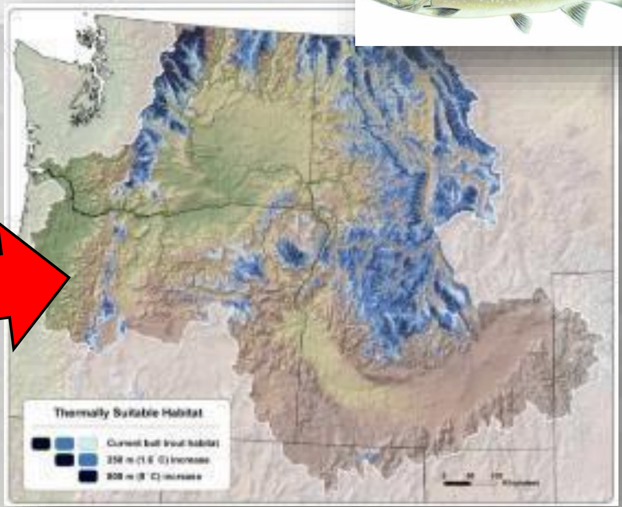
…instead of here

Sparse Empirical Support Creates Imprecision

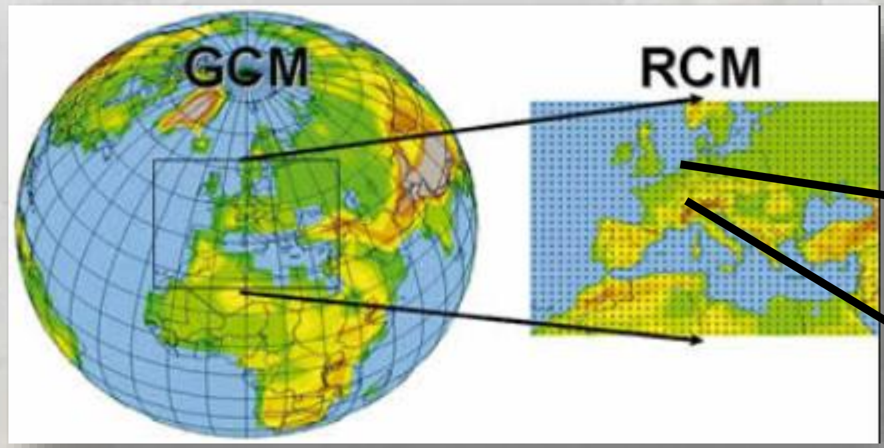
Long-Distance Interpolations Magnify Local Uncertainty

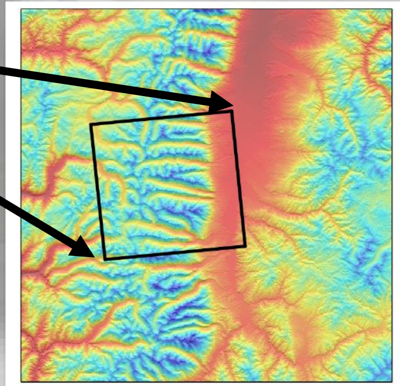


n = 191 weather stations



"Downscaling" Techniques Ameliorate the Problem but Don't Fix it

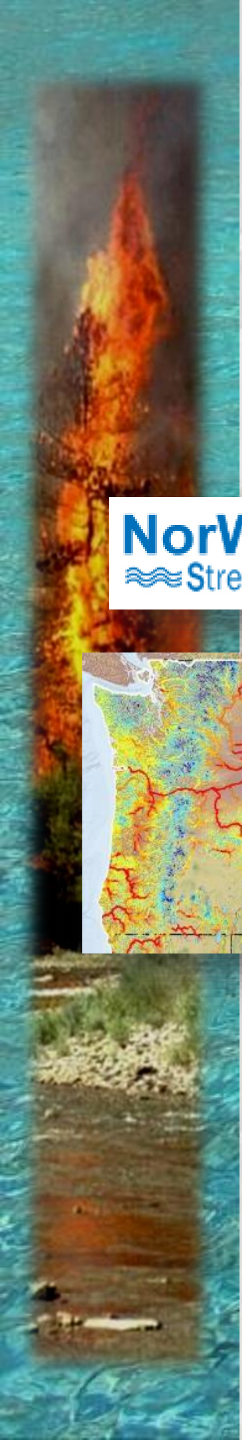




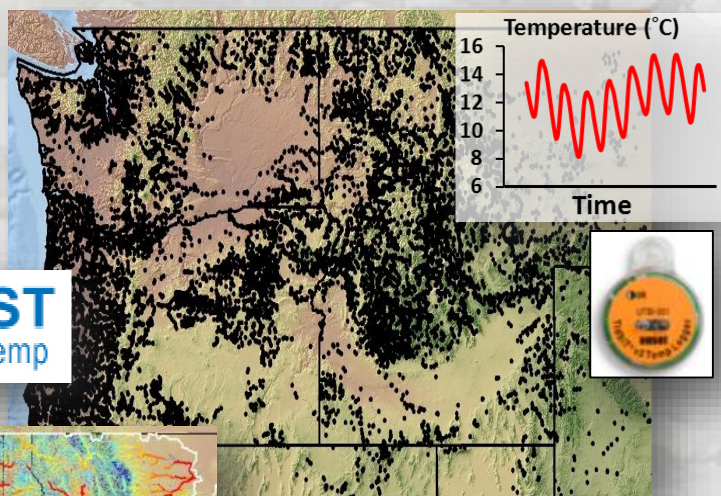
Predictions Depend on Covariate Relationships

Temp ~
Elevation +
Slope +
Aspect +
Etc...

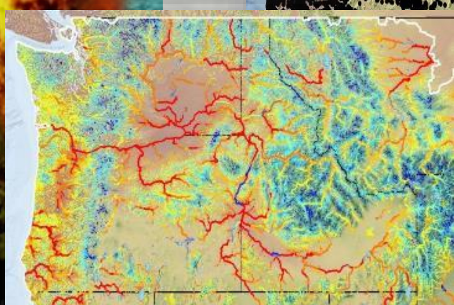
Stream World Often has High Density Datasets



