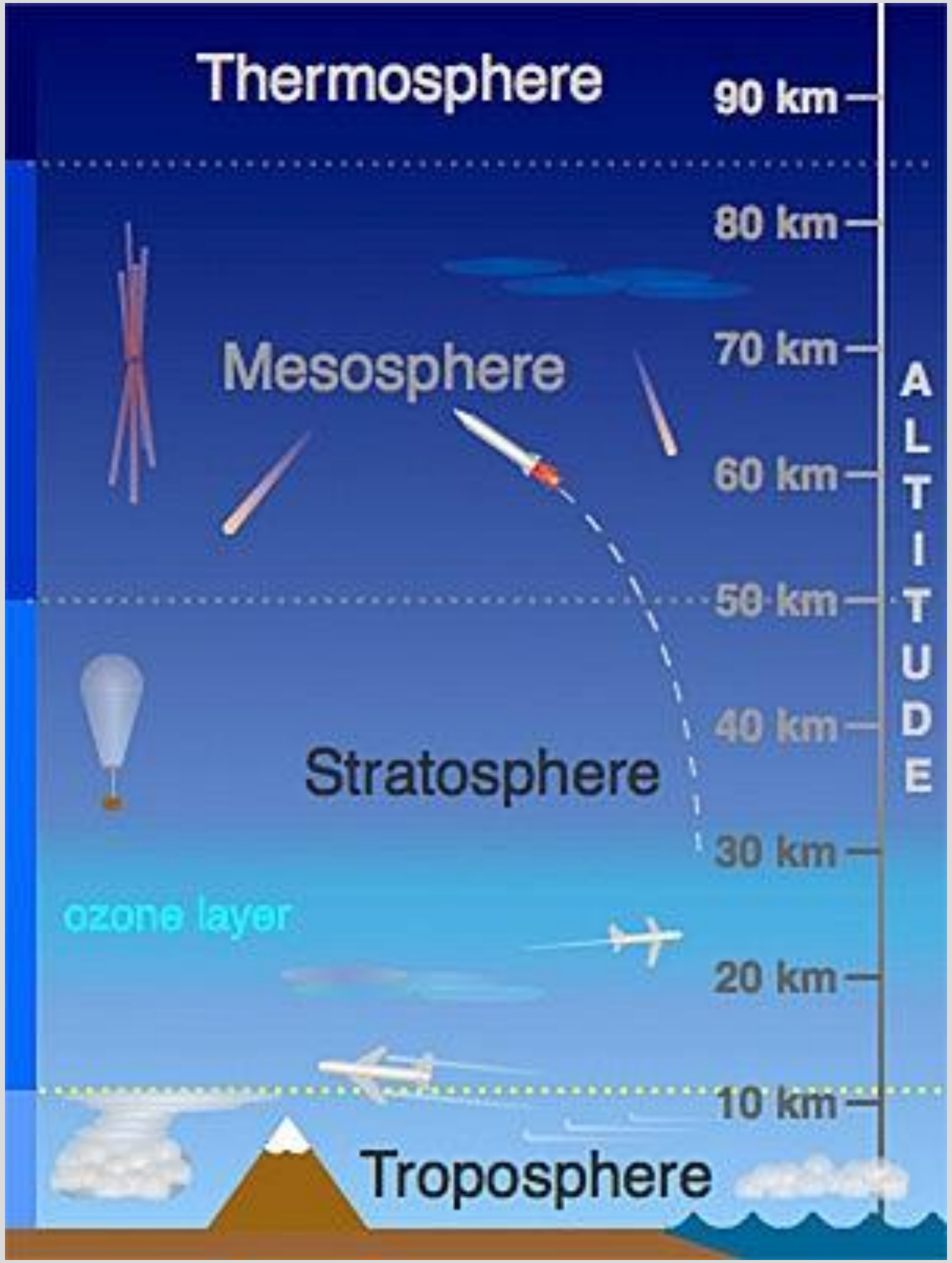
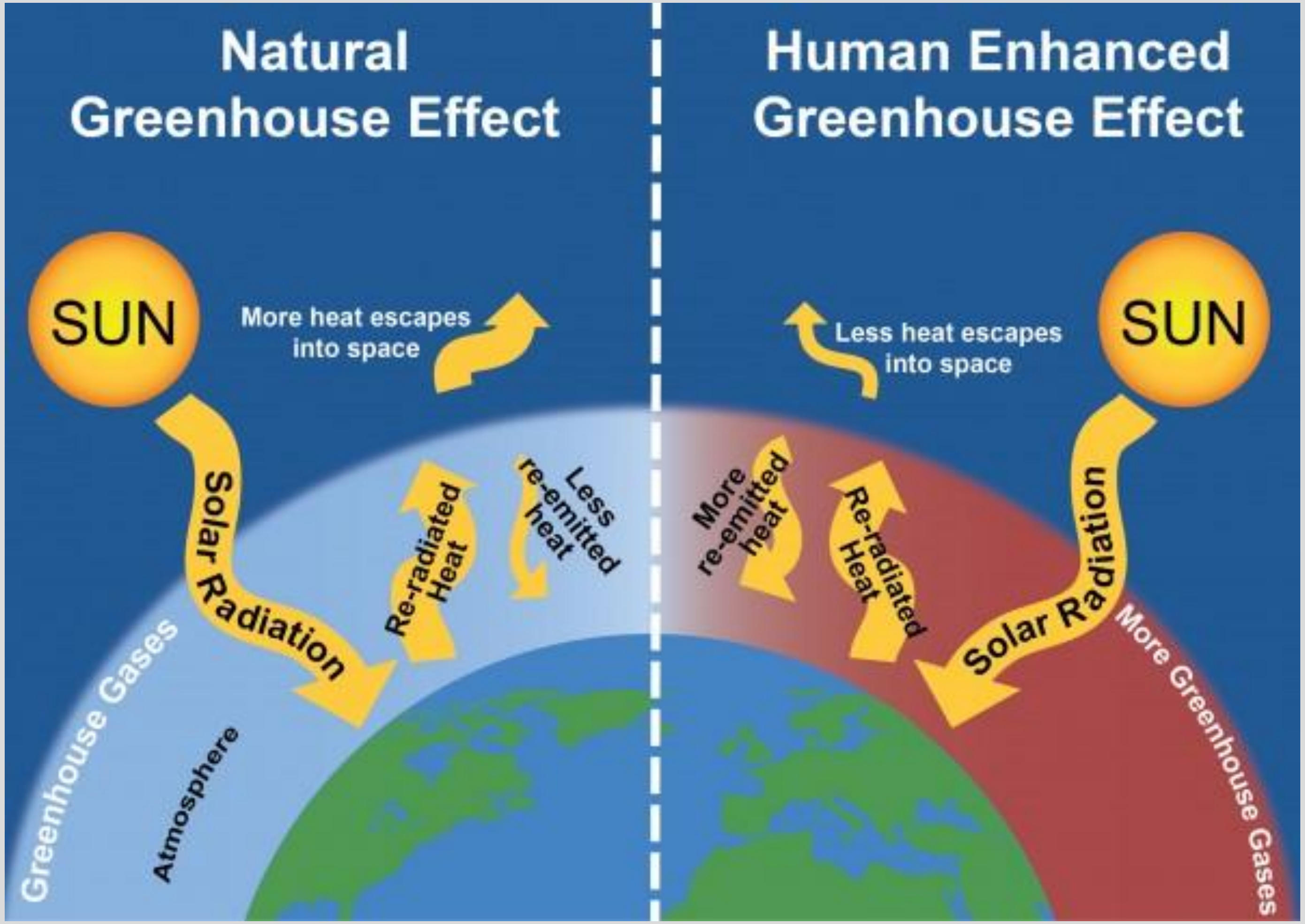
Climate Change and Fish in the Bitterroot

Outline

- **Scientists, and the science of climate change**
- **What about fish?**
- **What can we do?**

