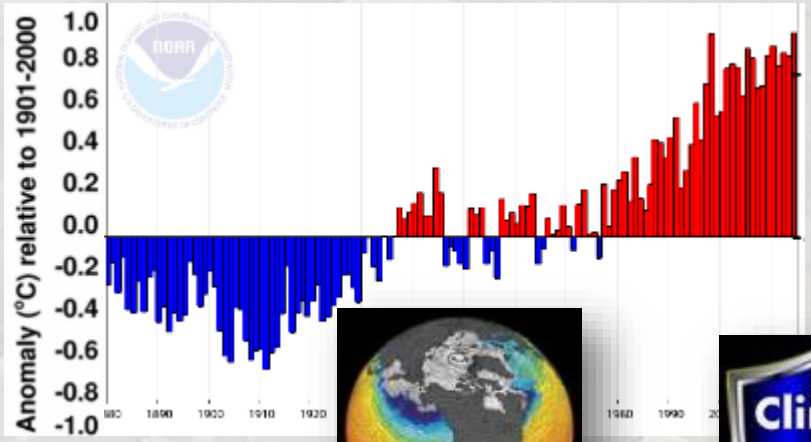
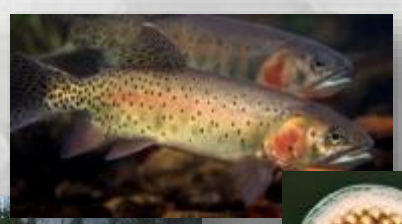
Building a Crowd-Sourced Climate Shield & Aquatic eDNAtlas to Protect BioDiversity in the American West

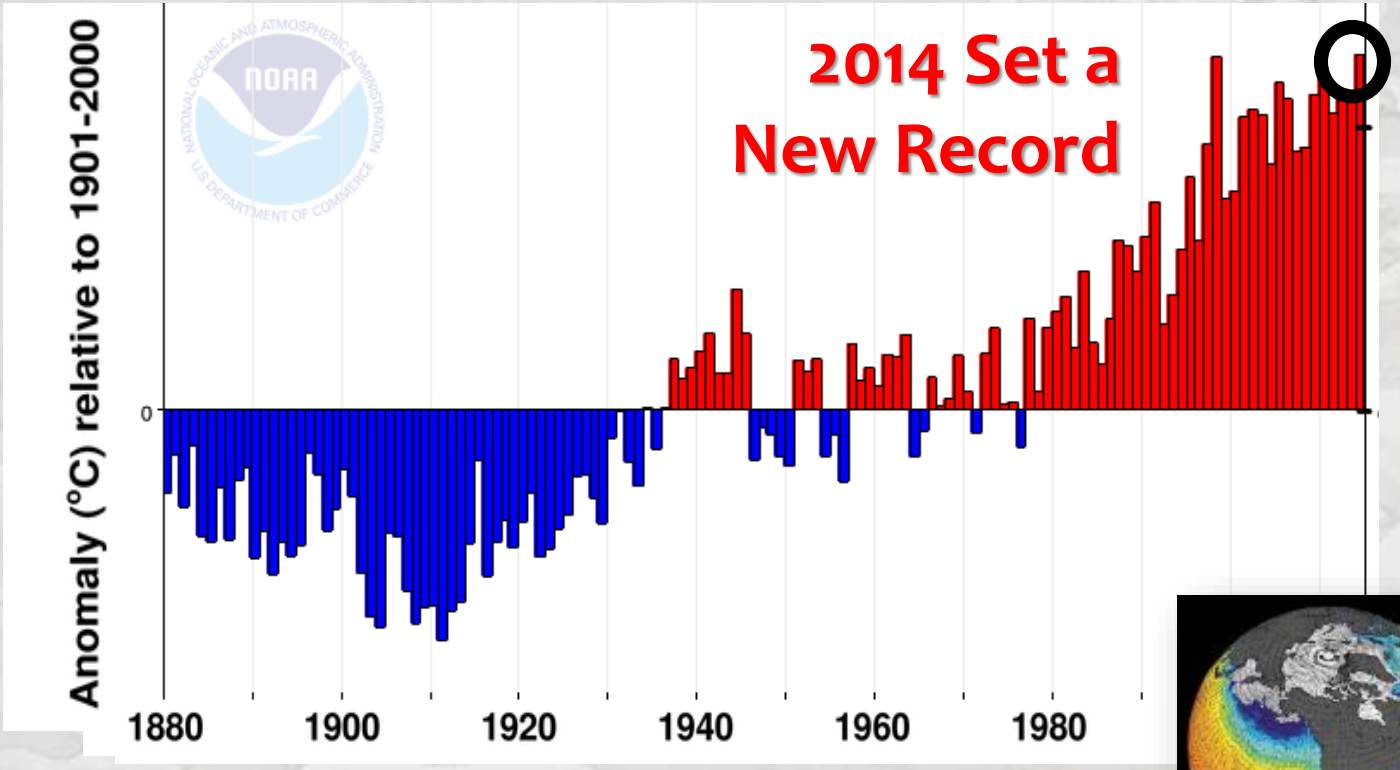
Dan Isaak and Mike Young

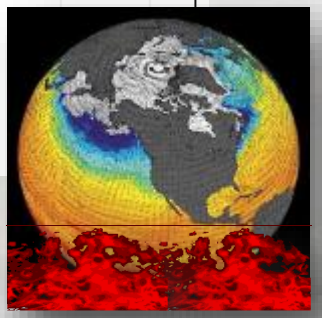




The New Reality…

1880-2014 Global Air Temperature Trend





The New Reality…

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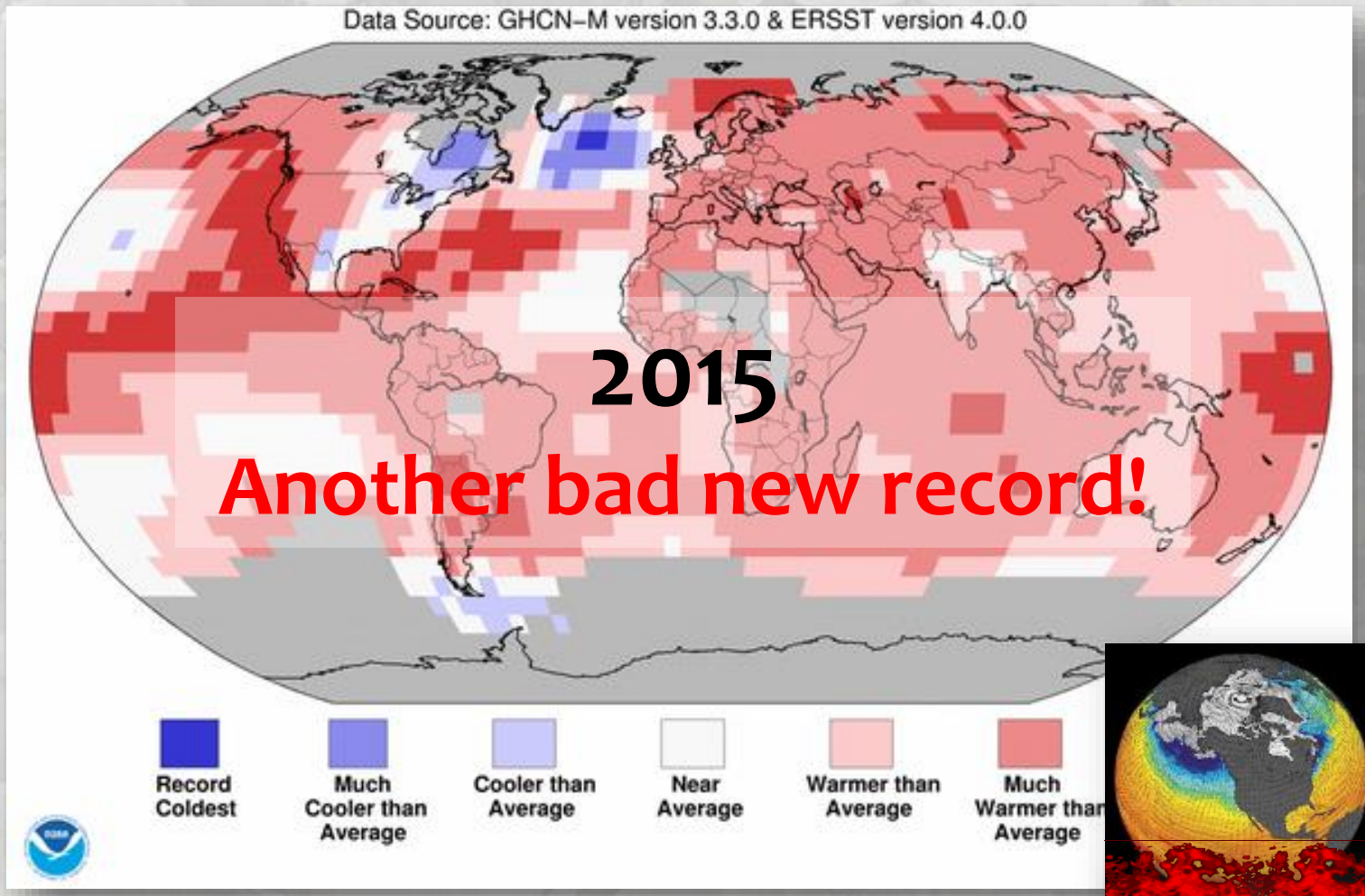
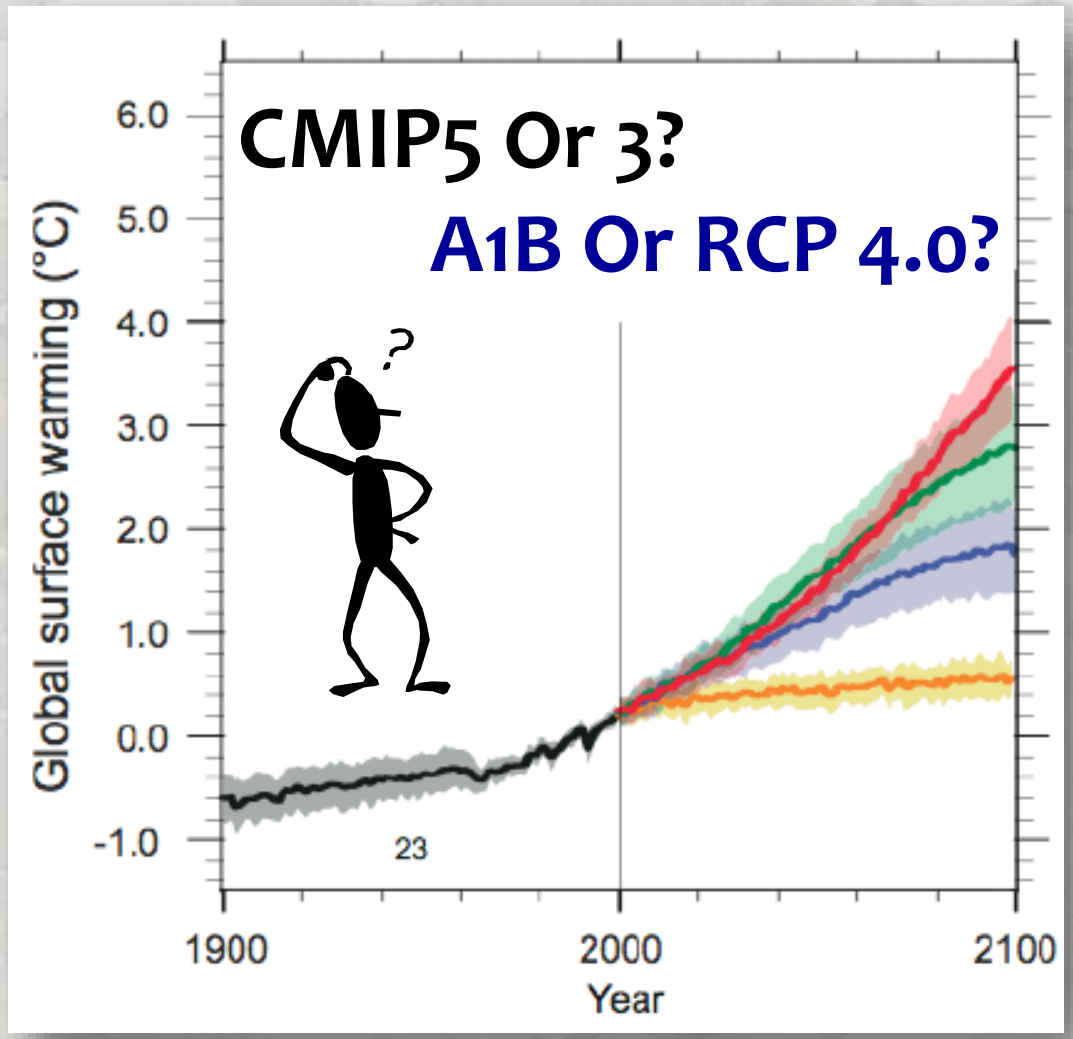


How Much Warmer & When?