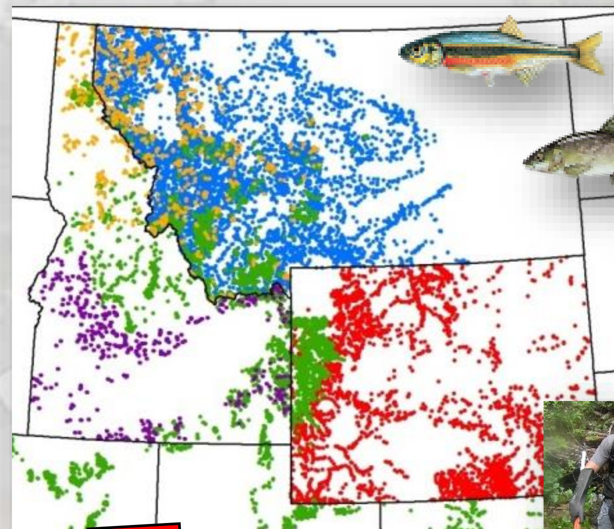
>16,000 stream temperature sites



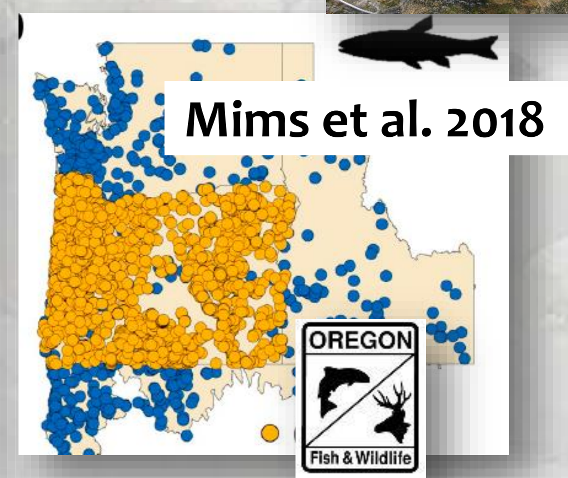
NorWeST Stream Temp



>13,000 fish sample sites

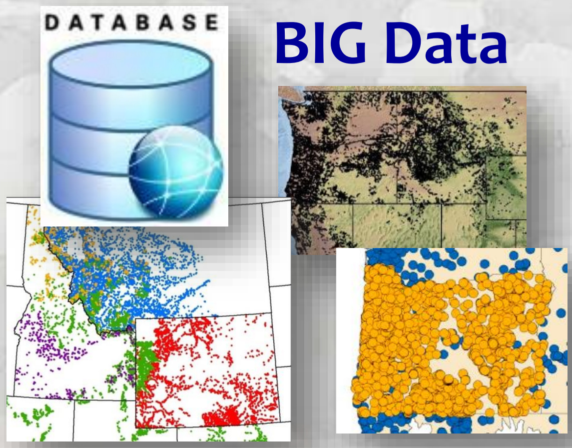


Dozens of agencies collect similar data

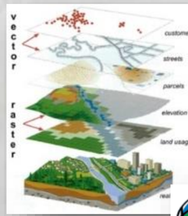


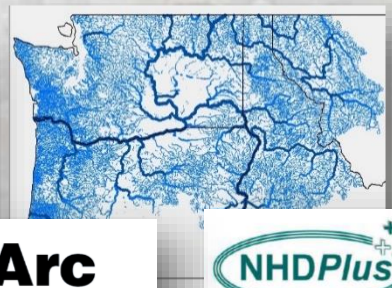
Powerful Analytical Tools & GeoSpatial Technologies Can Leverage Big, Dense Datasets

BIG Data



GeoSpatial hydrography & environmental covariates





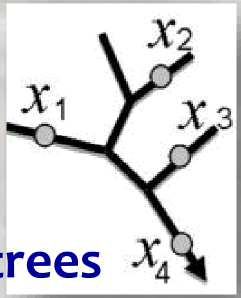
ArcGIS ESRI

NHDPlus

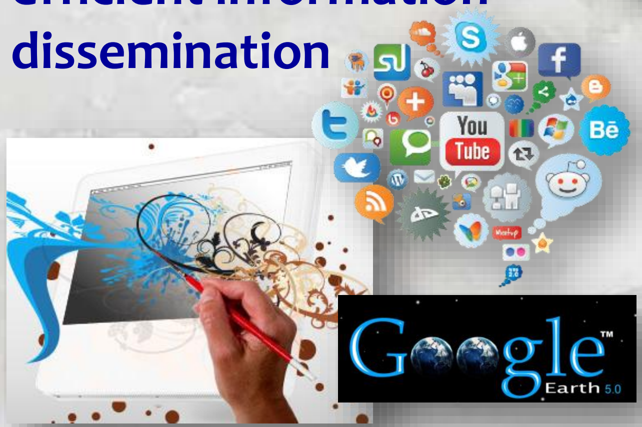
Many models applicable to spatial stream datasets

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

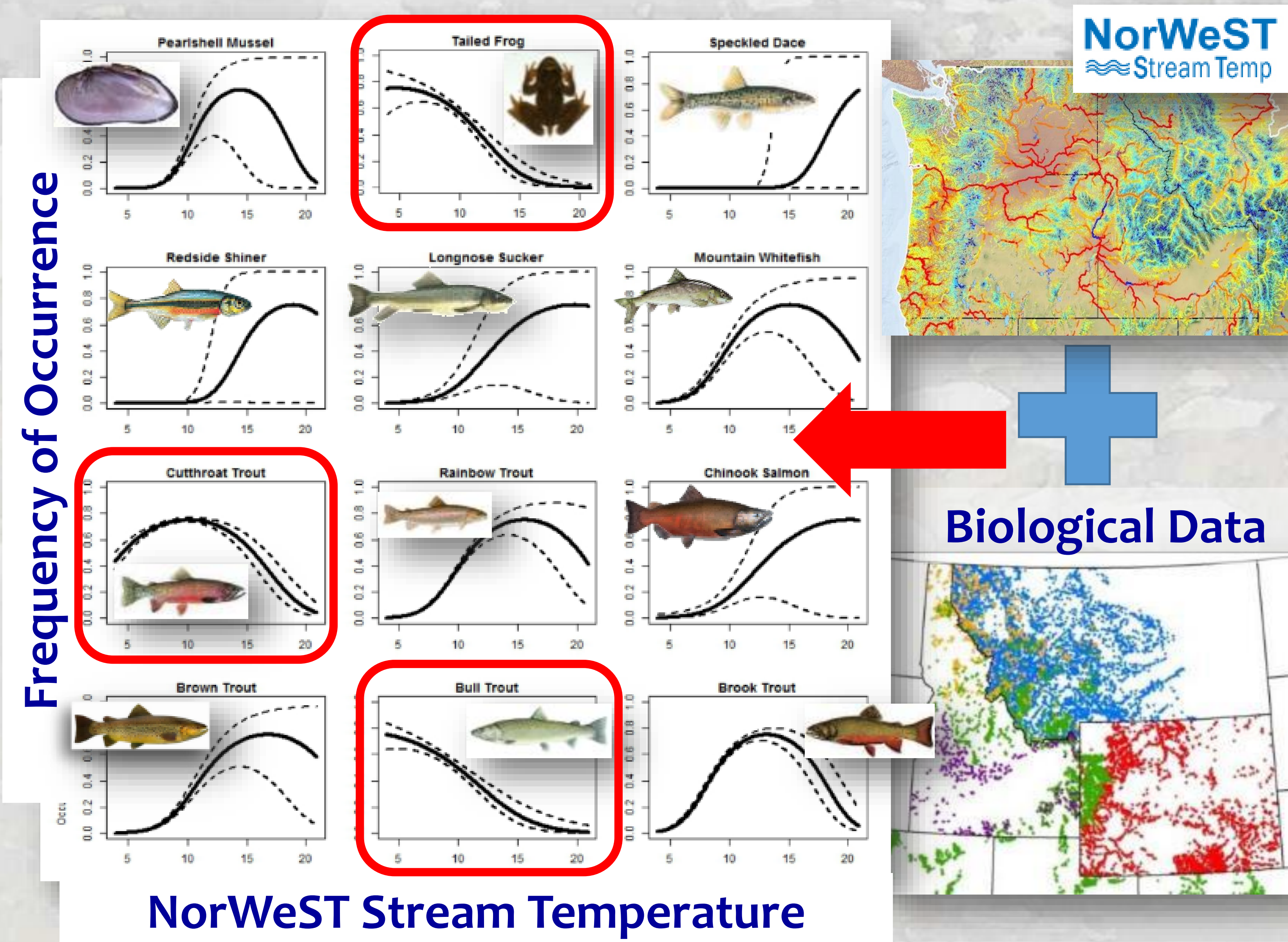
- MaxEnt
- GLM
- GLMM
- SSN
- Regression trees
- Etc.