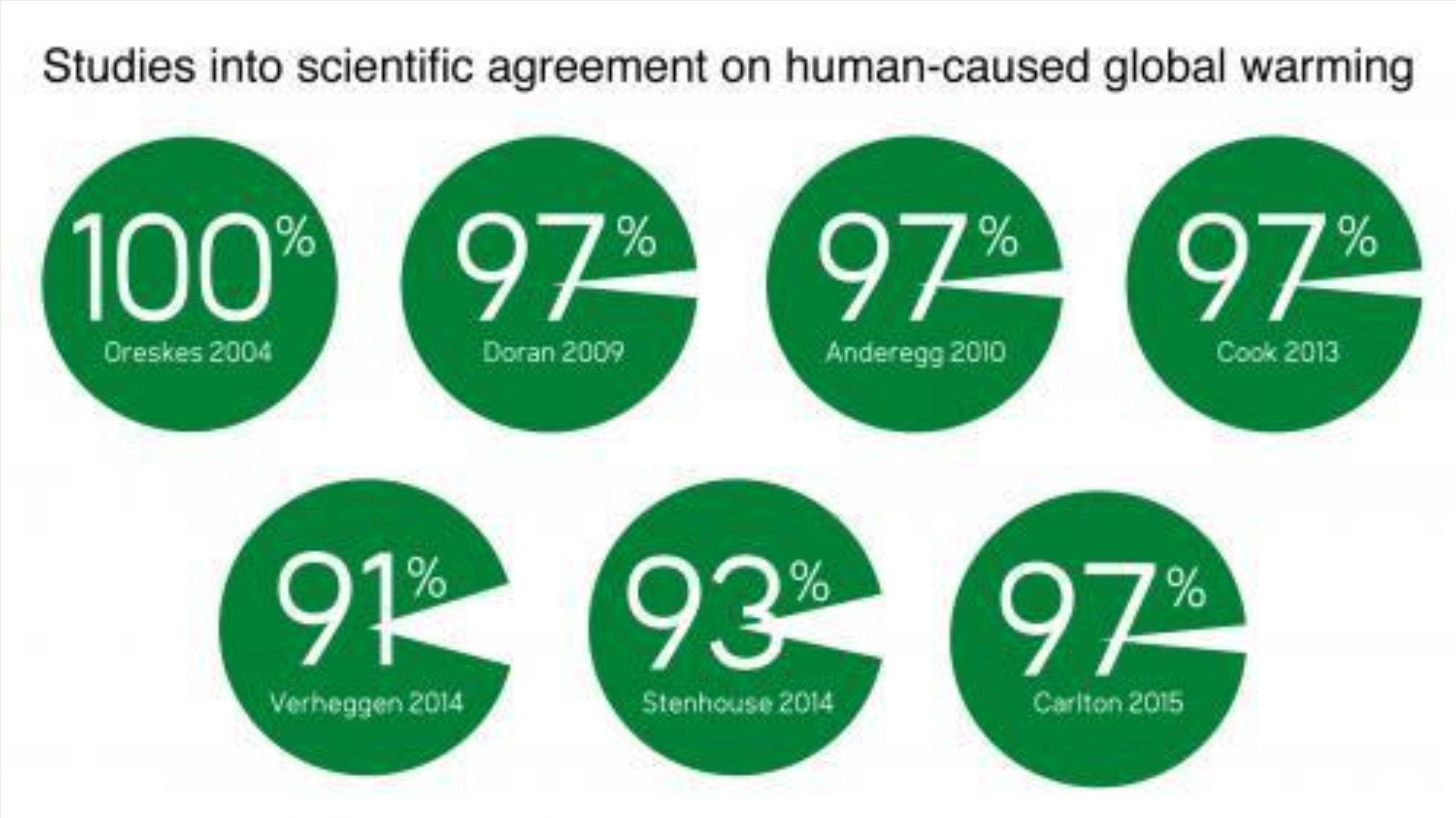

Thermosphere
90 km
80 km
Mesosphere
70 km
60 km
50 km
40 km
Stratosphere
30 km
ozone layer
20 km
10 km
Troposphere
ALTITUDE


Natural Greenhouse Effect
Human Enhanced Greenhouse Effect
SUN
More heat escapes into space
Solar Radiation
Re-radiated Heat
Less re-emitted heat
Greenhouse Gases
Atmosphere
SUN
Less heat escapes into space
More re-emitted heat
Re-radiated Heat
Solar Radiation
More Greenhouse Gases

Jean-Baptiste Joseph Fourier..1827 **Earths atmosphere might be an insulator**

John Tyndall, in **1859**
- ....**fluctuations in water vapor and carbon dioxide could be related to climate change.**

Svante Arrhenius, in **1896**, **estimates of the extent to which increases in atmospheric (CO_2) will increase Earth's surface temperature through the greenhouse effect.**



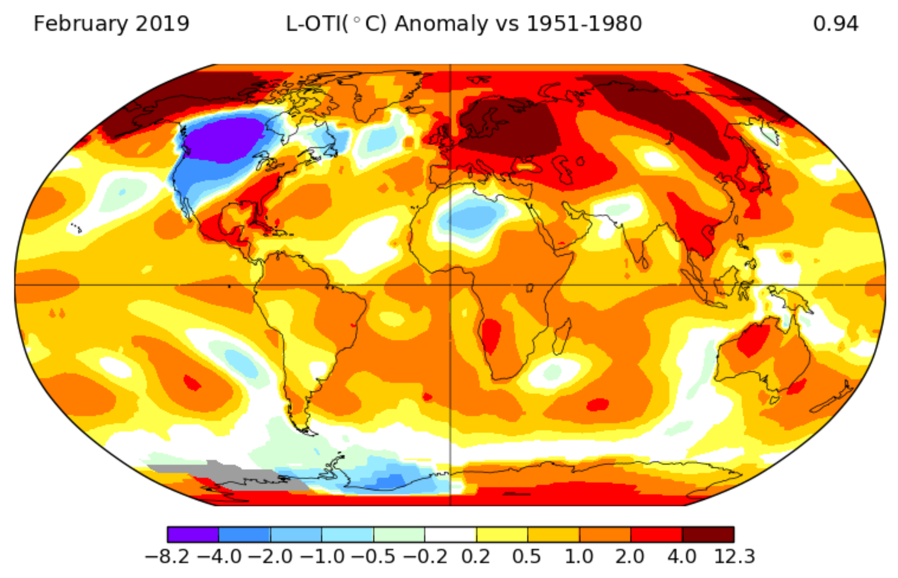
Authors: …….the finding of 97%…robust and consistent with other surveys of climate scientists and peer-reviewed studies. (Some of the 3% are eminent scientists)

U.S. Global Change Research Program:

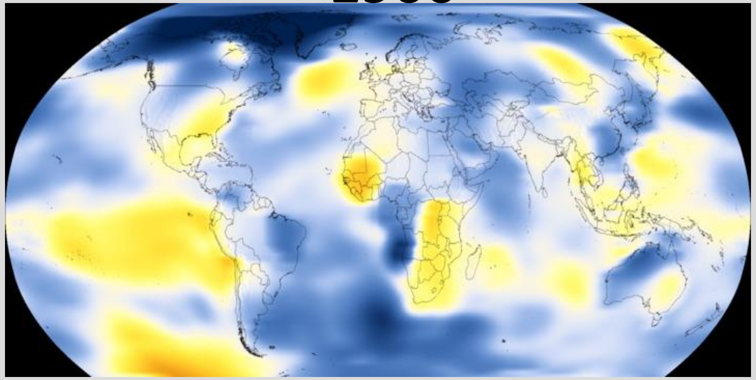
1. The burning of coal, oil, and gas, and clearing of forests.. Increased…. carbon dioxide in the atmosphere by more than 40% since the Industrial Revolution,
2. …… natural factors like the sun and volcanoes cannot have caused the warming
3. if not for human activities, global climate would actually have cooled slightly over the past 50 years.