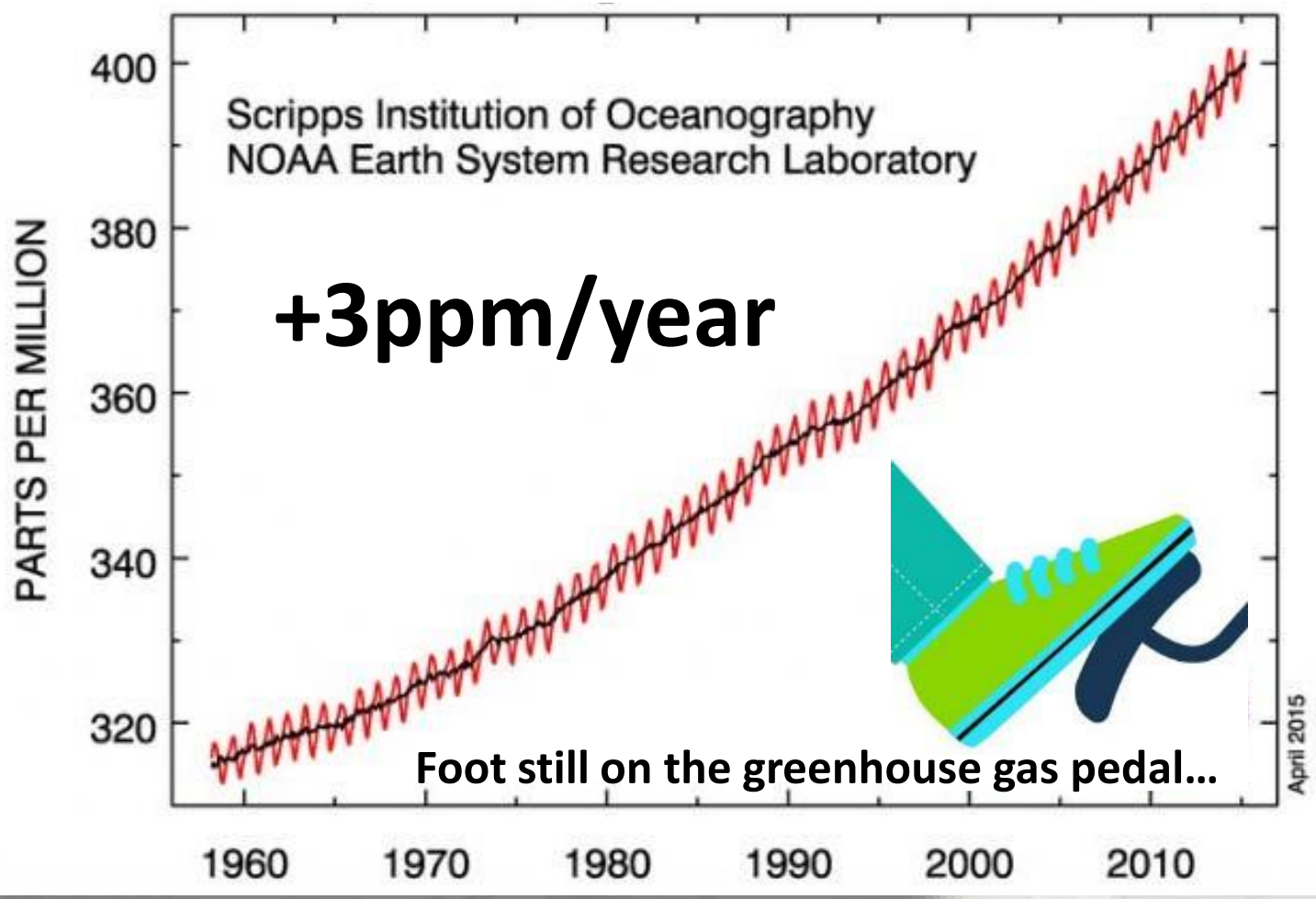
The Future is Uncertain…



The Specifics are an "Unknowable Unknown"

How Much Warmer & When?

Atmospheric CO2 Concentration

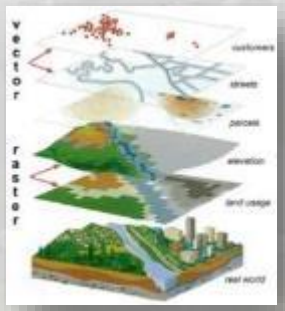


Plan on continued warming for decades…

Coordination is Needed to Create Synergies Among All Natural Resource Groups

Many stakeholders

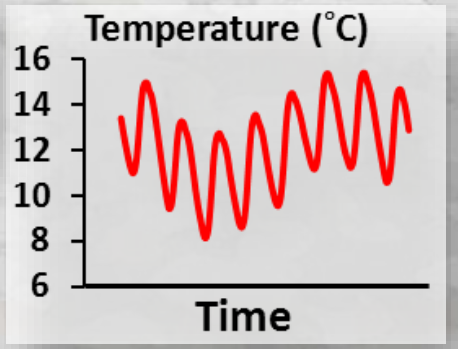
"Boots-on-the-Ground"



Research develops databases & relevant information

Standardized data protocols

An Example with Stream Temperature Data…



Funding agencies:

Great Northern Landscape Conservation Cooperative · NASA · NFWF · North Pacific Landscape Conservation Cooperative · USFWS · USFS

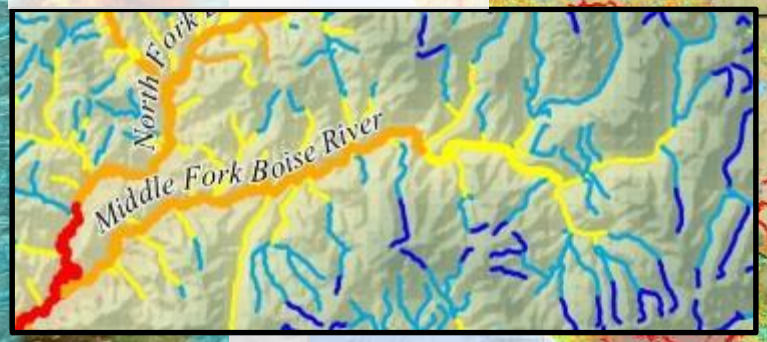
>100 agencies

>200,000,000 hourly records

>20,000 unique stream sites

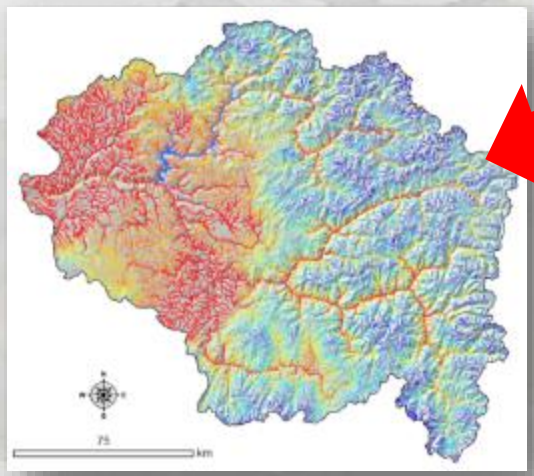
High-Resolution Stream Climate Scenarios

1-km resolution
400,000 kilometers

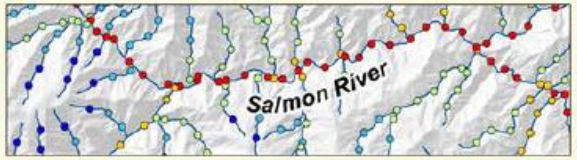


Website: Distributes Data Products in User-Friendly Digital Formats

1) GIS shapefiles of stream temperature scenarios



Google "NorWeST temperature"



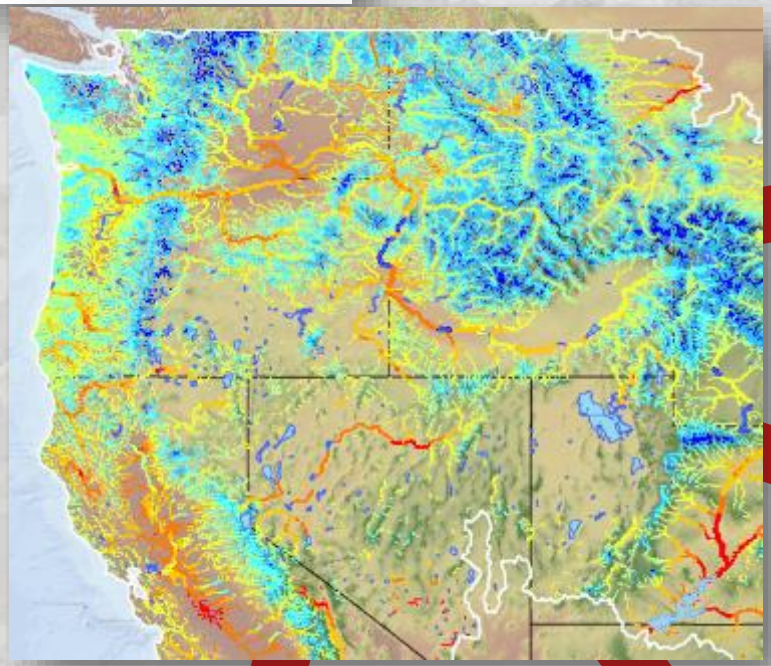
Regional Database and Modeled Stream Temperatures