Digital media for efficient information dissemination



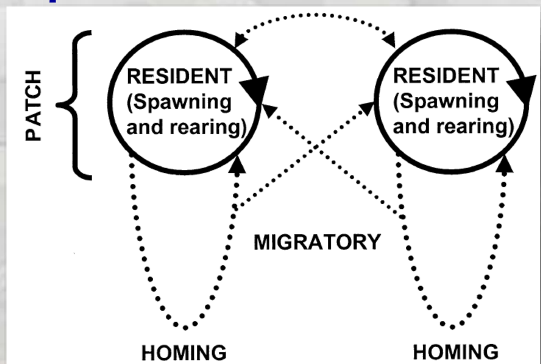
Example, Step 1: Screen Species for Climate Sensitivity



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

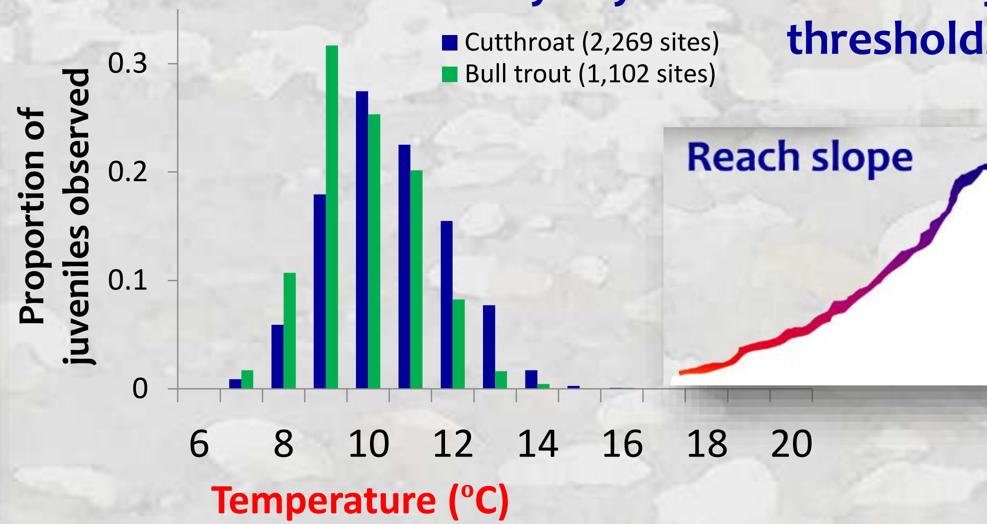
Example, Step 2: Build a Robust Modelling Dataset

1. Choose model attribute: a) life stage or b) all species occurrences?

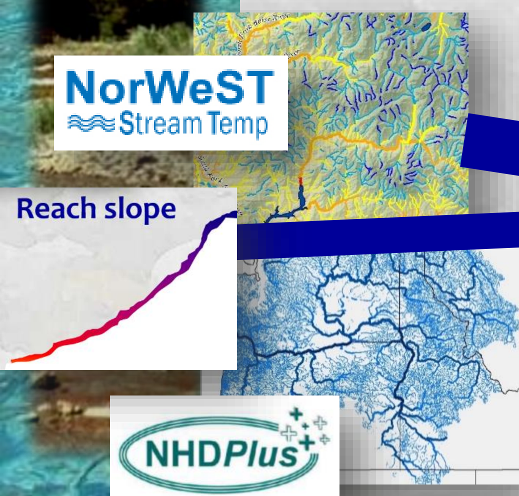


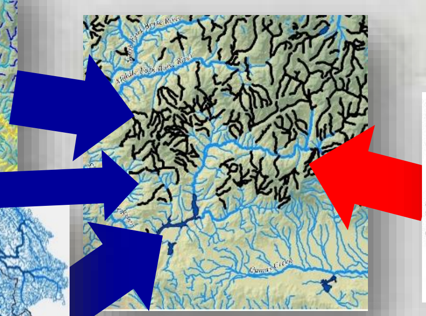
Dunham et al. 2002

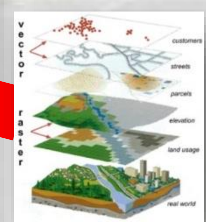
2. Identify key habitat suitability thresholds



3. Apply thresholds to delineate potentially suitable habitats, attribute habitats w/ additional covariates

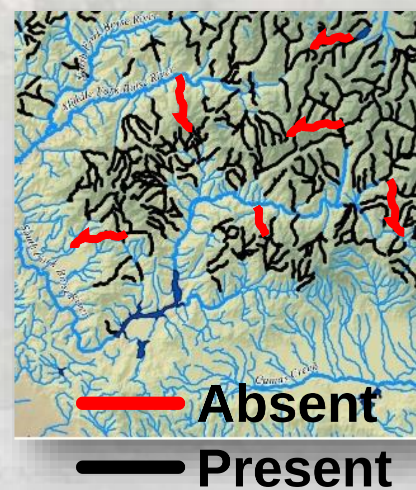






Flow variables, land-uses, geology, riparian, invasive species, etc.

4. Assign occupancy status (0/1) to suitable habitats



Example, Step 3: Build a Species Distribution Model

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

Bull trout example:

512 natal habitat patches with 4,300 electrofishing surveys

1. Model selection

Model	p	ΔAIC_c
Size, MinTemp, Slope, BKT, Size*BKT	**6**	**0.0**
Size, MinTemp, Slope, BKT, Size*BKT, Slope*BKT	7	0.5
Size, MinTemp, Slope, BKT	5	7.8
Size, MinTemp, BKT	4	18.2
Size, MeanTemp, BKT	4	25.7
Size, MinTemp, Slope	4	29.7
Size, MinTemp	3	31.2
Size, BKT	3	49.7

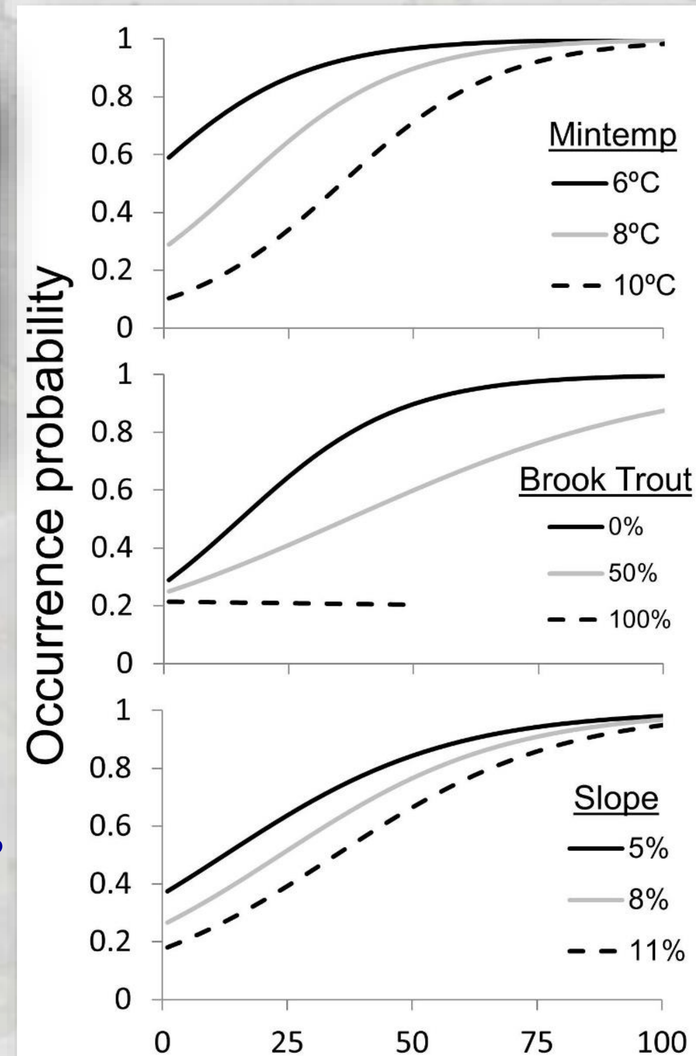
2. Is model accurate enough to be useful?