- United States Department of State
- United States Department of Transportation
- United States Geological Survey,
- United States Department of the Interior
- Environmental Protection Agency
- National Aeronautics and Space Administration
- National Science Foundation
- Smithsonian Institution
- Agency for International Development
- United States Department of Agriculture
- National Oceanic and Atmospheric Administration, United States Department of Commerce and National Institute of Standards and Technology
- United States Department of Defense
- United States Department of Energy
- National Institutes of Health, United States Department of Health and Human Services

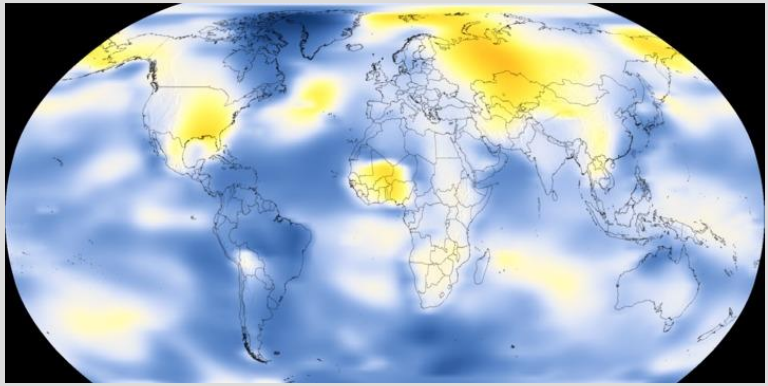
Weather vs. Climate



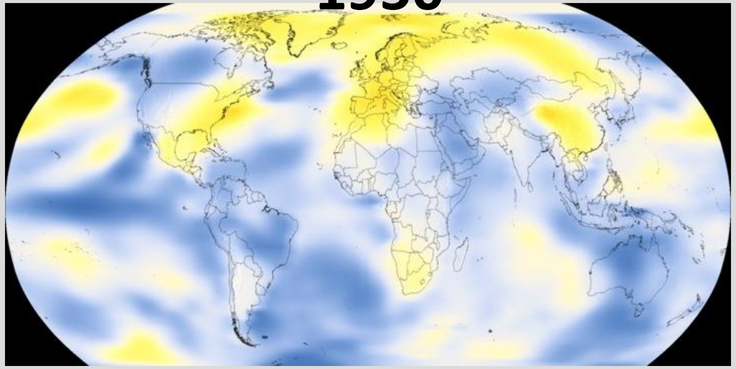
1900



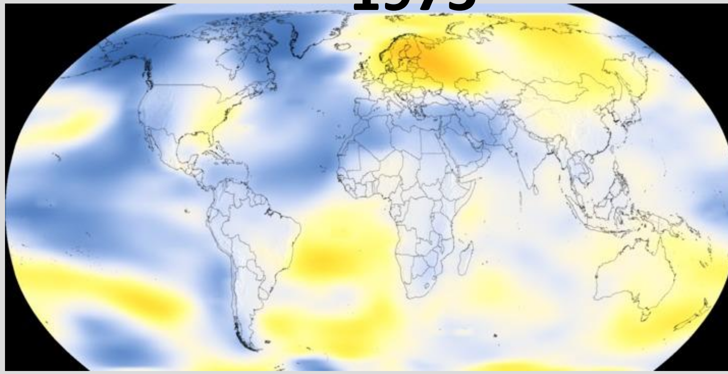
1925



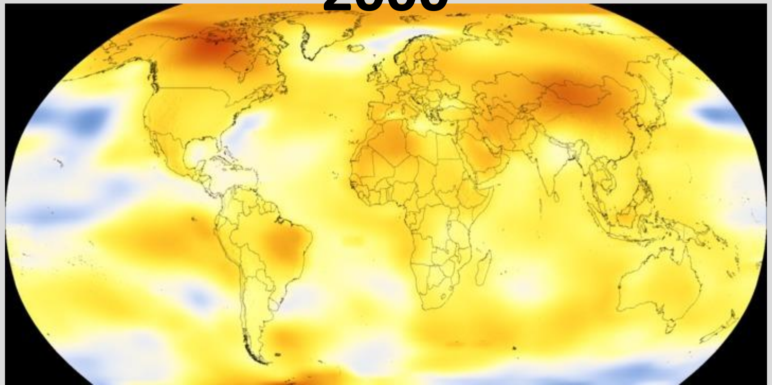
1950



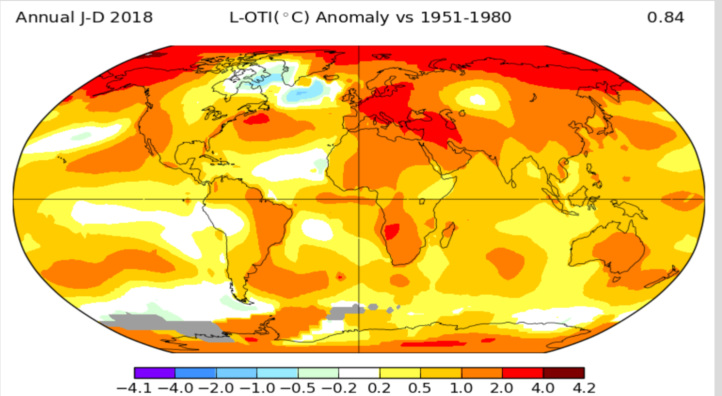
1975

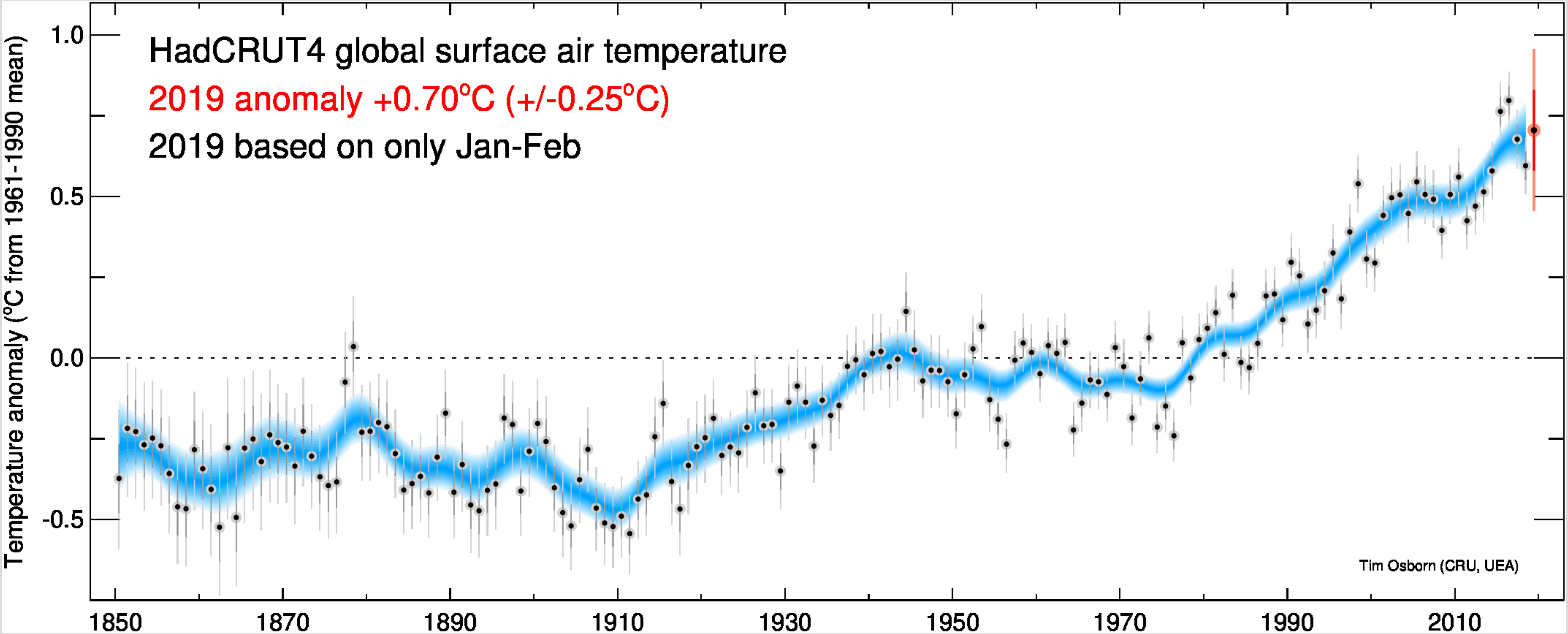


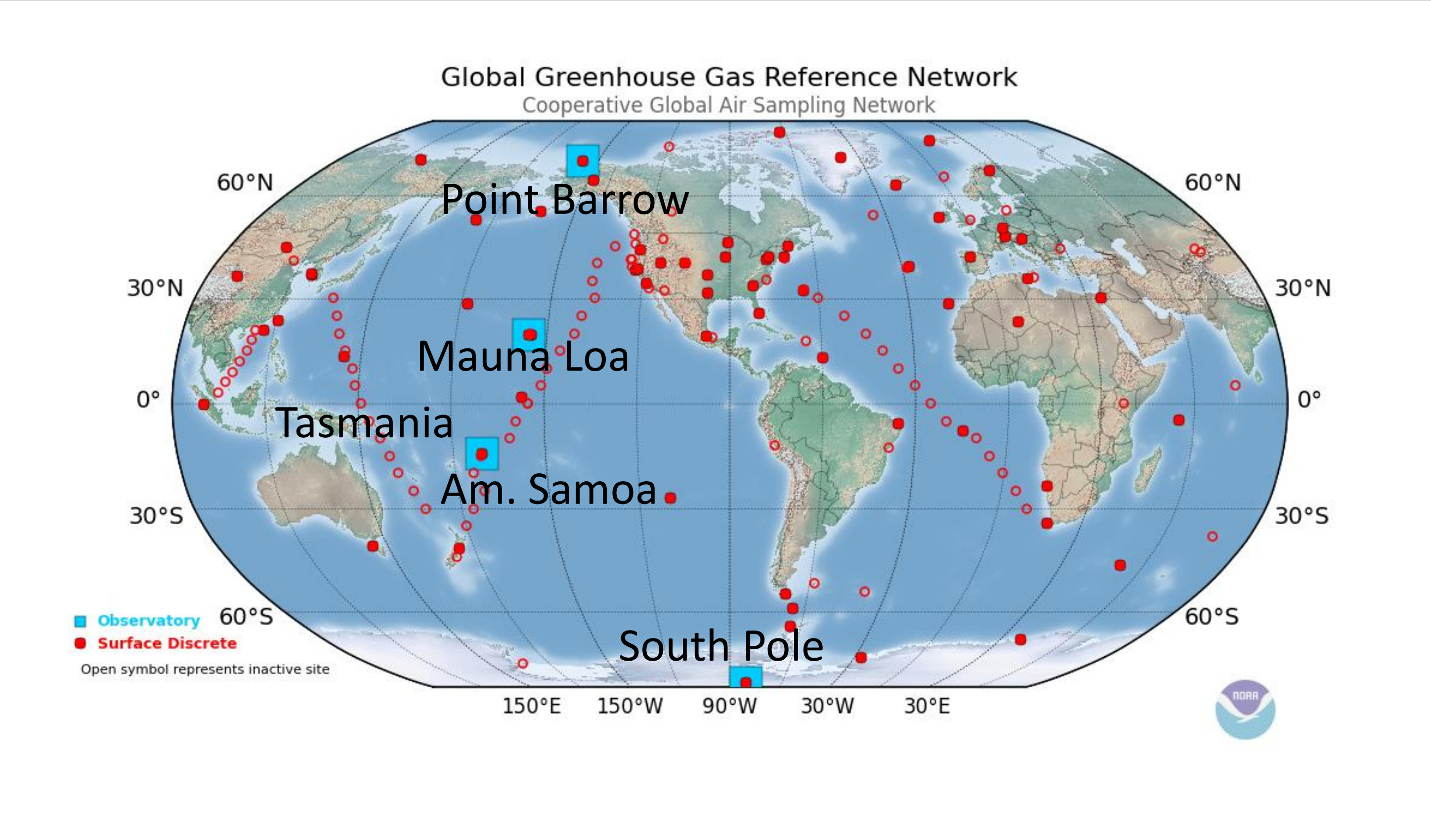
2000

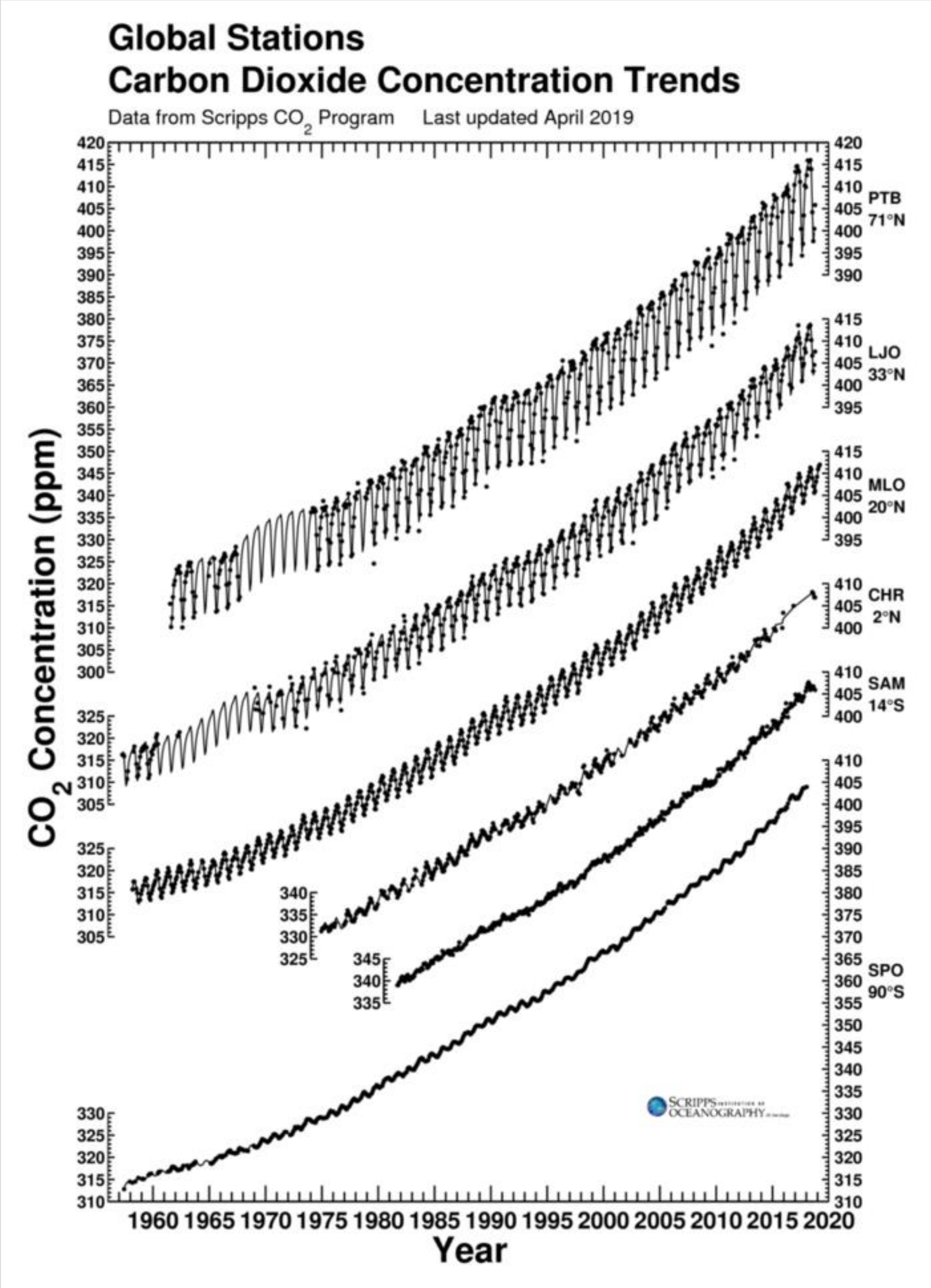


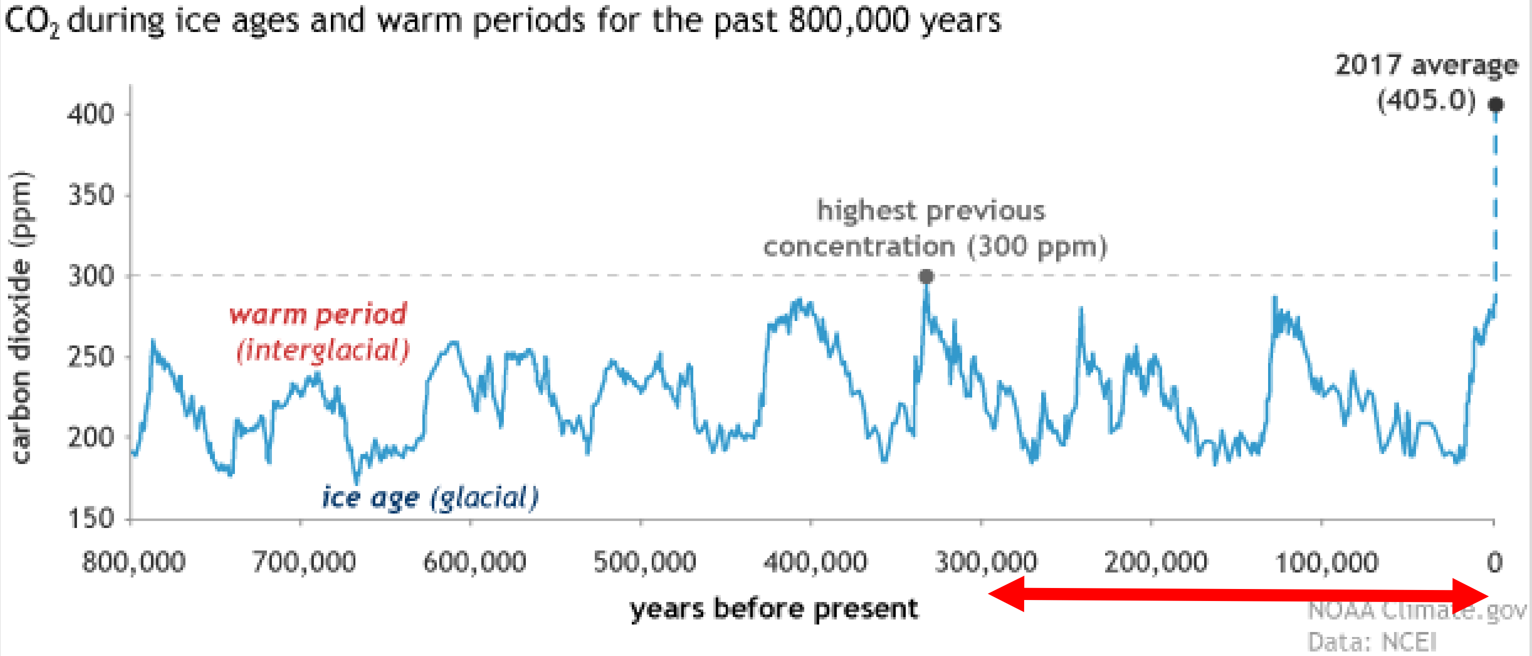
2018




HadCRUT4 global surface air temperature
2019 anomaly +0.70°C (+/-0.25°C)
2019 based on only Jan-Feb
Temperature anomaly (°C from 1961-1990 mean)
1.0
0.5
0.0
-0.5
1850
1870