2) Temperature data

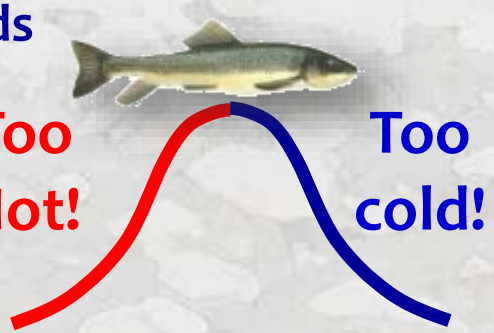
40-50 visits/day; 12,000 visits/year

NorWeST Stream Temp

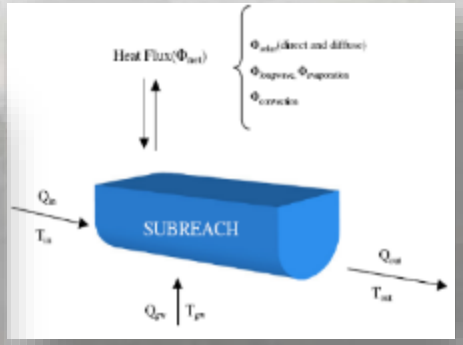
Temperature Applications



Regulatory temperature standards



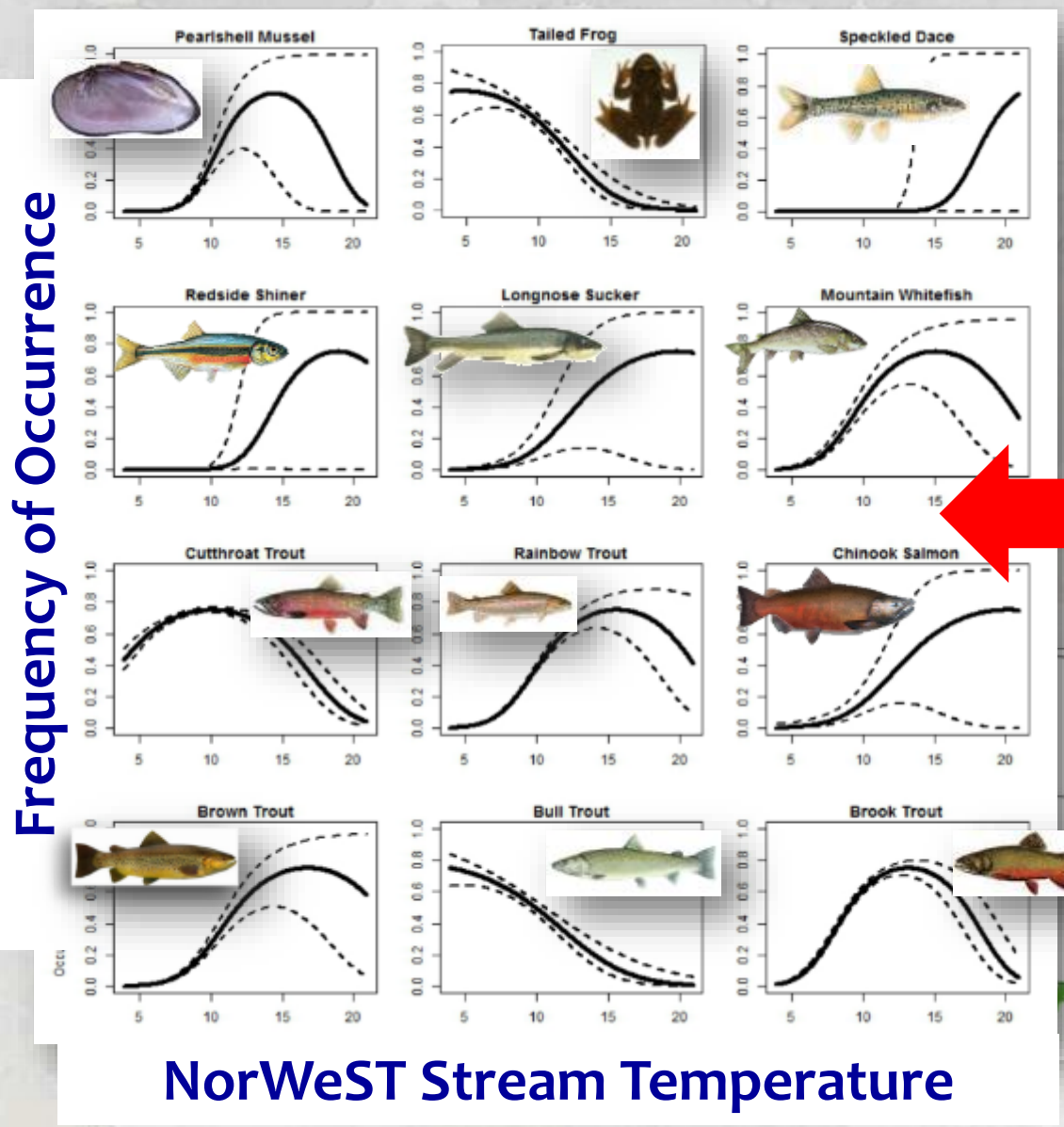
Data access accelerates temperature R&D



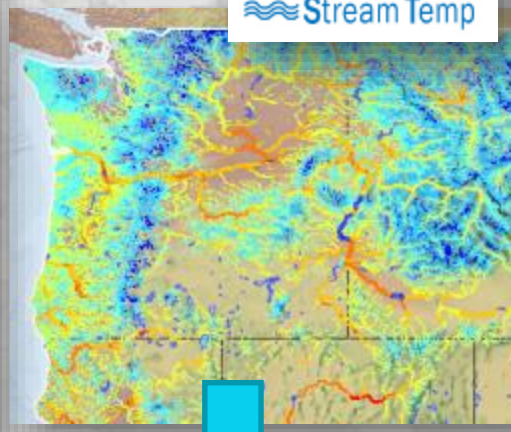
Coordinated Interagency monitoring

Species distribution models & climate assessments

Temperature is Destiny for Aquatic Species



NorWeST Stream Temp

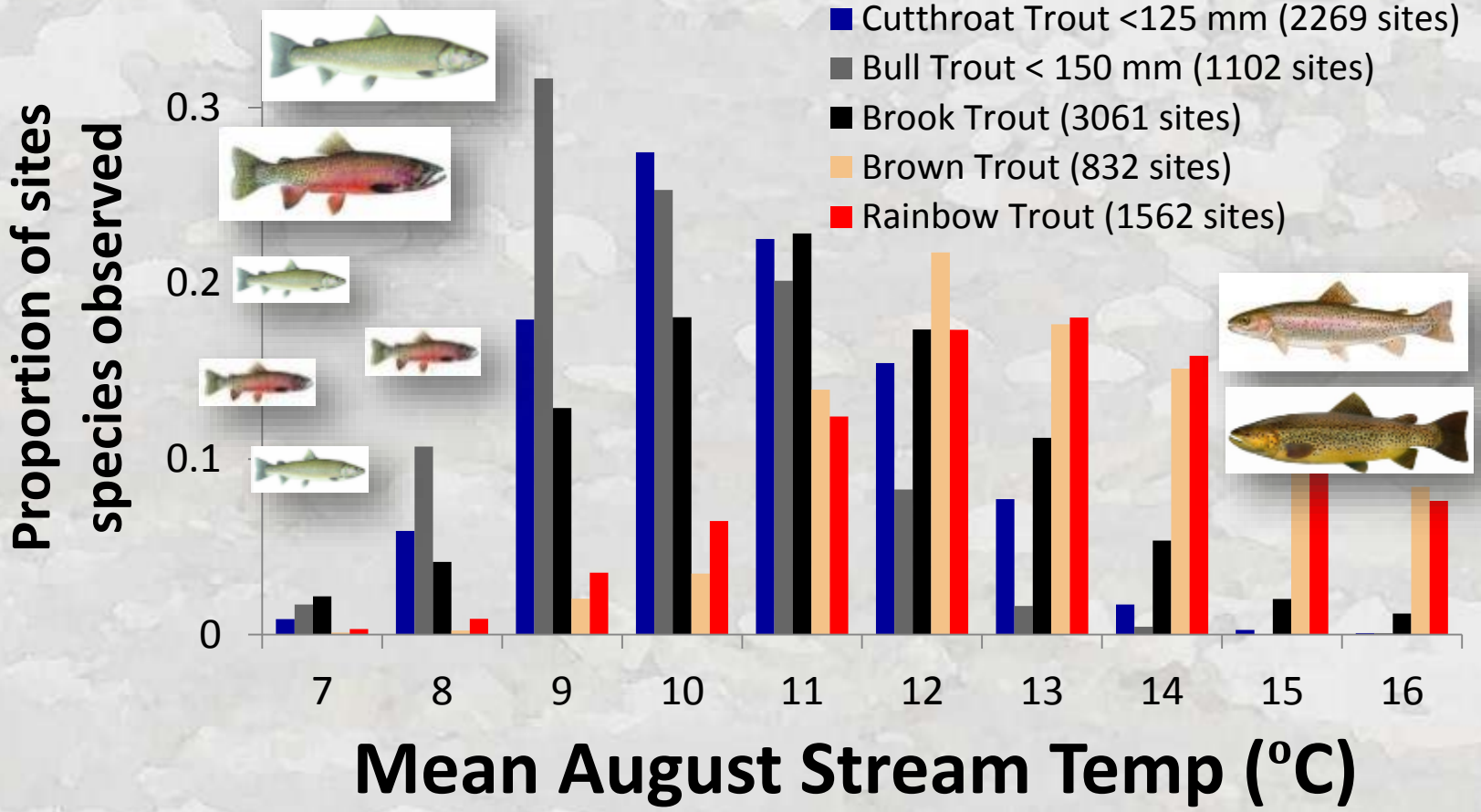


BIG FISH Data

13,000 sites

Isaak et al. 2017. Big biology meets microclimatology. *Ecological Applications*

Cold Climates Exclude Invaders from Native Trout Habitats

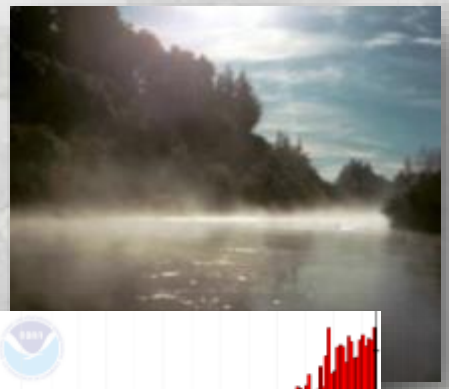


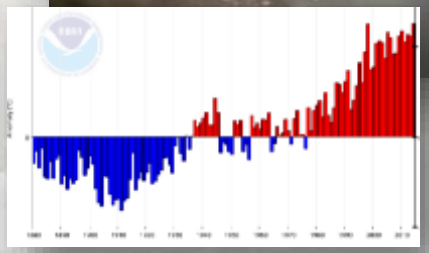
The Cold-Water Climate Shield

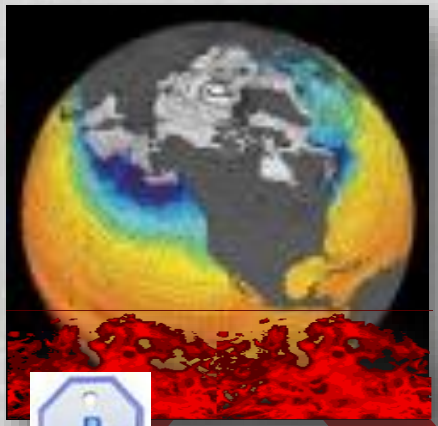
Delineating Refugia for Preserving Native Trout

Dan Isaak, Mike Young, Dave Nagel, Dona Horan, Matt Groce

US Forest Service - RMRS







Climate Shield

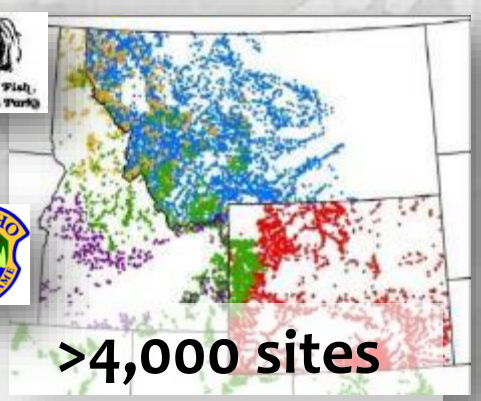
Rocky Mountain Research Station

Boise Spatial Streams Group

NorWeST Stream Temp

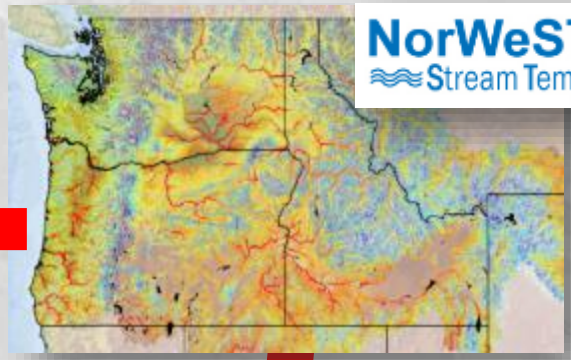
Precise Species Distribution Models to Highlight Climate Refugia