AUC: 0.83

Accuracy: 78% (i.e., population occupancy correctly predicted for 400 of 512 streams)

3. Is it ecologically realistic?

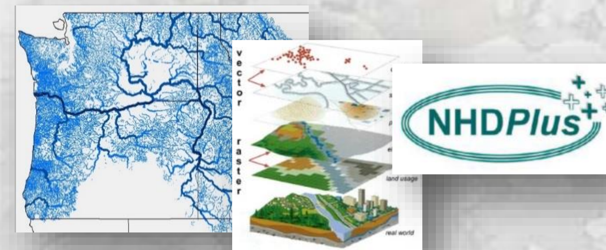
4. Are there climate sensitivities?



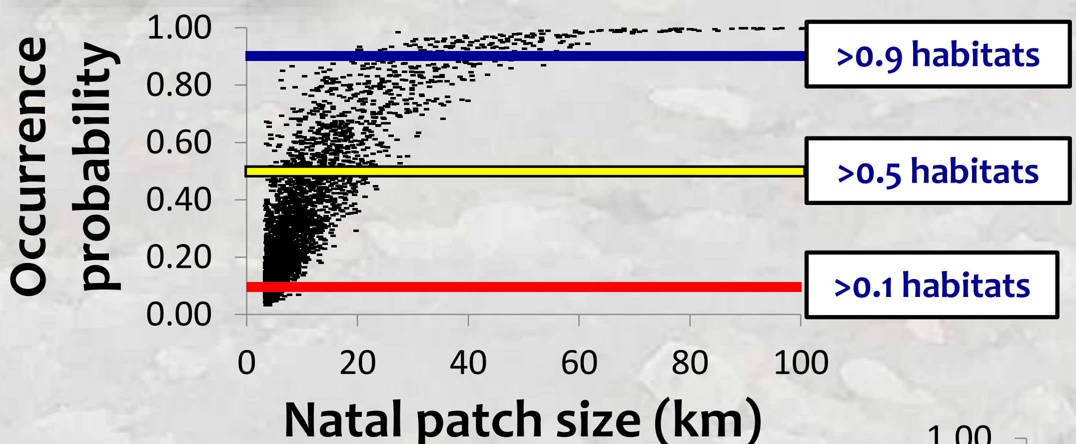
Natal patch size (km)

Example, Step 4: Estimate Size of Potential Habitat Universe & Set Probabilistic Refuge Criteria