1890
1910
1930
1950
1970
1990
2010
Tim Osborn (CRU, UEA)

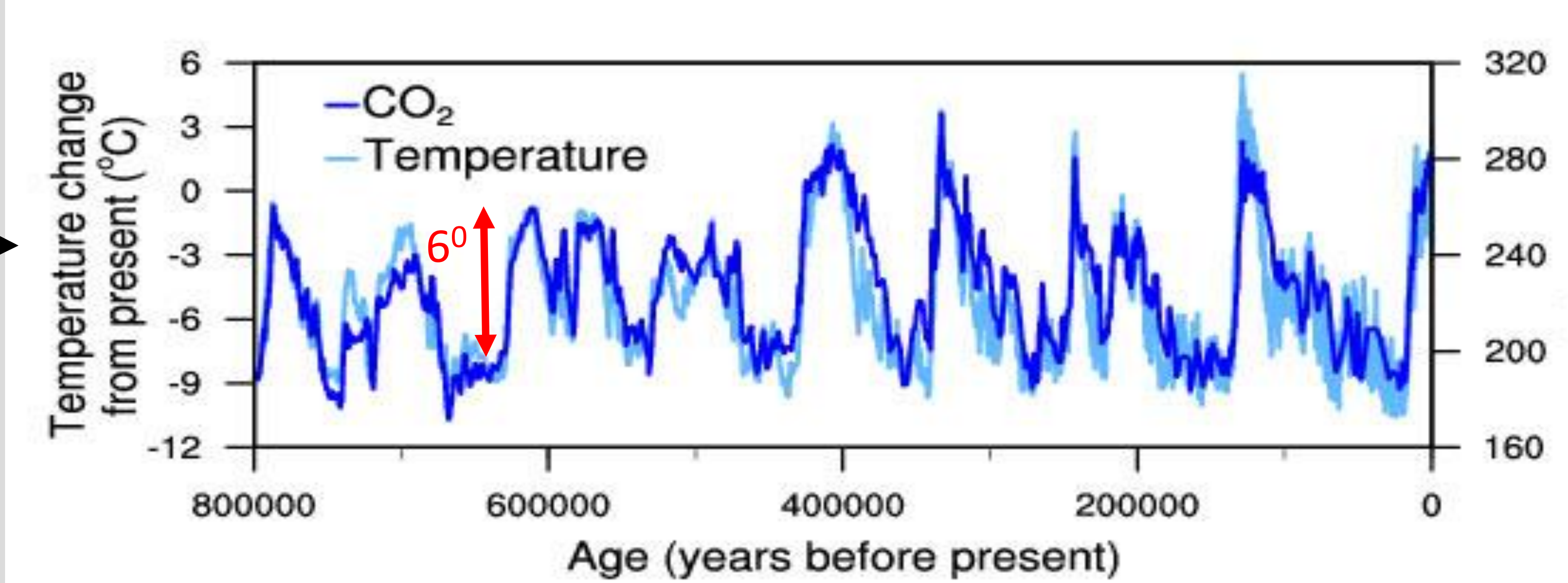

Global Greenhouse Gas Reference Network
Cooperative Global Air Sampling Network
Point Barrow
Mauna Loa
Tasmania
Am. Samoa
South Pole
60°N
30°N
0°
30°S
60°S
150°E
150°W
90°W
30°W
30°E
Observatory
Surface Discrete
Open symbol represents inactive site
NOAA


Global Stations
Carbon Dioxide Concentration Trends
Data from Scripps CO_2 Program
Last updated April 2019
CO_2 Concentration (ppm)
Year
PTB 71°N
LJO 33°N
MLO 20°N
CHR 2°N
SAM 14°S
SPO 90°S
1960 1965 1970 1975 1980 1985 1990 1995 2000 2005 2010 2015 2020
SCRIPPS INSTITUTION OF OCEANOGRAPHY