BIG FISH DATA

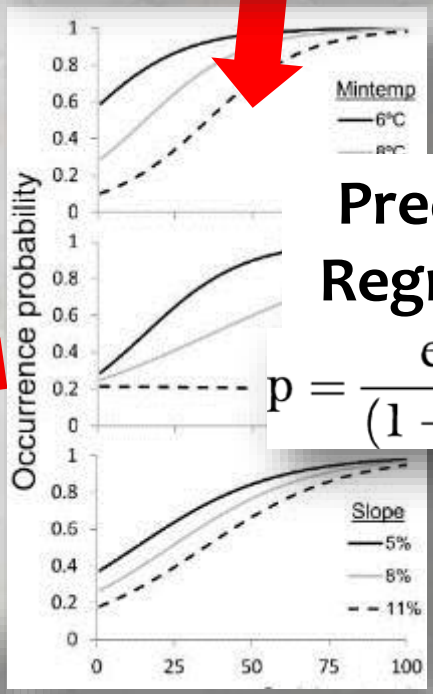


>4,000 sites

>500 streams

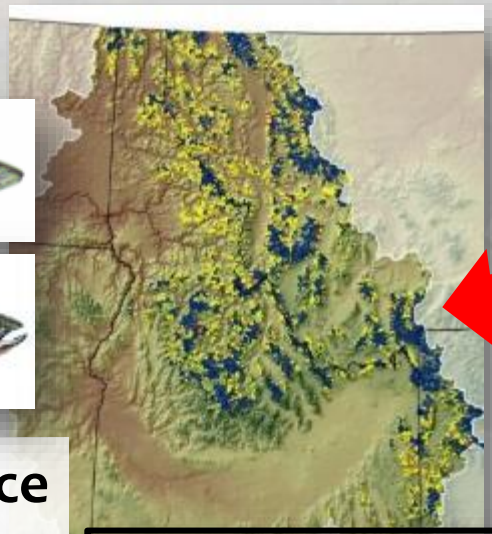


Climate Shield

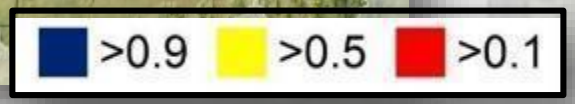


Predictive Logistic Regression Models

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



Occurrence probability maps



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 Probability Map

1980s

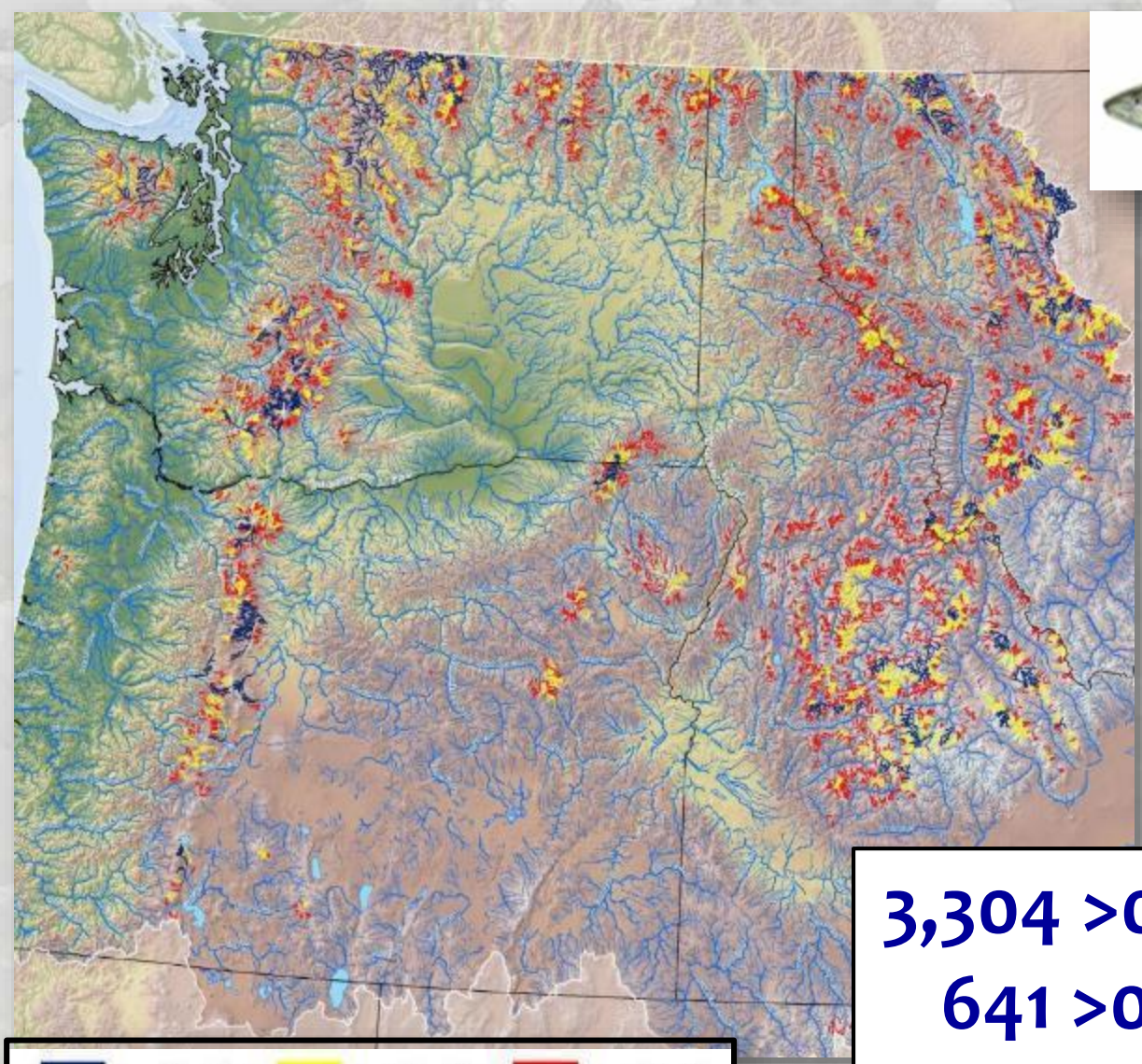
Stream population scale predictions

>0.9 >0.5 >0.1

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

Bull Trout Probability Map

2040s



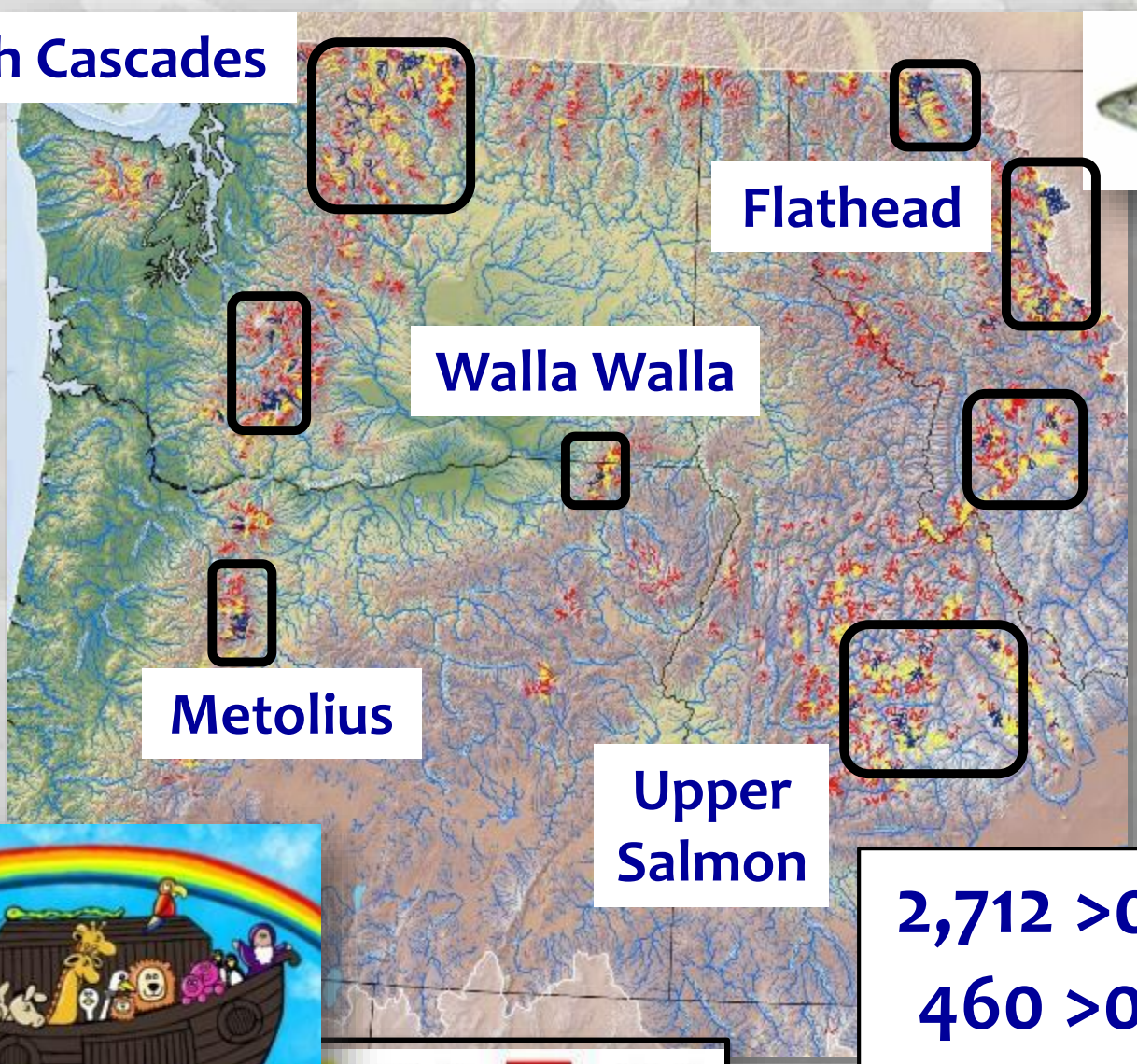
3,304 >0.1 habitats

641 >0.5 habitats

130 >0.9 habitats

Bull Trout Probability Map

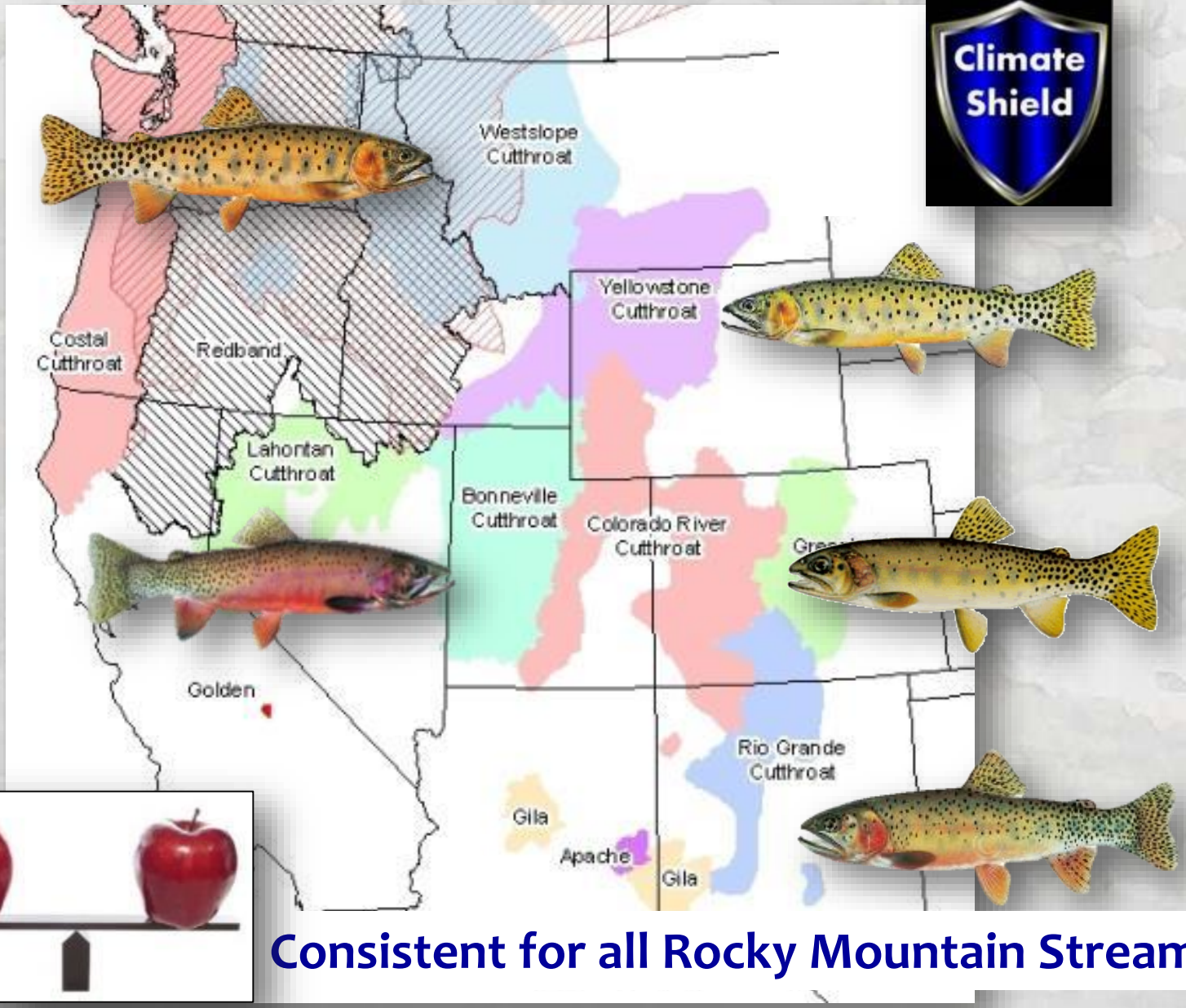
2080s



Extreme scenario!
+5°C

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

All Cutthroat Trout Streams too…



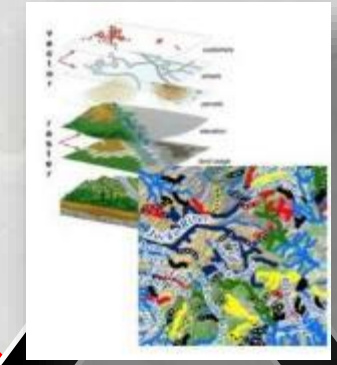
Consistent for all Rocky Mountain Streams

Website Provides Information in User-Friendly Digital Formats

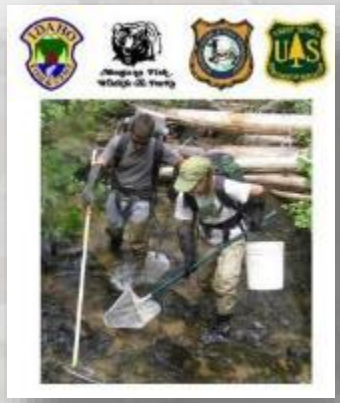
Just Google "Climate shield trout"

Presentations & Publications

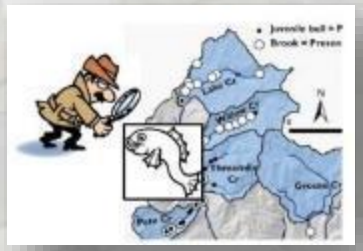
Digital Maps & ArcGIS Shapefiles



Fish Data Sources



Distribution Monitoring



File formats:

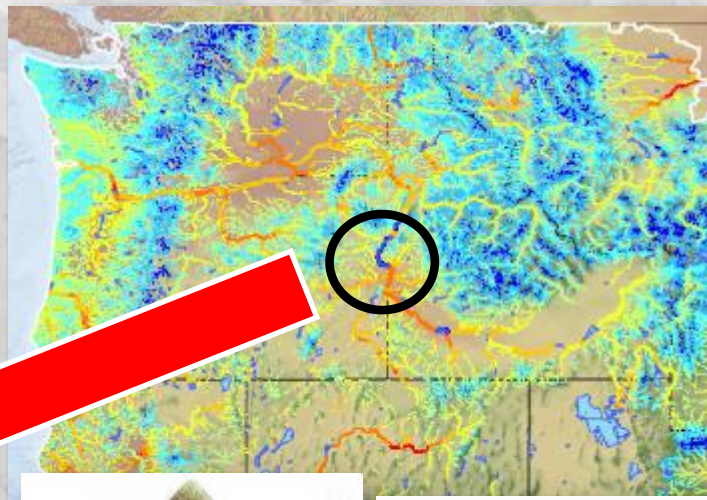
- ArcGIS files
- pdf files

15 Scenarios:

- 3 climate periods
- 5 Brook invasion levels

Precise Information Across Broad Scales

Empowers local decision makers & facilitates efficient coordination



Highest priority conservation investment!