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

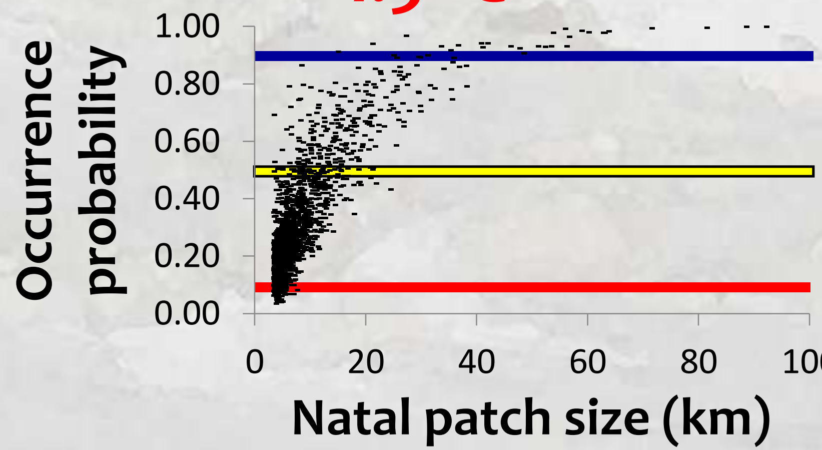


2000's: *N* = 5,300 habitats



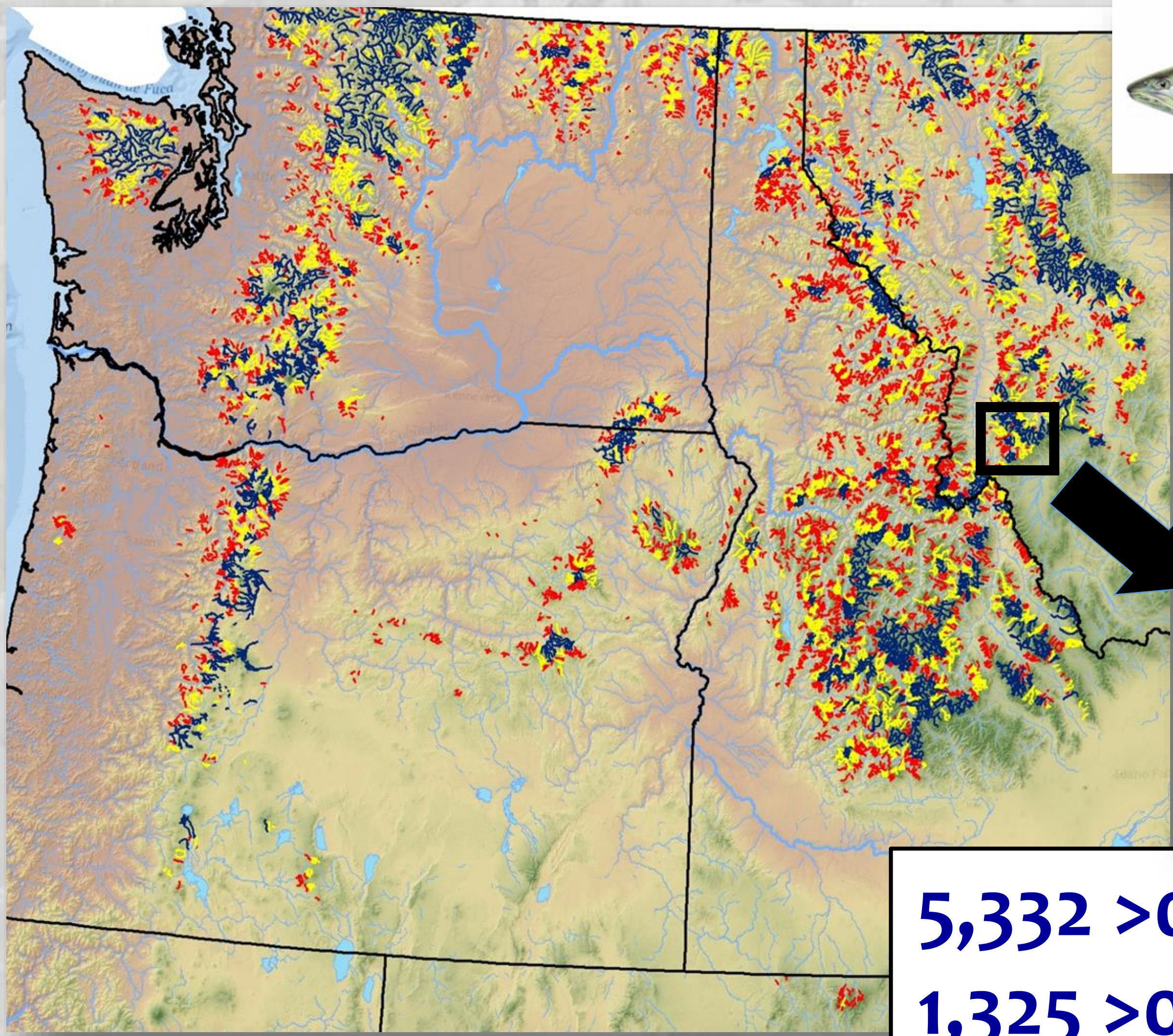
2080's: *N* = 3,300 habitats

+1.5 °C



Example, Step 5: Map Habitat Occupancy Probabilities

U.S. Bull Trout Range: 2000's



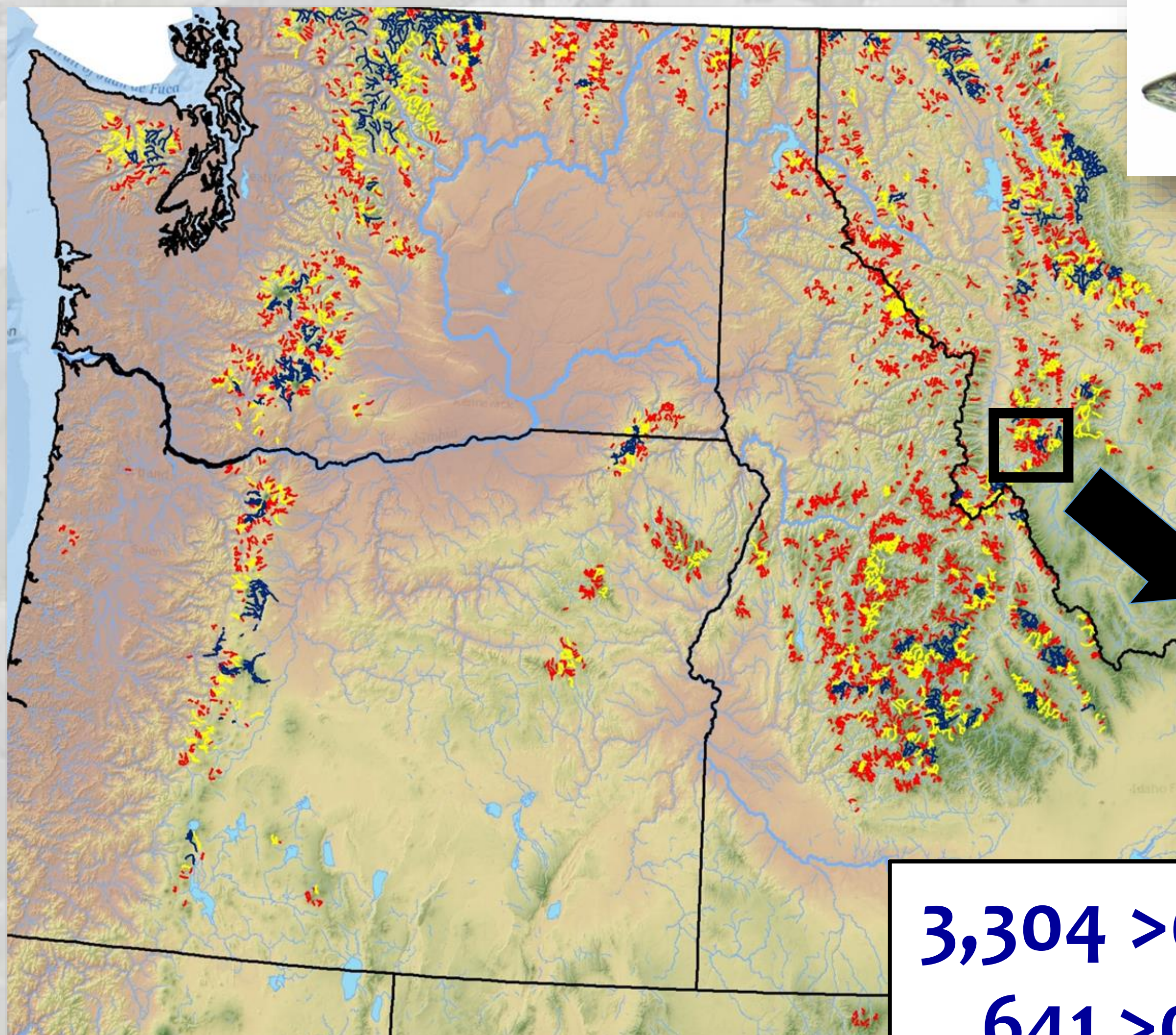
Local population scale predictions

>0.9 >0.5 >0.1

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

Example, Step 5: Map Habitat Occupancy Probabilities

U.S. Bull Trout Range: 2080's



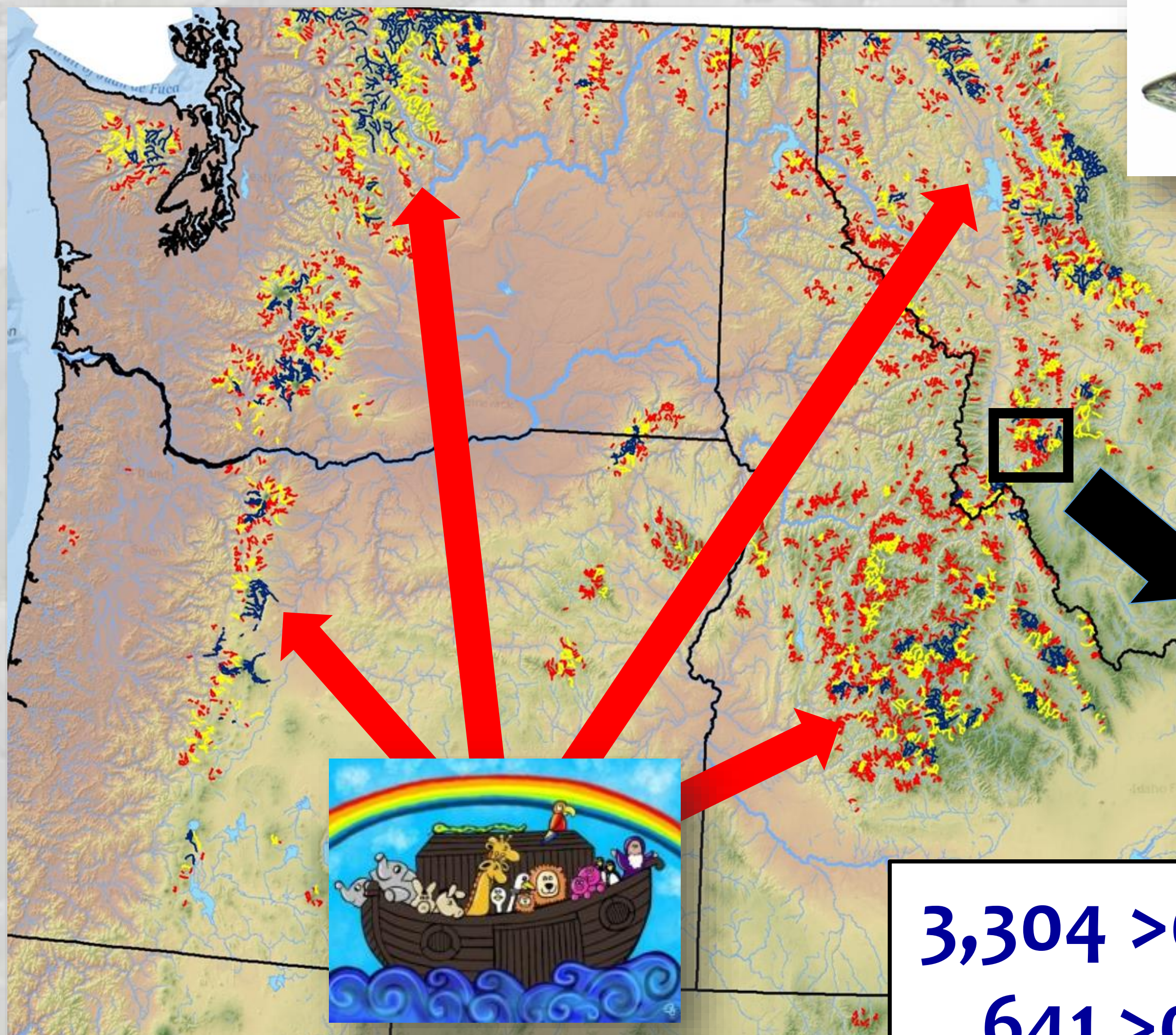
Local population scale predictions

>0.9 >0.5 >0.1

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

Example, Step 5: Map Habitat Occupancy Probabilities

U.S. Bull Trout Range: 2080’s



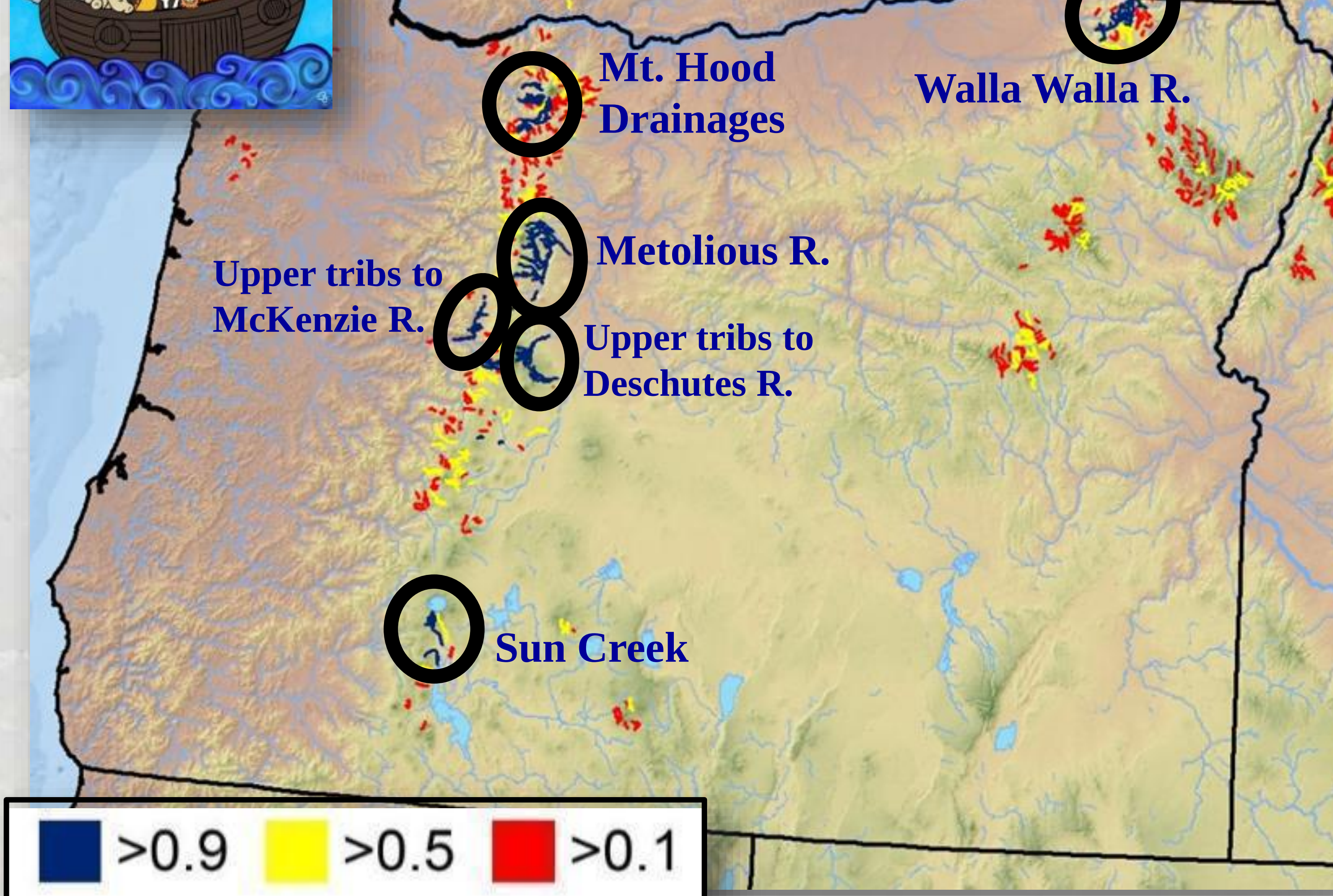
Local population scale predictions

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

>0.9 >0.5 >0.1

Example, Step 5: Map Habitat Occupancy Probabilities

Oregon Bull Trout Range: 2080's