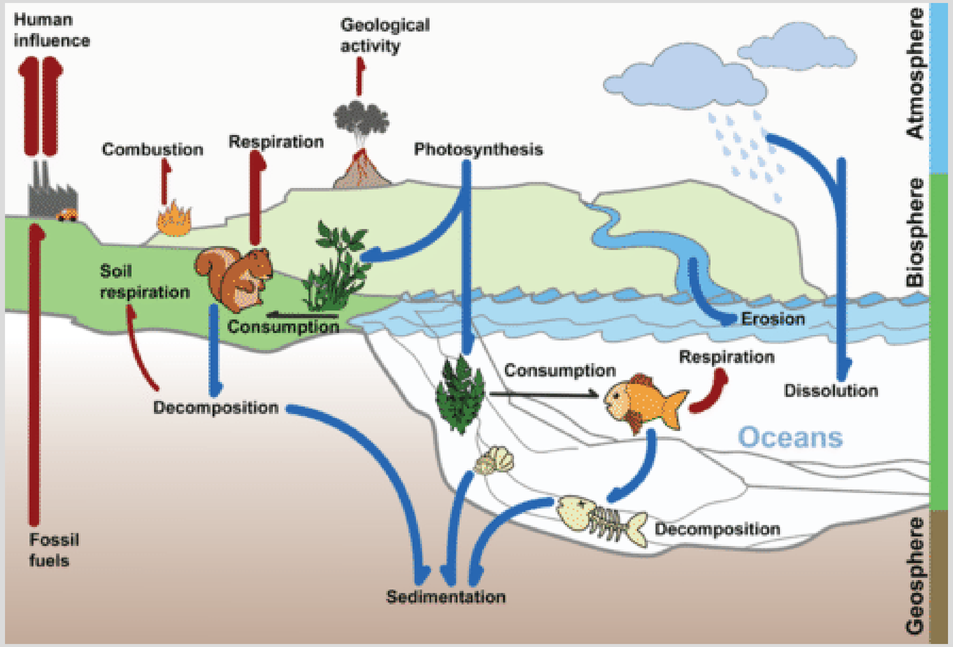


Temperature before 1850

By proxy methods- tree rings, coral growth, hydrogen and oxygen isotopes



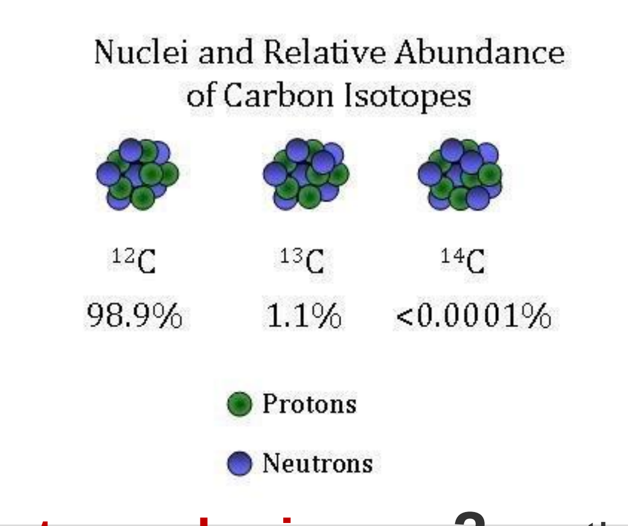
Carbon Cycle



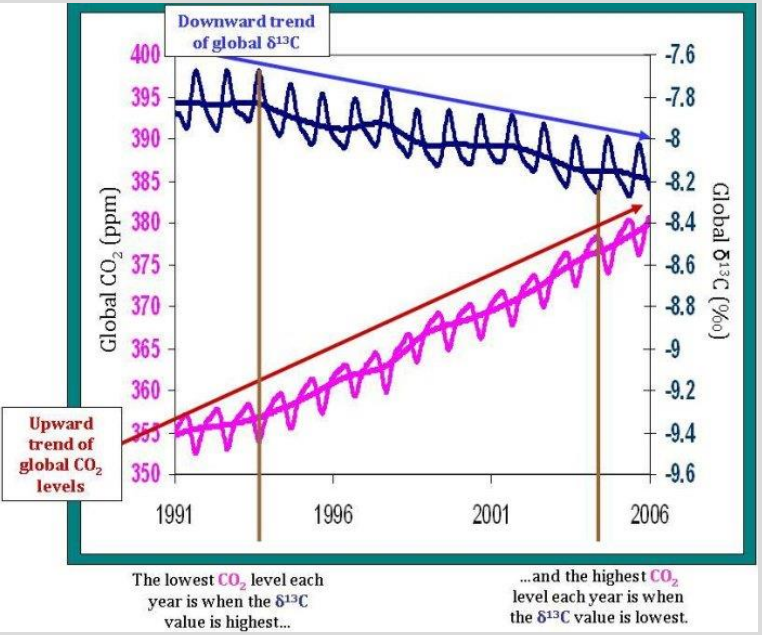
Atmospheric CO_2 Account		10^{15} grams of carbon per year*
Date	Origin	Balance
annual	Biosphere	− 2
annual	Ocean	− 3
annual	Fossil Fuel Burning	+8
annual	Deforestation	+1
Annually Reported Atmospheric Balance		+4

*These numbers are approximate and are for the whole globe

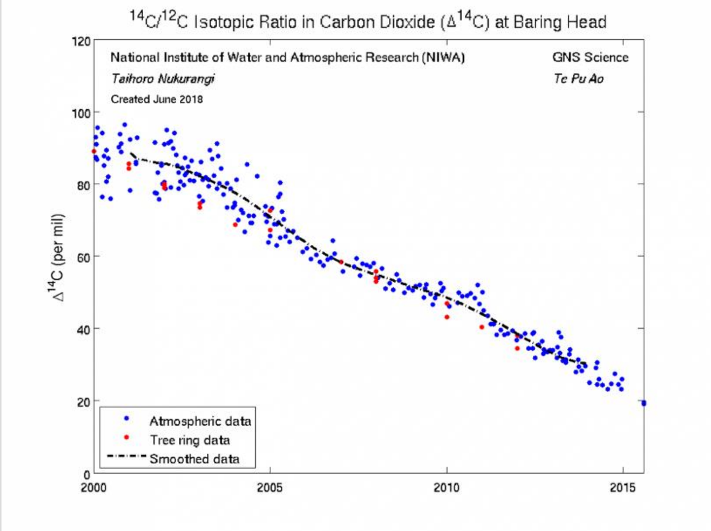
Wolfgang Knorr, 2009



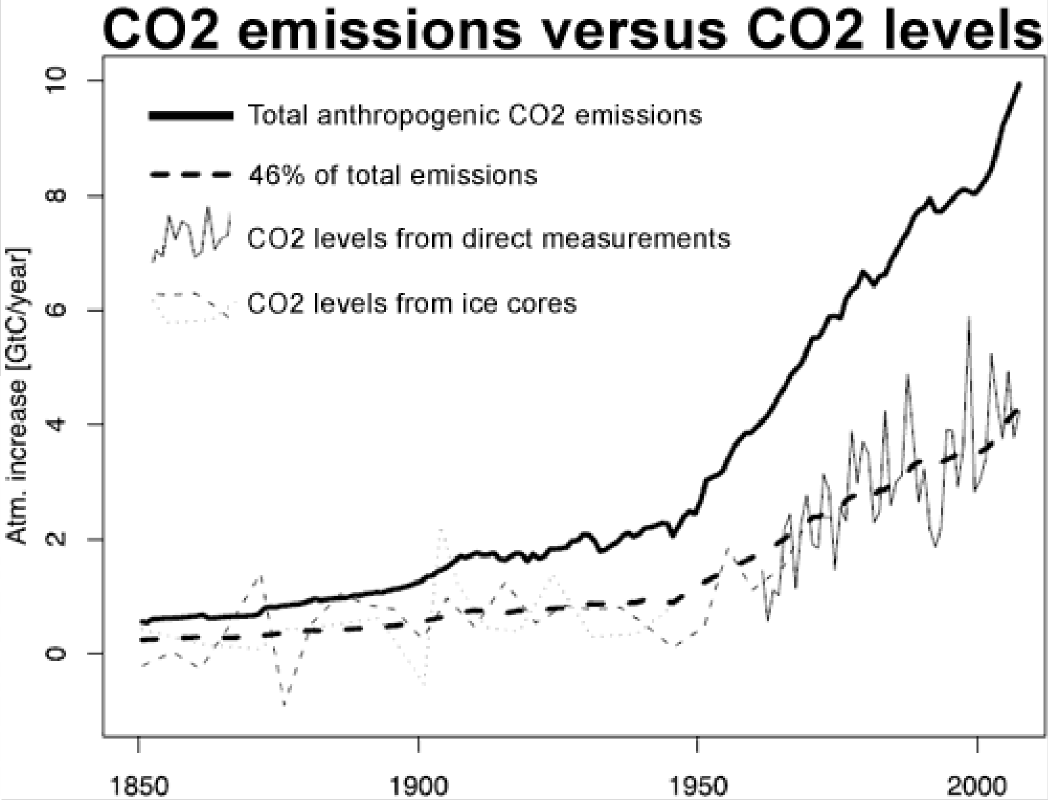
1. ..decrease in atmospheric $\delta^{13}C$ ….. must come from the terrestrial biosphere and/or fossil fuels.



2. …the greatest factor altering **global $\Delta^{14}C$ levels is fossil fuel emissions.**