Goal: Extend Climate Shield to All Species

Climate Shield

Assessing aquatic biodiversity requires knowing <u>who lives where</u>

- Knowing who
- Knowing where
- Sharing that knowledge



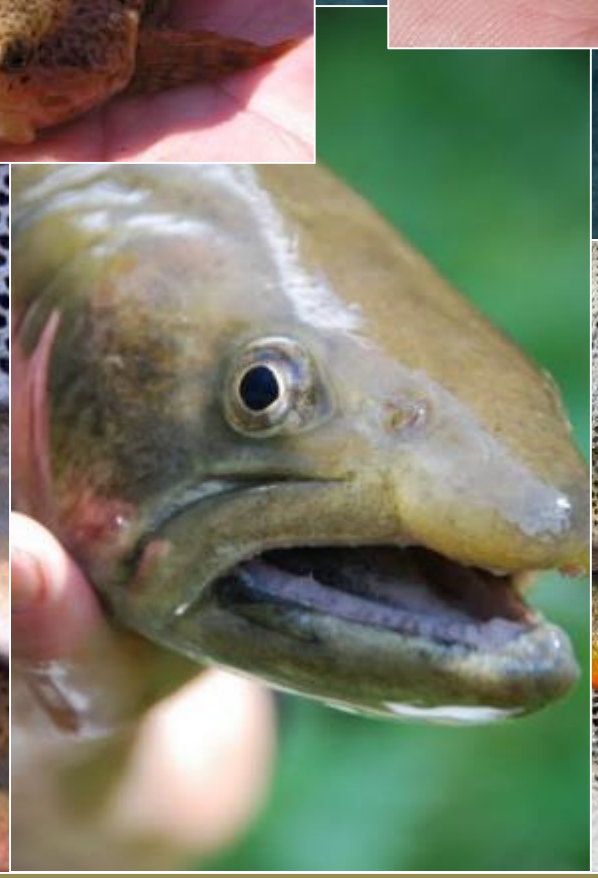









The range-wide, eDNA-based inventory of everything: the Aquatic eDNAtlas

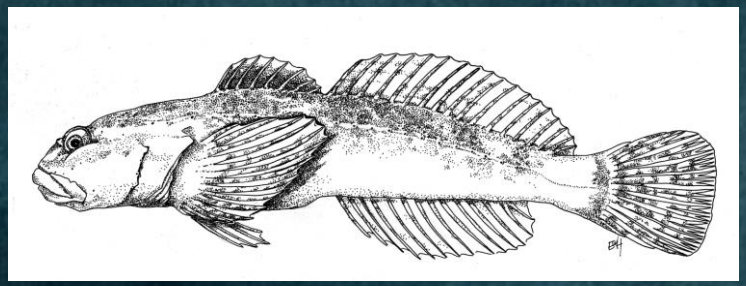


11 January 2017 – Conservation Biology Institute, Corvallis, OR

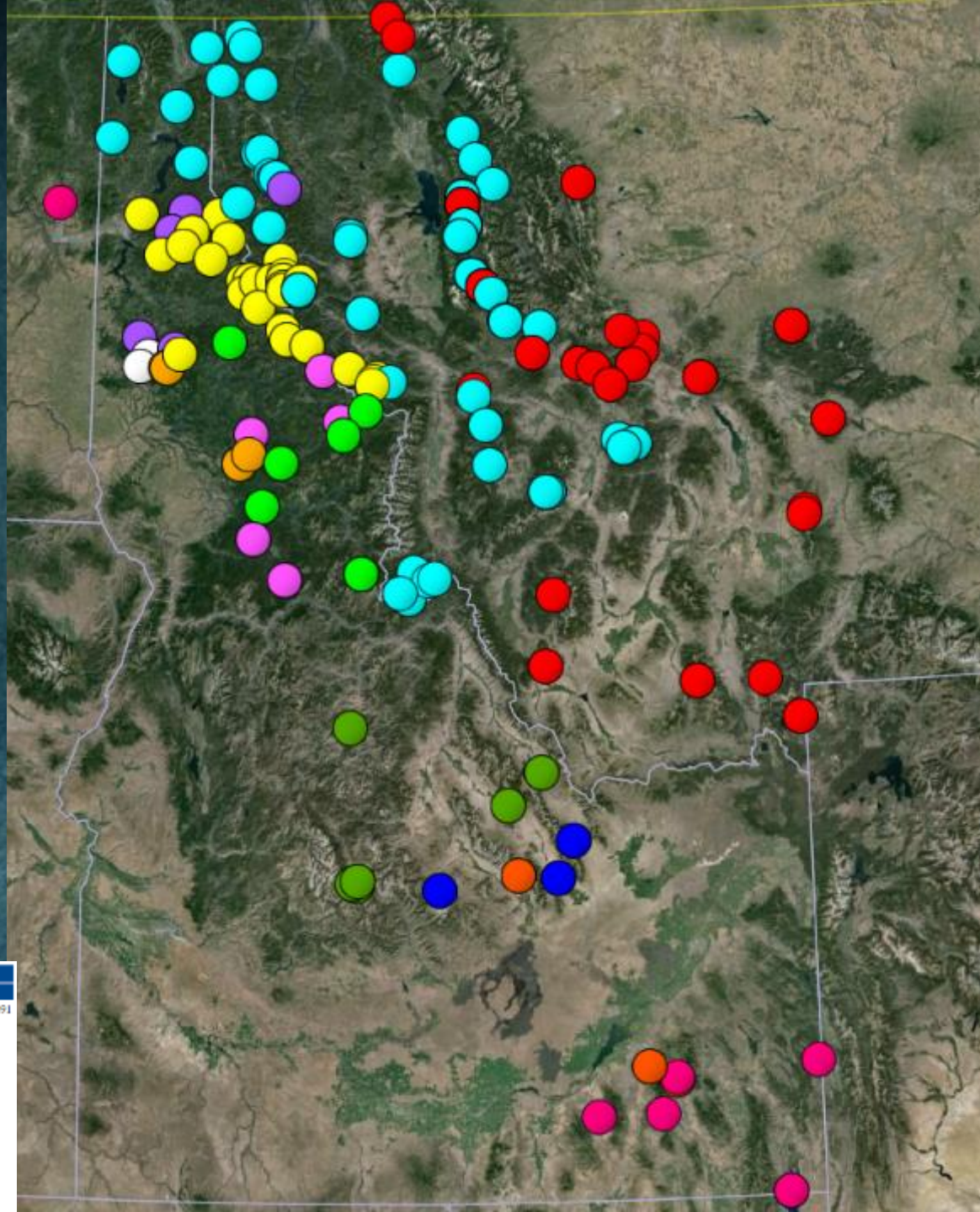
Knowing who

- For most species, we know who we're looking for

- Sculpin are not like most species: 15—40 West-wide



- How to know:
  - Traditional DNA methods
  - Region-wide
  - Crowd-sourced sampling
  - Sharing that knowledge



MOLECULAR ECOLOGY
RESOURCES
Molecular Ecology Resources (2013) doi: 10.1111/1755-0998.12091

DNA barcoding at riverscape scales: assessing biodiversity among fishes of the genus *Cottus* (Teleostei) in northern Rocky Mountain streams

MICHAEL K. YOUNG, KEVIN S. MCKELVEY, KRISTINE L. PILGRIM and MICHAEL K. SCHWARTZ
U.S. Forest Service, Rocky Mountain Research Station, 800 East Beckwith Avenue, Missoula, MT 59801, USA

Sculpins of the West

Broad-scale genetic monitoring of aquatic species

Wanted: Your help to understand the diversity of *Cottus* in western North America

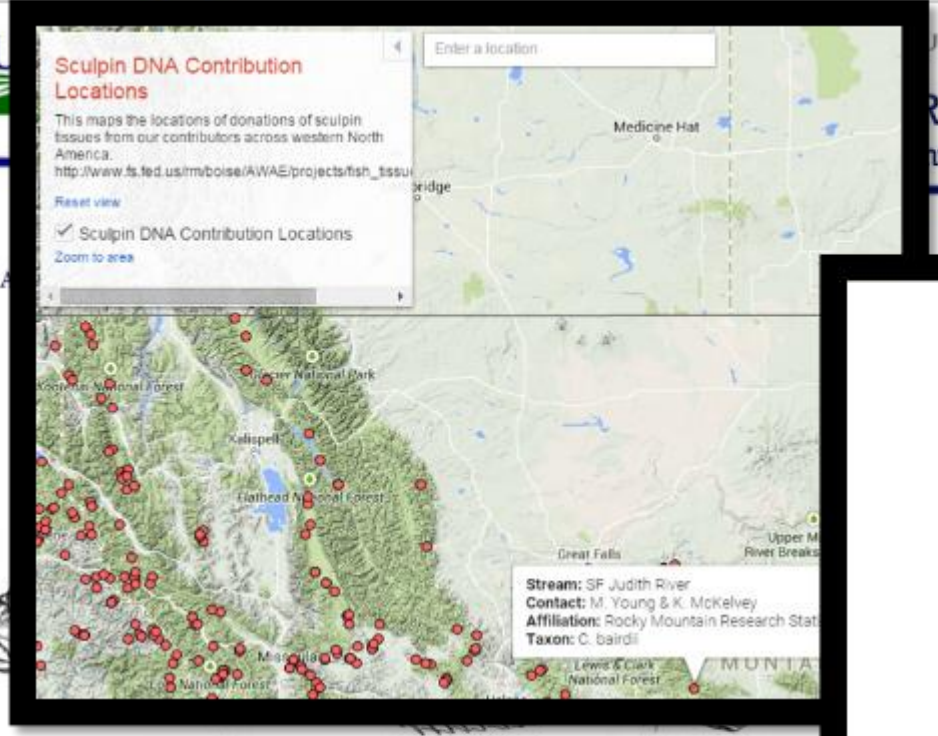
Fishes of the genus *Cottus* –the sculpins– have long been a challenge for fish managers and ichthyologists in the West. They share streams, rivers, and lakes with trout and salmon, and depend on the same kinds of habitats with relatively cold, clean water. Yet we don't know how many kinds of sculpins there are. The morphological differences between species are so subtle that even experts are occasionally baffled. Thus, it seems likely that the biodiversity of sculpins in the West is underestimated and unappreciated.

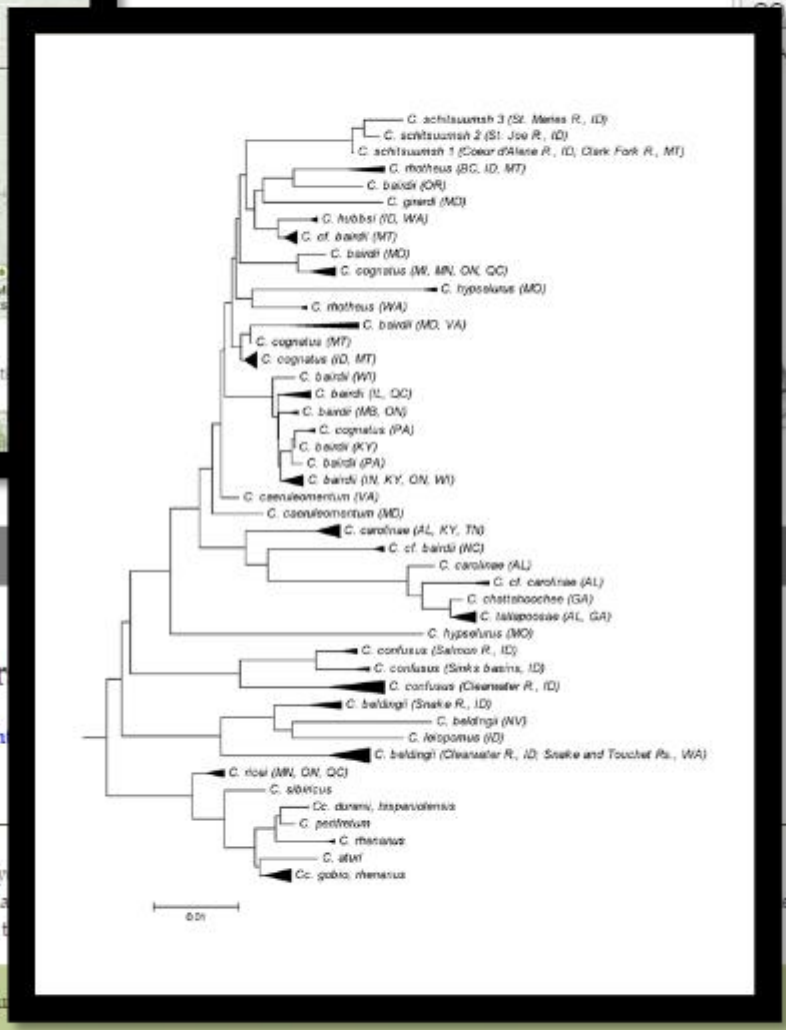
Sculpin Qwest

"In our studies of the freshwater cottid fishes of weste… …tematic review is still incomplete . . ."

-- Reeve Bailey & Carl Bond, 1963

The last major attempt to understand this diversity was over a half-century ago. With your assistance, we would like to renew the efforts to characterize the sculpins of western North America.