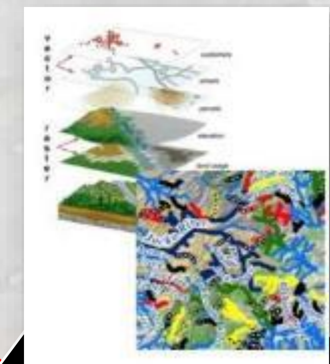


Example, Step 6: Make Results Usable for the Conservation & Management Communities

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

Presentations & Publications

Digital Maps & ArcGIS Shapefiles



Dataset for replicability

File formats:

- ArcGIS files
- pdf files

15 Scenarios:

- 3 climate periods
- 5 Brook invasion levels

A website for distributing information in user-friendly formats

Uses of Climate Refuge Maps, Datasets, & Models

- Prioritizing locations of conservation investments (e.g., habitat restoration, assisted migration, invasive species control)

- Facilitating coordinating among stakeholder groups

- Developing efficient monitoring strategies to track population shifts or local extirpations

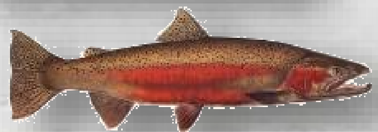
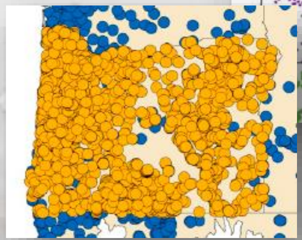
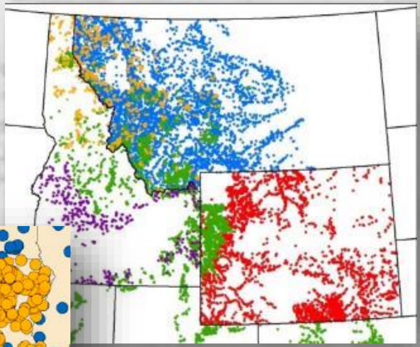
- Conducting efficient biological inventories to determine habitat occupancy in areas of uncertainty regarding population status