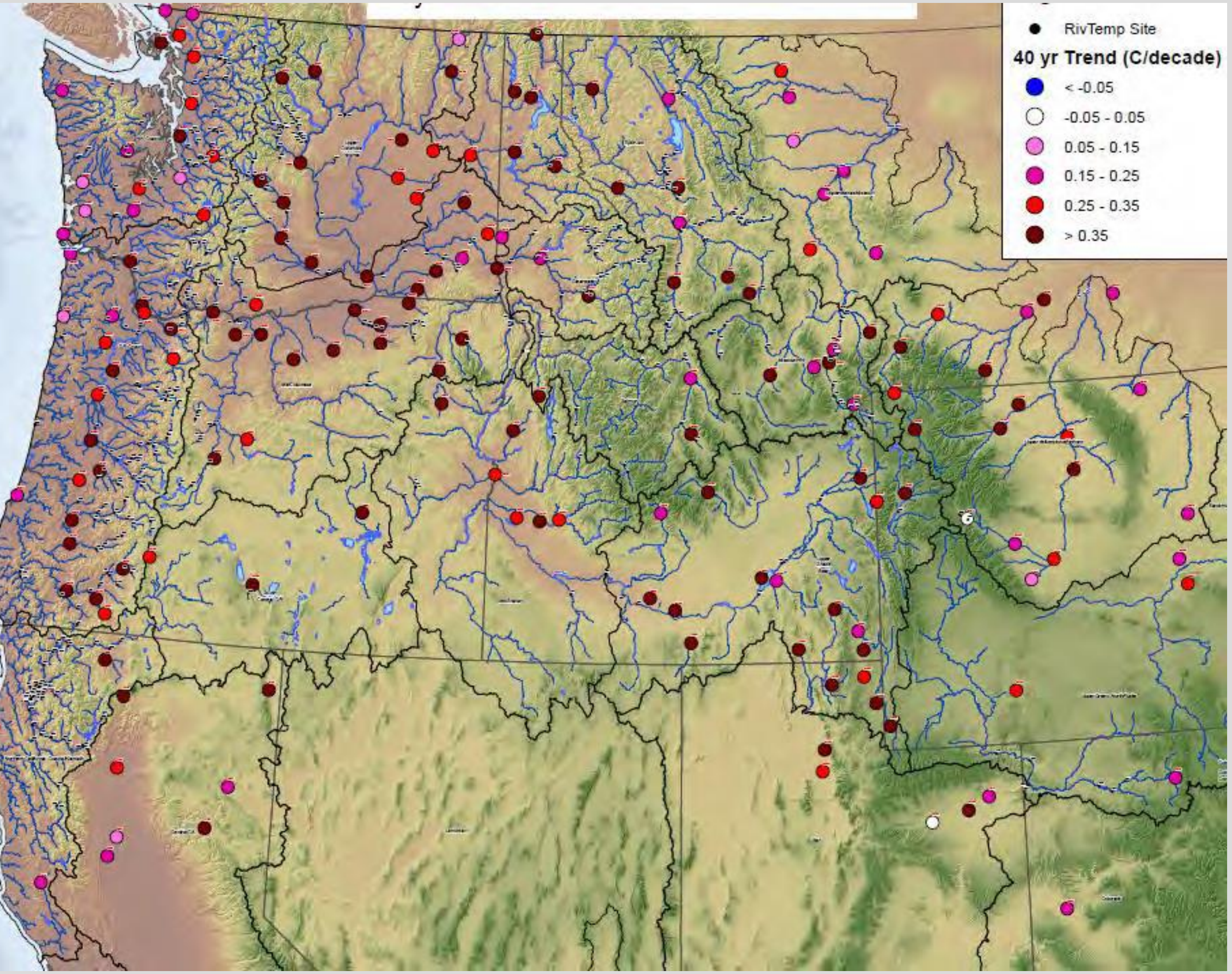


3. Global carbon emission estimates

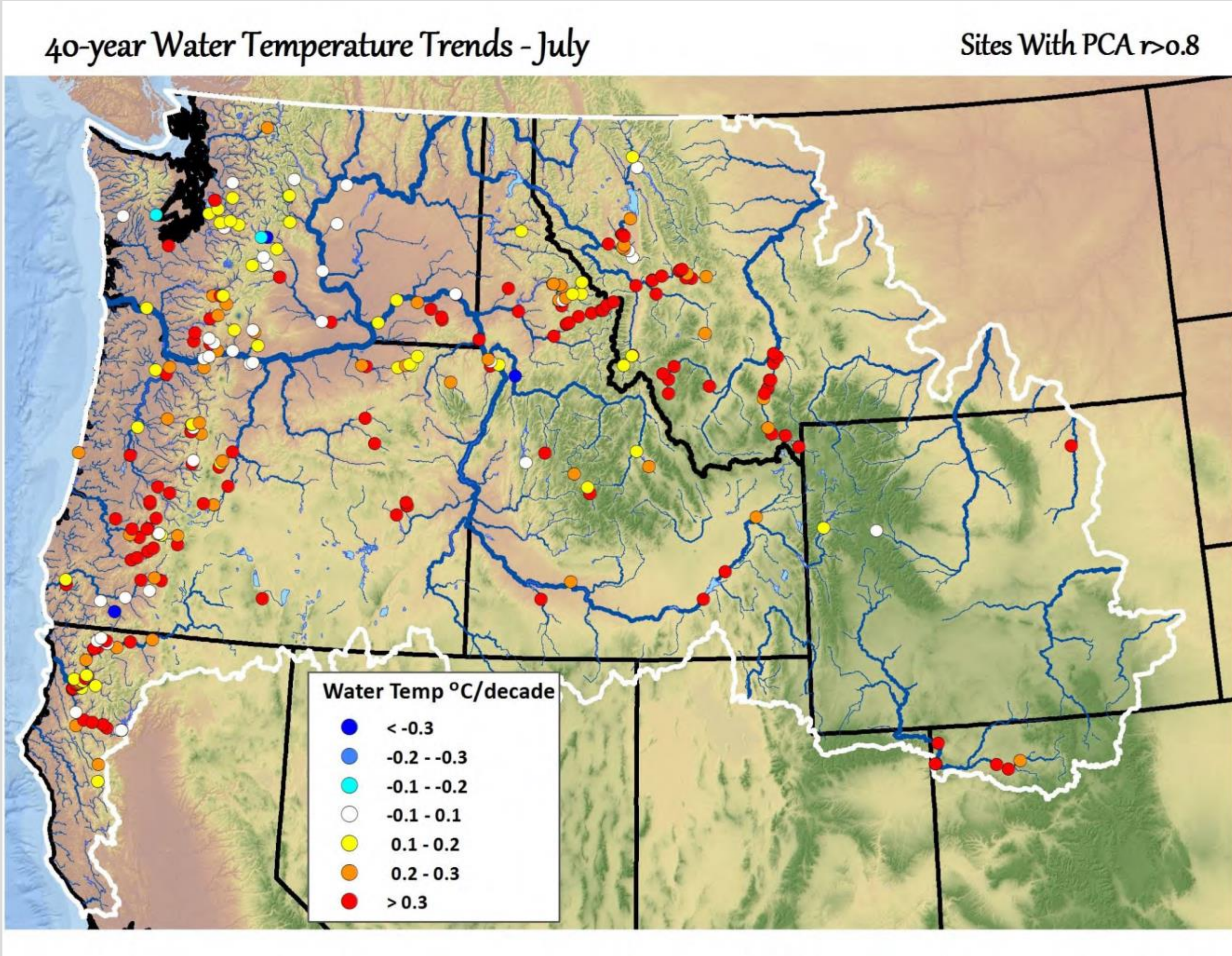


Regional Air Temp Trends (1976–2015)

Summer = 0.35°C / decade



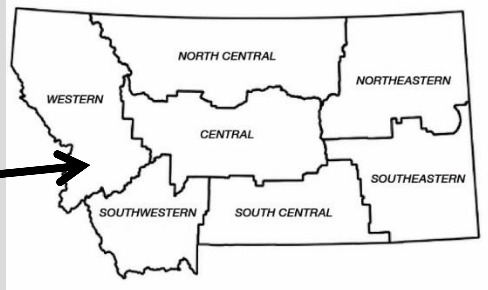
40 Year (1976–2015) Monthly River Temperature Trend -July



Isaak, D.J., C. Luce, D. Horan, G. Chandler, and S. Wollrab. 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*147:566-587.