A template for any eDNA study
Exemplifies parts of the eDNAtlas

Knowing who's where: eDNA sampling (A)

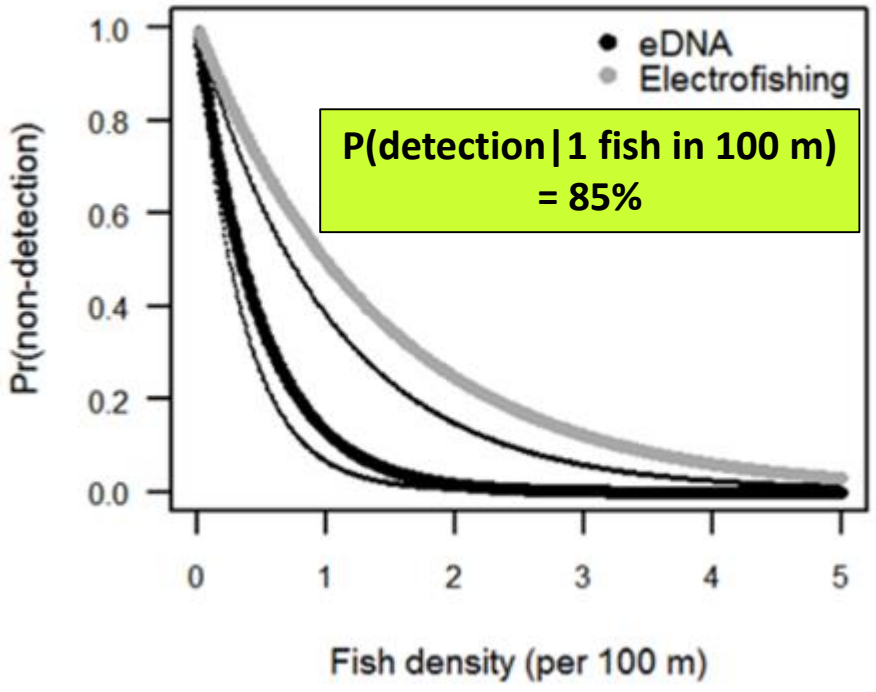
- e = environmental
- Fast
- Portable
- Stable
- Cost: pennies on the dollar, minutes on the hour
  - Rapid, broad-scale surveys are feasible

Knowing who's where: eDNA sampling (B)

- Reliably* species-specific
- Sensitivity: high & quantified
  - Occupancy estimates are robust

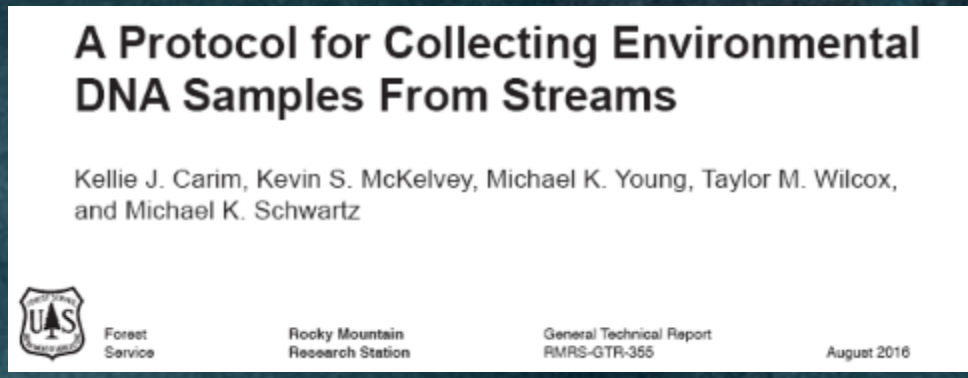
A smattering of eDNA assays

- Trout: rainbow, westslope cutthroat, Yellowstone cutthroat, brown, golden
- Charr: bull, brook, Dolly Varden, lake, Arctic
- Salmon: Chinook, chum, coho, pink, sockeye
- Arctic grayling
- Any salmonid
- Pacific & brook lamprey
- Game fish/invaders: northern pike, sauger, walleye, smallmouth bass
- Non-game fish: sculpin (several), northern leatherside chub, loach minnow, spikedace
- Amphibians: Rocky Mountain tailed frog, western toad
- Mussels: western pearlshell, California floater
- Invertebrates: opossum shrimp
- North American river otter
- Harlequin duck
- Your species here...



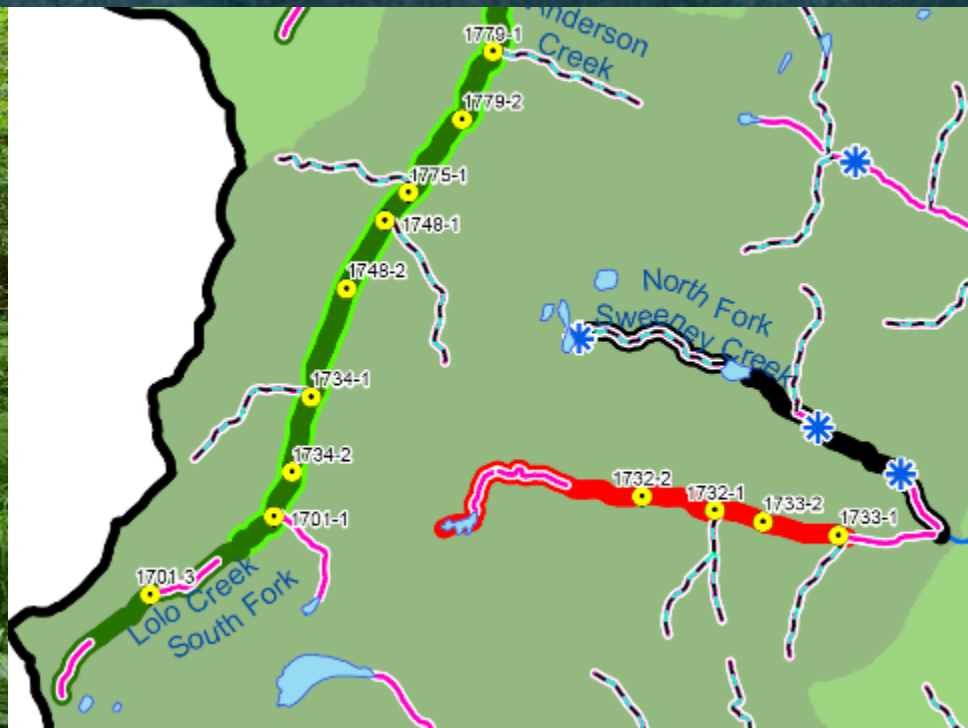
Knowing who lives where: eDNA sampling (C)

- Apply a consistent approach
- Craft a sampling design
- Engage the stakeholders
  - Defensible, consistent, precise, and range-wide estimates of occupancy for priority species in real time at reasonable cost


A Protocol for Collecting Environmental DNA Samples From Streams

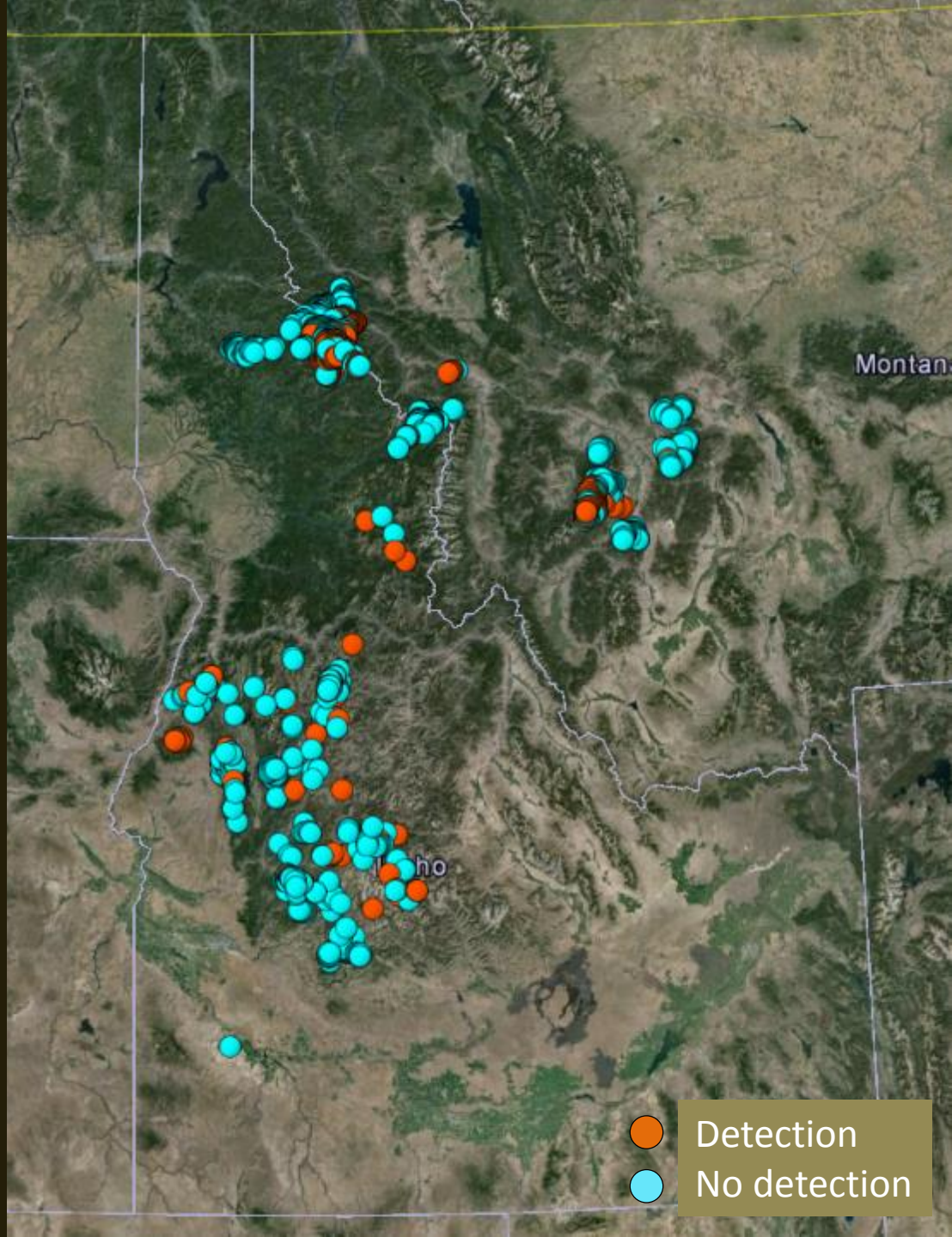
Kellie J. Carim, Kevin S. McKelvey, Michael K. Young, Taylor M. Wilcox, and Michael K. Schwartz

Forest Service | Rocky Mountain Research Station | General Technical Report RMRS-GTR-355 | August 2016



Example: the range-wide bull trout eDNA project

- Scope: 117 8-digit HUs
- Target: natal bull trout habitats
  - Climate Shield cold-water habitats
  - USFWS critical habitat
  - Habitats formerly occupied
- Grain: sites at 1-km intervals
- Timing: finish by 2018
- Team: NGC, BASL, and 100s of volunteers across the Northwest



The Team

Michael Young, Dan Isaak, Kevin McKelvey, Michael Schwartz, Kellie Carim, Wade Fredenberg, Tommy Franklin, Taylor Wilcox, Matt Groce, Dave Nagel, Dona Horan, Sherry Wollrab

Collaborators

Bureau of Land Management
Bureau of Reclamation
Chehalis Tribe
Clark Fork Coalition
Clearwater Resource Council
Coeur d'Alene Tribes
GNLCC
Idaho Conservation League
Idaho Department of Environmental Quality
Idaho Department of Fish and Game
Idaho Power Company
Kalispel Tribes
Lewis River Bull Trout Recovery Team
Montana Department of Natural Resources Conservation
Montana Fish, Wildlife & Parks
National Fish and Wildlife Foundation
The Nature Conservancy
Nez Perce Tribe
North Cascades National Park
Oregon Department of Fish and Wildlife
Shoshone-Bannock Tribes
Trout Unlimited
University of Washington
U.S. Fish and Wildlife Service
USFS National Forests: Beaverhead-Deer Lodge, Boise, Colville, Deschutes, Flathead, Helena, Idaho Panhandle, Lolo, Mount Baker-Snoqualmie, Nez Perce-Clearwater, Payette, Salmon-Challis, Sawtooth, Wallowa-Whitman, Wenatchee
USFS Regions 1, 4, and 6
Washington Department of Fish and Wildlife
Yakama Nation