- Providing baseline datasets & models for future refinements & updates

Challenge:

Lots of Data for a Few Species…



Organization & QA/QC challenge

Limited Data for Many Species

Species	Occurrences
Longnose dace	169
Speckled dace	52
Redside shiner	129
Longnose sucker	235
Whitefish	2,026
Cutthroat trout	11,543
Rainbow trout	3,977
Chinook salmon	1,728
Brown trout	1,228
Bull trout	2,809
Brook trout	7,036



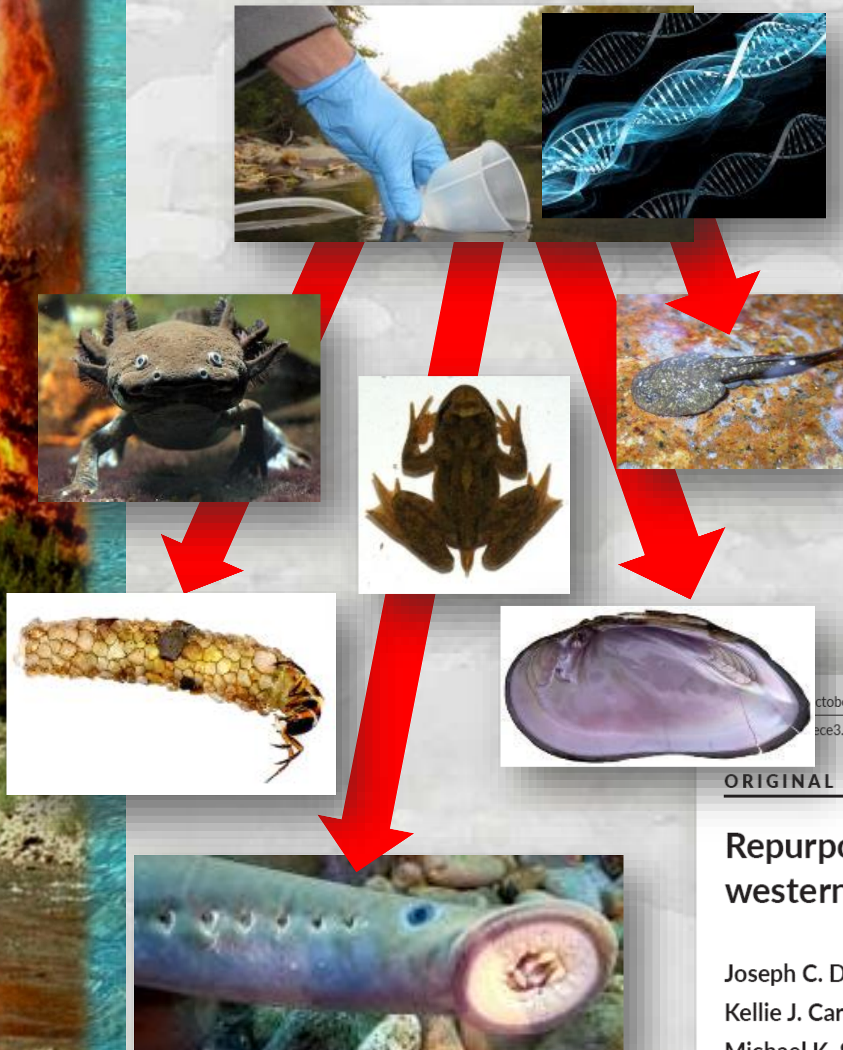


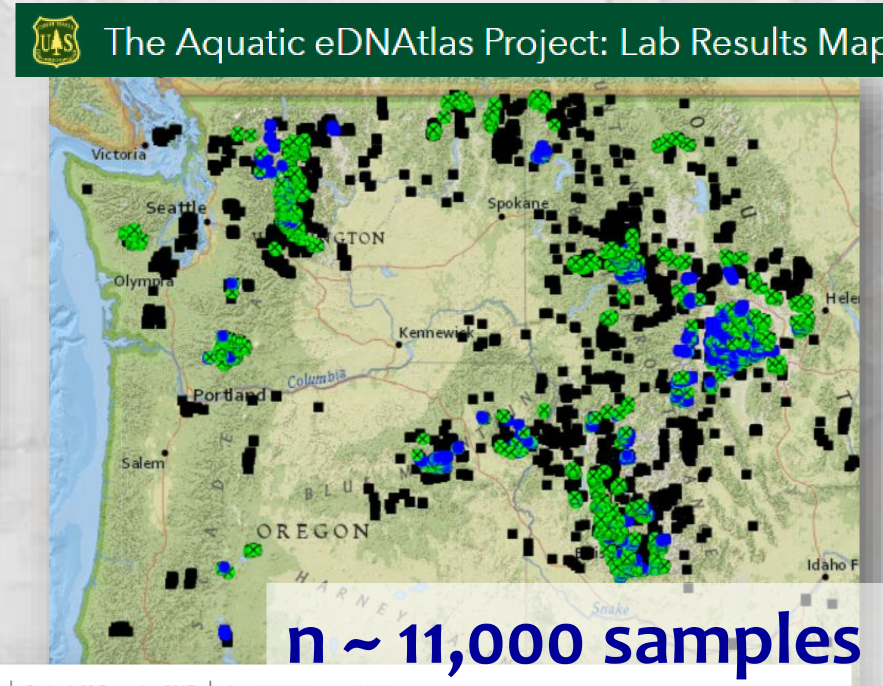


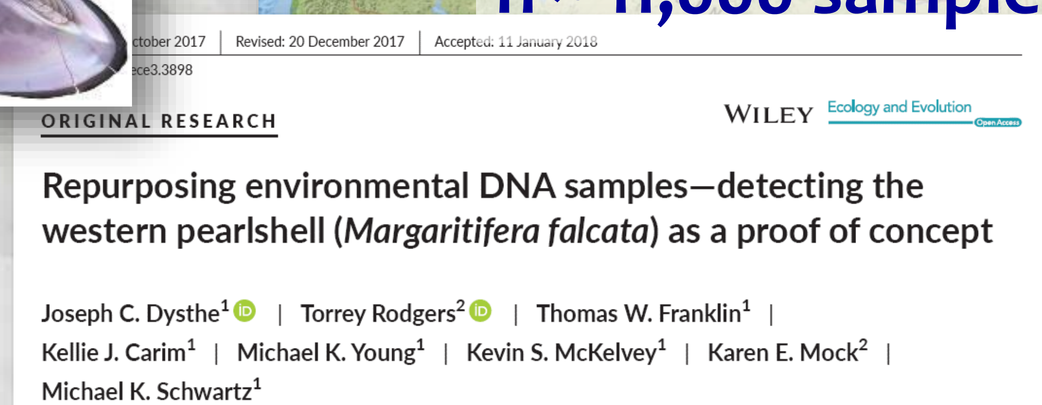


Isaak et al. 2017. Big biology meets microclimatology. *Ecol. Apps*. **27:**977-990.