Sponsors

Great Northern Landscape Conservation Cooperative

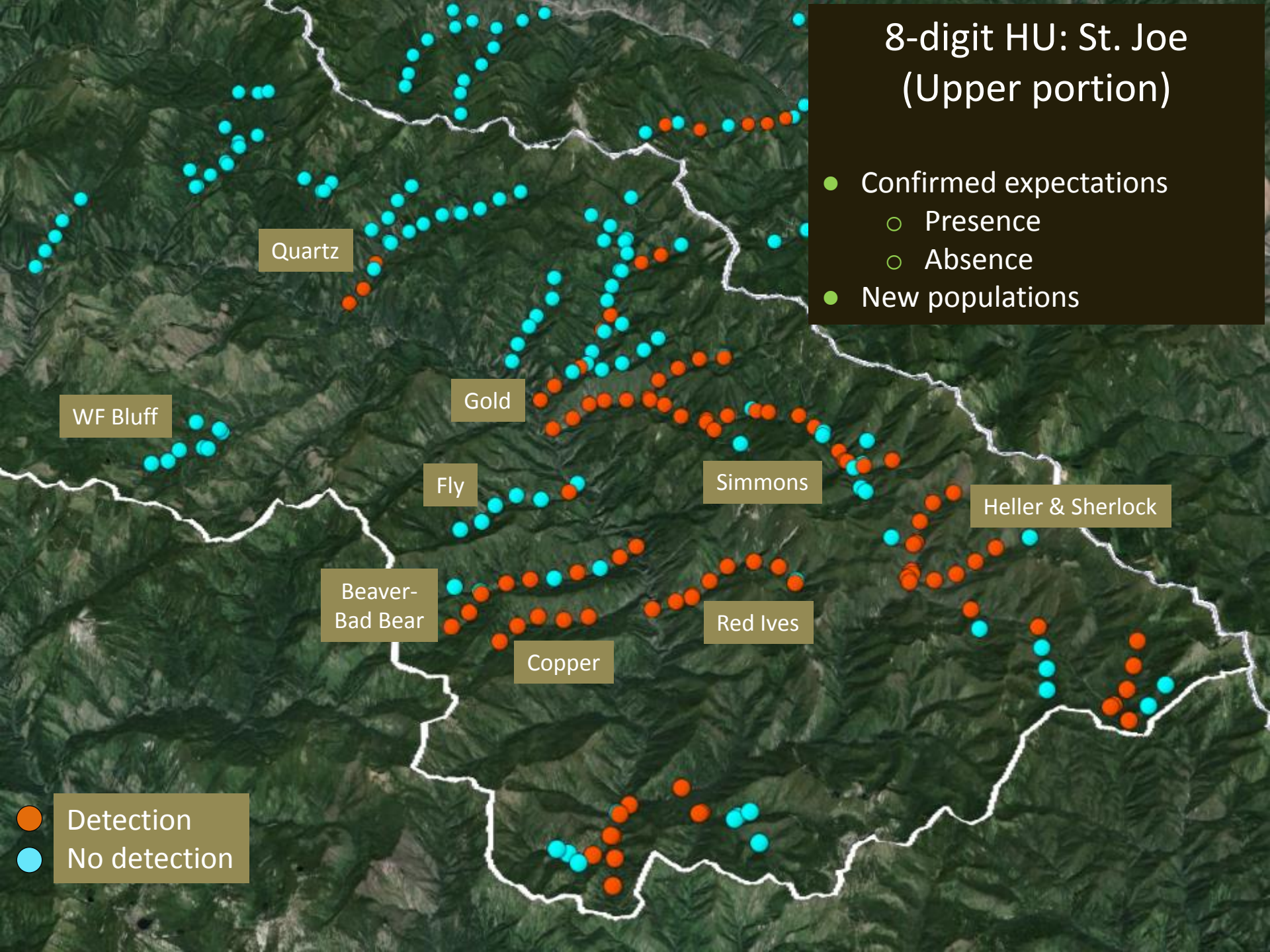
USDA U.S. Forest Service Region 1

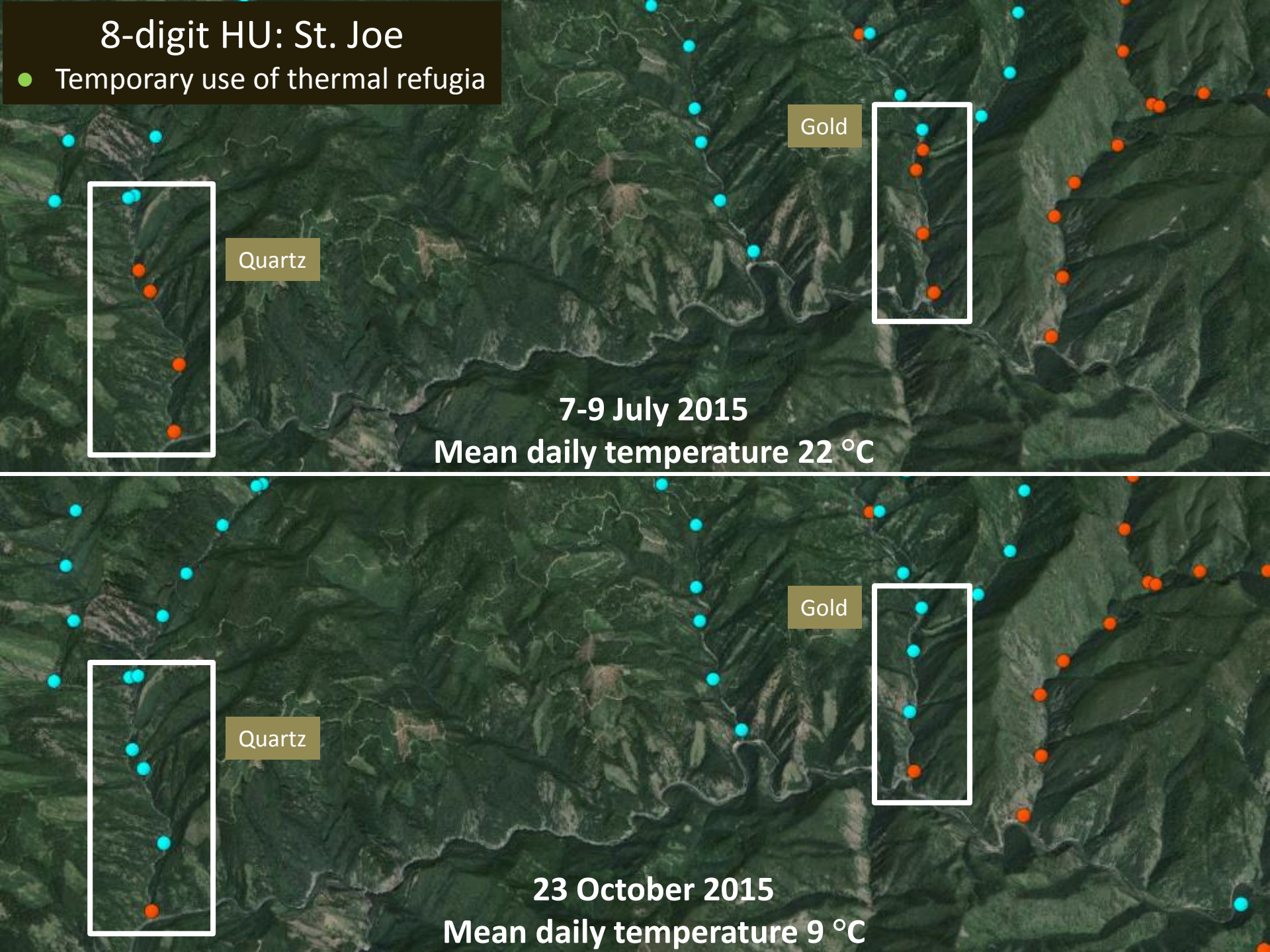
Institutional Support

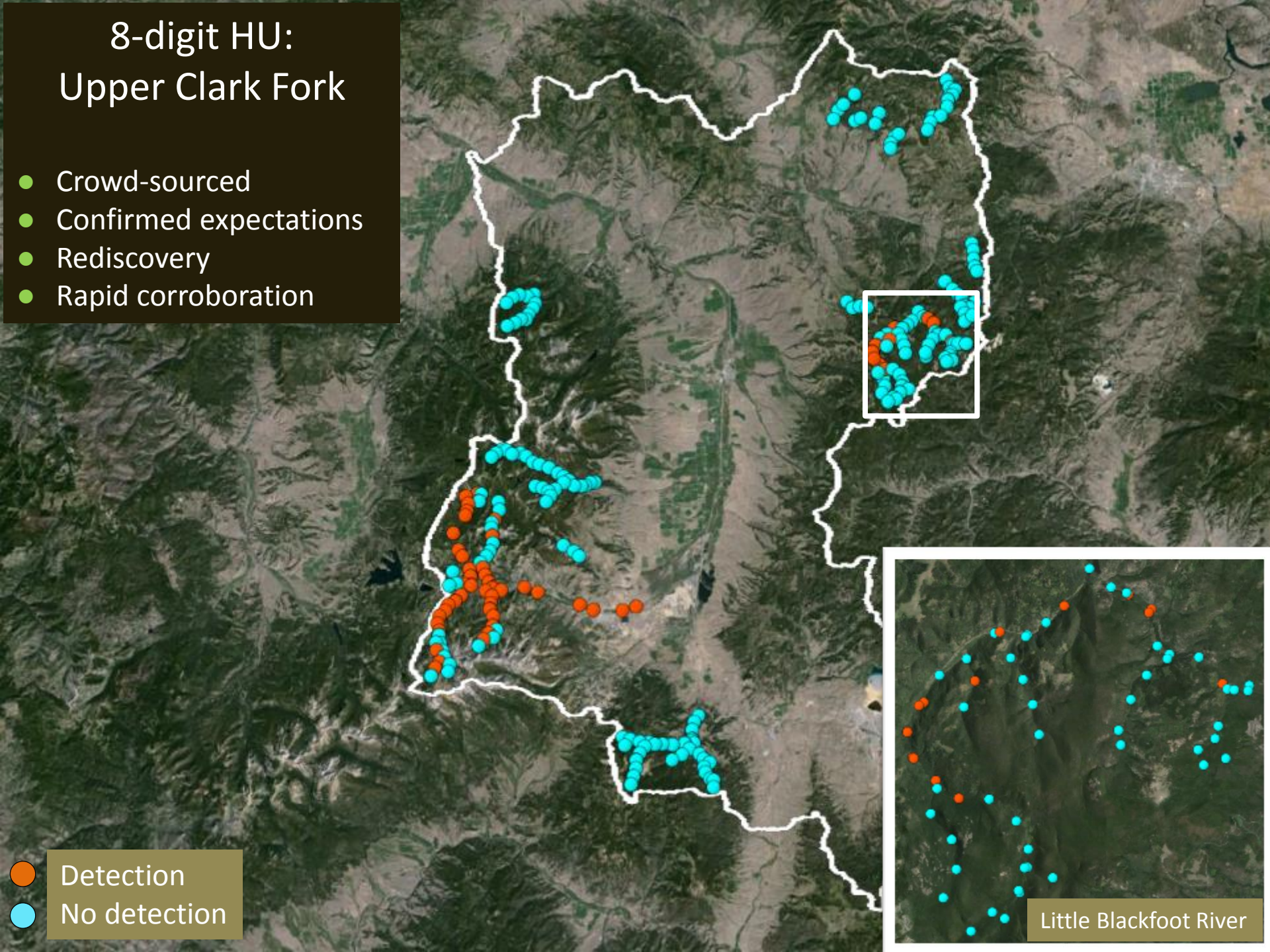
USDA Forest Service National Genomics Center for Wildlife and Fish Conservation