Rapidly Developing eDNA Databases will Provide Comprehensive Biodiversity Archives







ctober 2017 | Revised: 20 December 2017 | Accepted: 11 January 2018
ece3.3898

ORIGINAL RESEARCH

WILEY Ecology and Evolution

Repurposing environmental DNA samples—detecting the western pearlshell (*Margaritifera falcata*) as a proof of concept

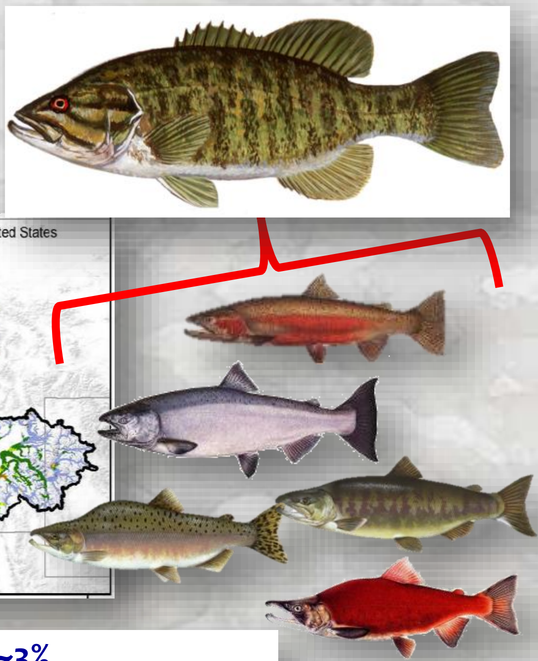
Joseph C. Dysthe[1] | Torrey Rodgers[2] | Thomas W. Franklin[1] | Kellie J. Carim[1] | Michael K. Young[1] | Kevin S. McKelvey[1] | Karen E. Mock[2] | Michael K. Schwartz[1]

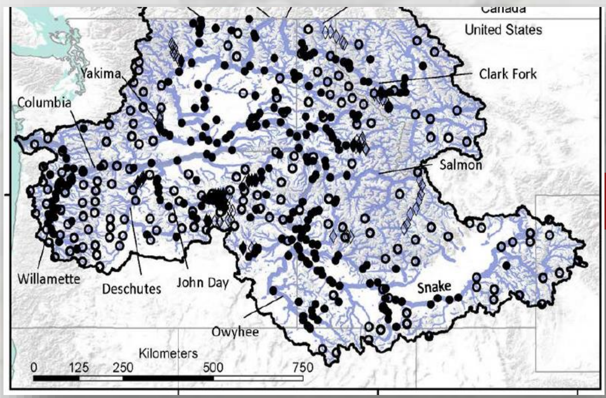
Young et al. 2018. Species occurrence data from the eDNAtlas database. U.S. Forest Service Data Archive. https://doi.org/10.2737/RDS-2018-0010.

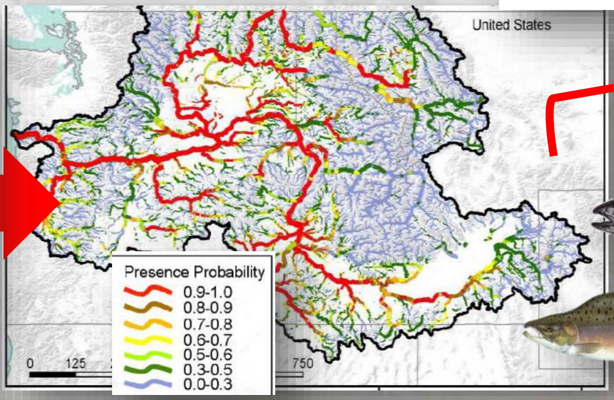
Challenge: Anadromous Species Applications?

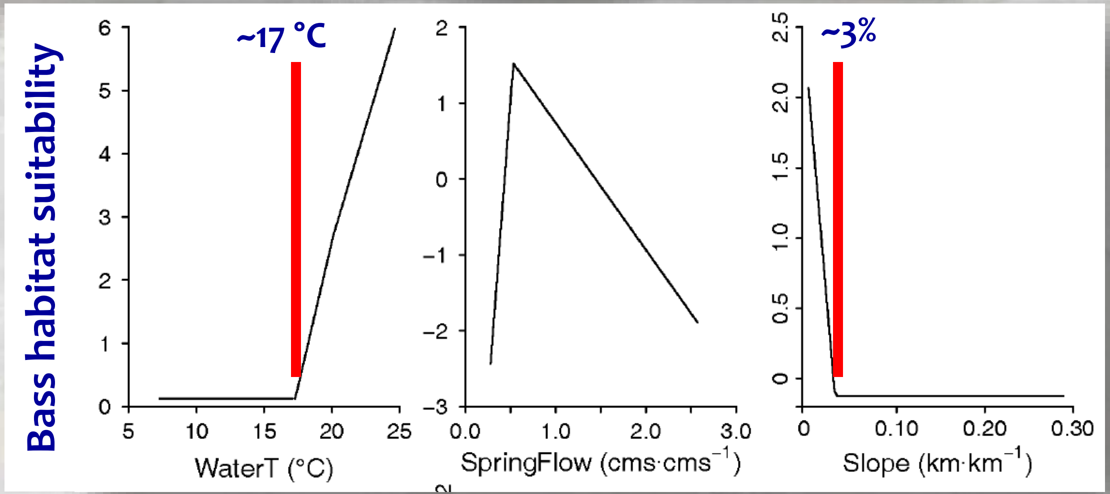
Spawning & rearing predation refugia

Accurate SMB distribution model from historical datasets & new eDNA occurrence surveys









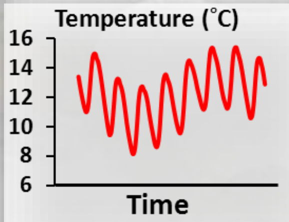
Rubenson & Olden. In press. An invader in salmonid rearing habitat: current and future distributions of smallmouth bass in the Columbia River Basin. *Canadian Journal of Fisheries and Aquatic Sciences* **76**:xxx-xxx.

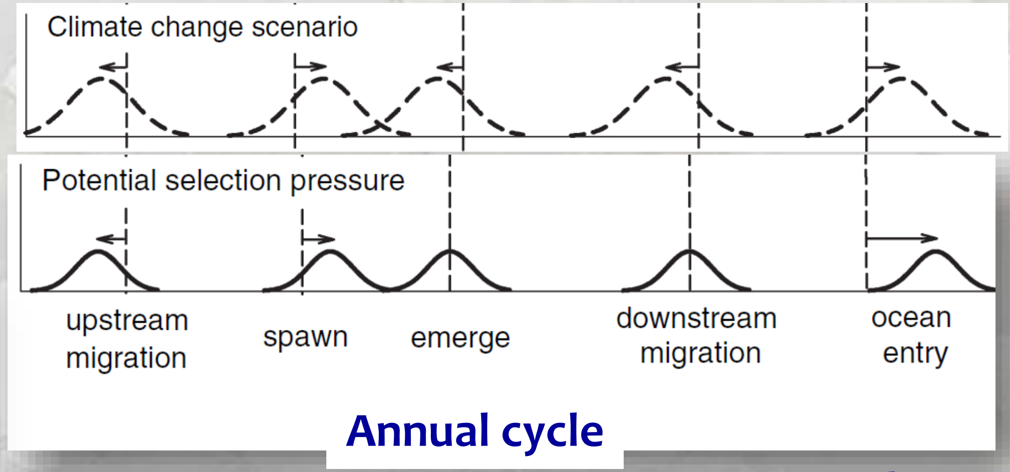
Challenge: Anadromous Species Applications?

Migratory habitats need higher resolution scenarios

FLIR inventory maps of spatial microrefugia along rivers

Climate forecasts with intra-annual resolution (i.e., river weather forecasting system)





Crozier et al. 2008

Climate Refugia put us on a Path to Preserve More Cool Critters in the Long-run