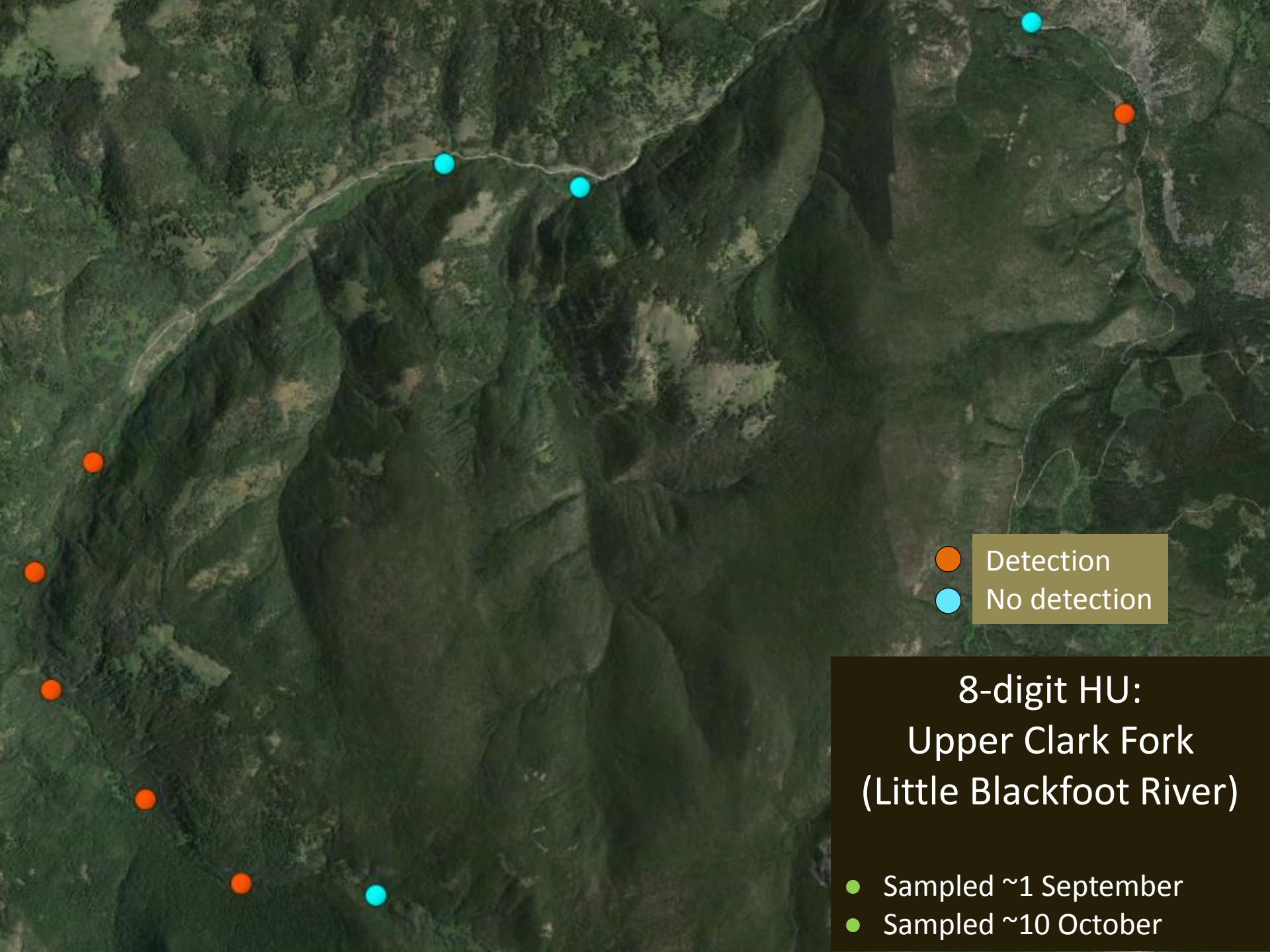
Boise Spatial Streams Group

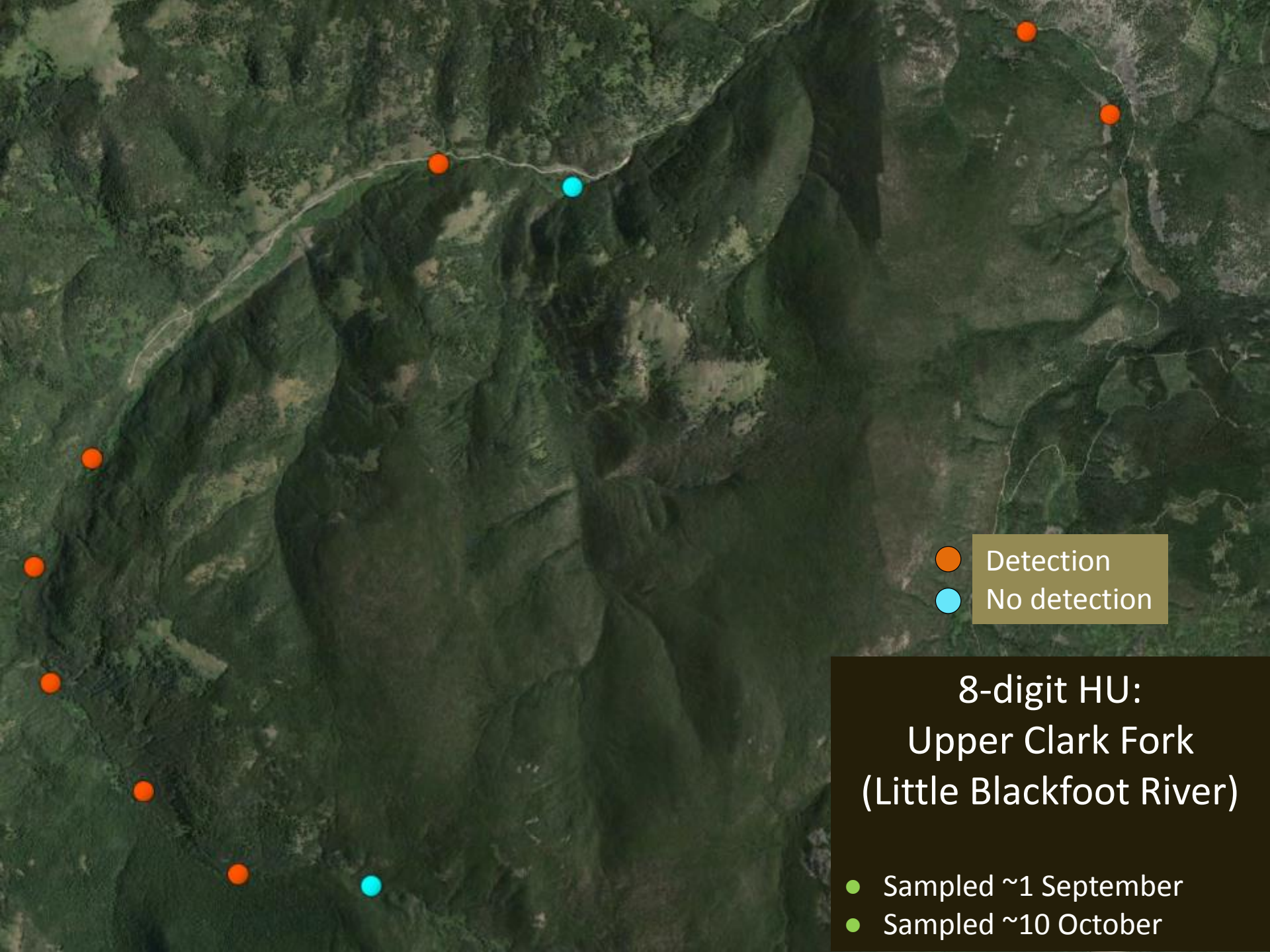
Rocky Mountain Research Station


8-digit HU: St. Joe
(Upper portion)
Confirmed expectations
Presence
Absence
New populations
Quartz
WF Bluff
Gold
Fly
Simmons
Heller & Sherlock
Beaver-
Bad Bear
Red Ives
Copper
Detection
No detection


8-digit HU: St. Joe
Temporary use of thermal refugia
Gold
Quartz
7-9 July 2015
Mean daily temperature 22 °C
Gold
Quartz
23 October 2015
Mean daily temperature 9 °C


8-digit HU:
Upper Clark Fork
Crowd-sourced
Confirmed expectations
Rediscovery
Rapid corroboration
Detection
No detection
Little Blackfoot River


Detection
No detection
8-digit HU:
Upper Clark Fork
(Little Blackfoot River)
Sampled ~1 September
Sampled ~10 October


Detection
No detection
8-digit HU:
Upper Clark Fork
(Little Blackfoot River)
Sampled ~1 September
Sampled ~10 October

The Range-wide Bull Trout eDNA Project: want to get involved?

- Visit the website
  - Google “rangewide bull trout eDNA project”
- Get your “library” card

Website: Rangewide eDNA Bull Trout Project

Many Resources

Supporting Science

Protocols

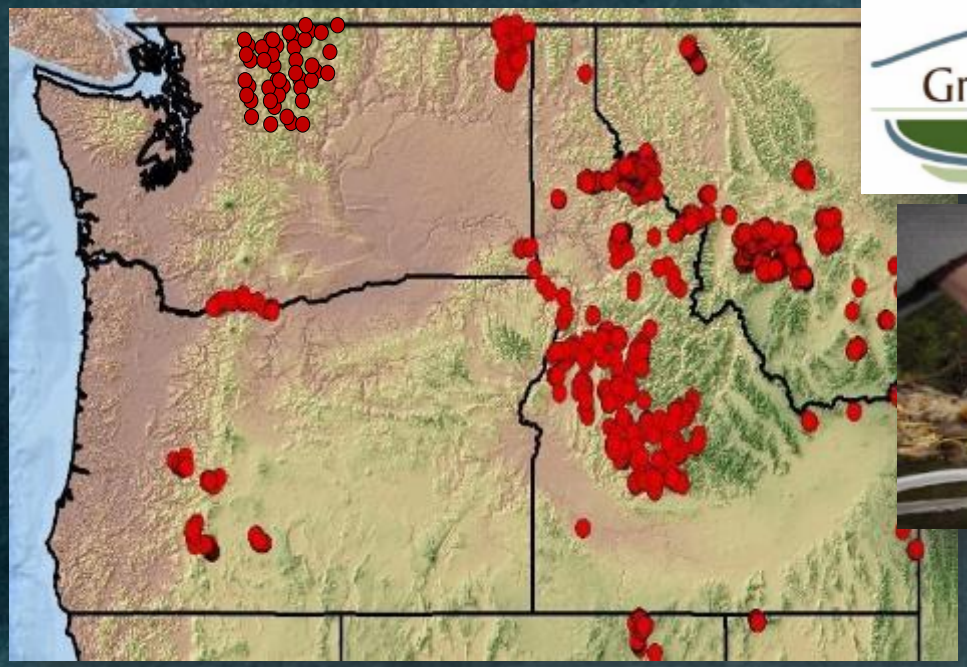
Sampling maps

Results

Range-wide Bull Trout eDNA Project:

2016: 3,500 stream sites sampled

2016-2018: ~10,000 stream sites sampled



Great Northern LANDSCAPE CONSERVATION COOPERATIVE

Sample sites are part of a well-organized database from day 1!

Aquatic eDNAtlas: Open-Access Database for all Species in the American West

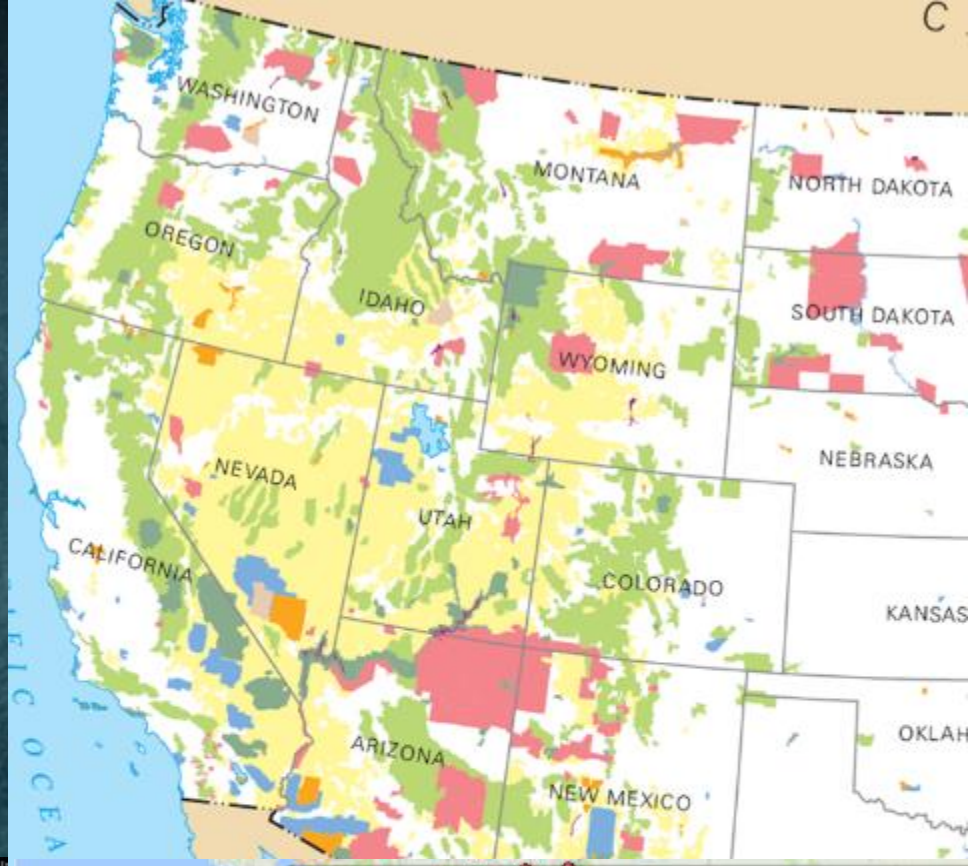
National Genomics Center for Wildlife & Fish Conservation

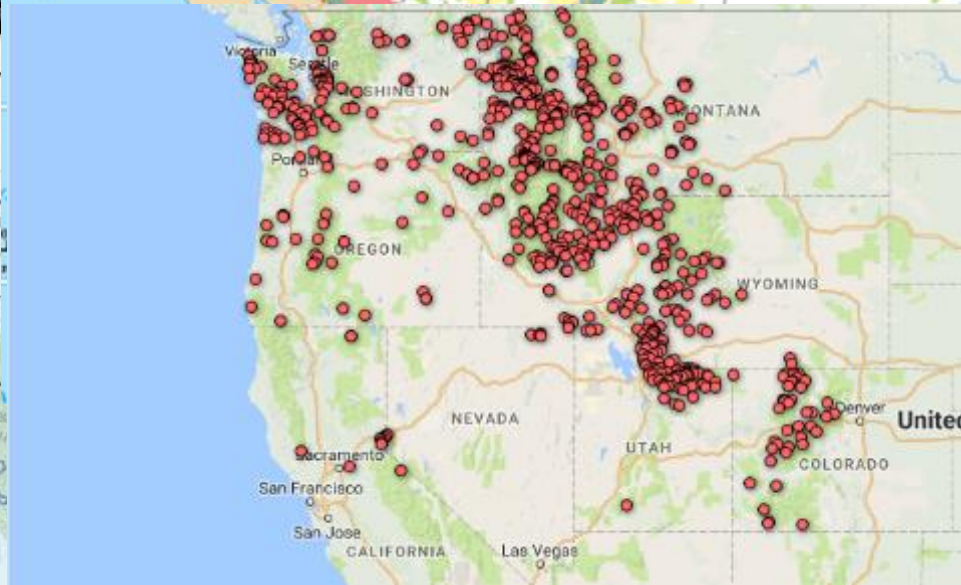
+

Partners have sampled >8,000 sites already…

Sharing the knowledge

- All-lands approach
- Pipeline for data to database
- Linked to NSI hydrography network
- Open access, query-friendly, and downloadable
- Value ++





eDNA samples @ NGC

- 1 sample = many species
- Permanent archives of biodiversity