Foot still on the greenhouse gas pedal!
Plan on continued warming for decades…

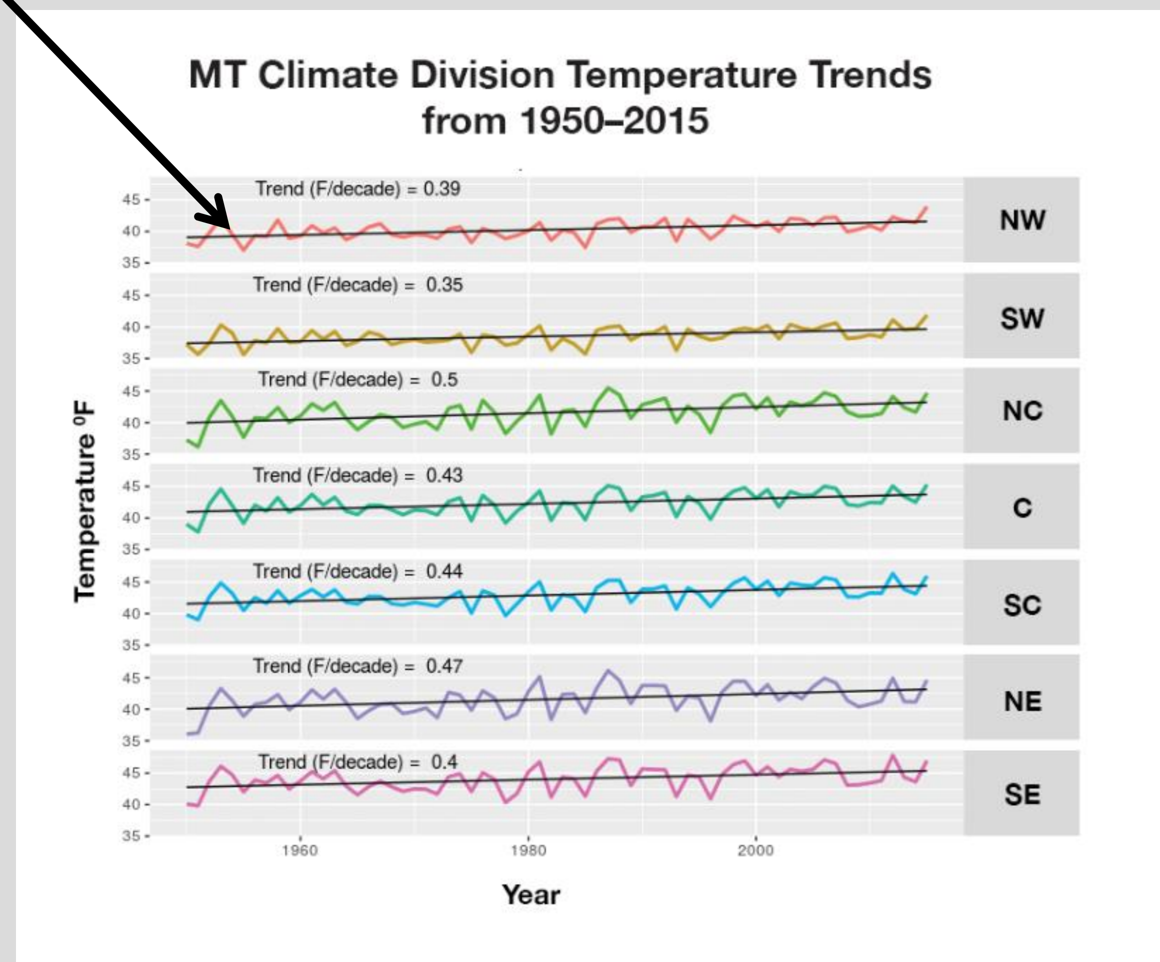
2017 MONTANA CLIMATE ASSESSMENT



+.39 º F per decade

High Agreement, Robust Evidence:

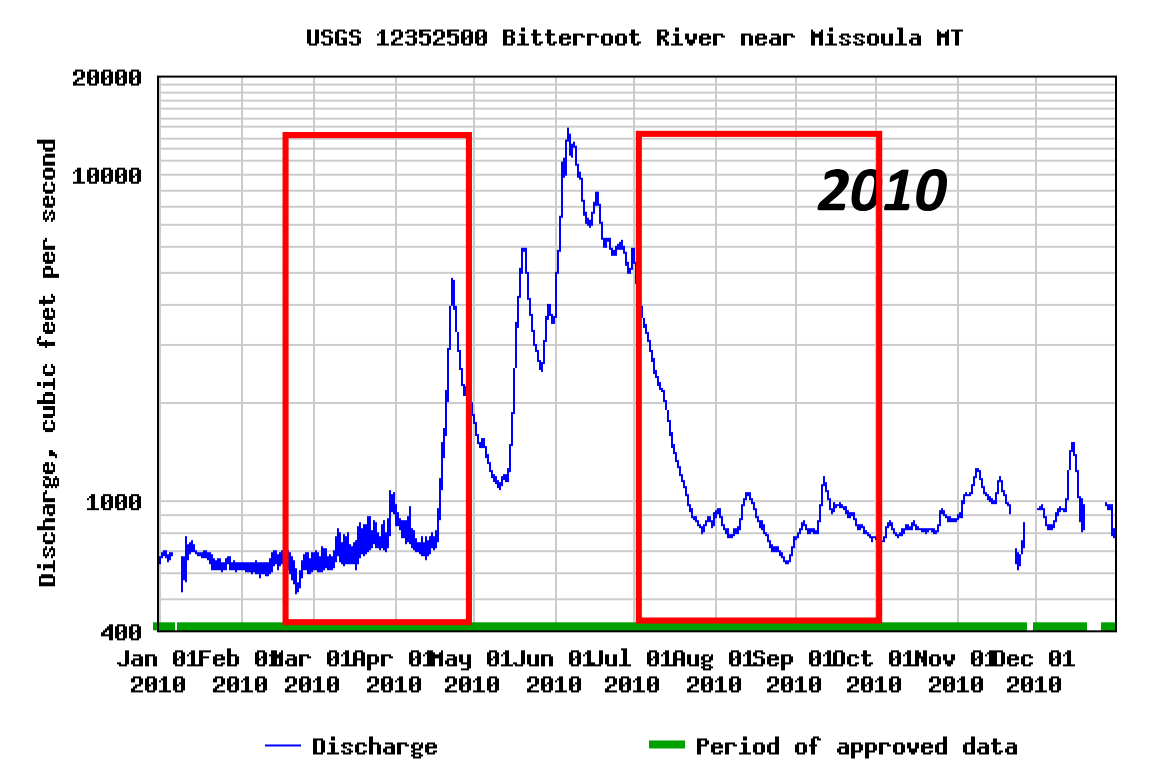
- **Warming temperatures**……, especially during spring, are likely to **reduce snowpack at mid and low elevations.**
- …………a shift toward **earlier snowmelt and an earlier peak in spring runoff** in the Mountain West. ……..these patterns are very likely to continue into the future… .
- **will reduce late-summer water availability** in snowmelt-dominated watersheds.

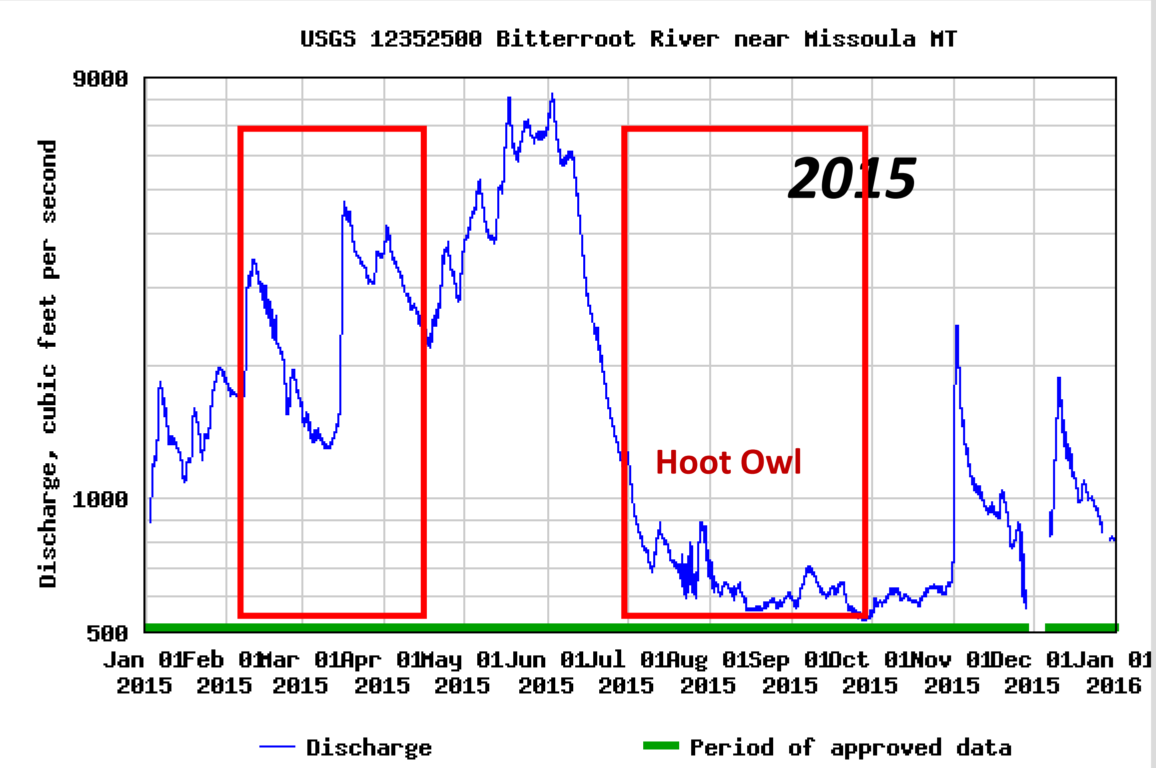


Trends

Red boxes indicate typical fishing seasons for the area

- **Earlier Runoff**
- **Lower and Warmer Summer Streamflows**





Criteria for Hoot Owl Fishing Restrictions

- Flows are at the 95% daily exceedence level (1-in-20-year low flows); OR
- **Daily maximum water temperature reaches or exceeds 23° C (73°) F for at least some period of time during three consecutive days**
- Maximum water temperature for Bull Trout is 15° C

Canadian Journal of Aquatic Science. 2016

NRC Research Press

ARTICLE

Are brown trout replacing or displacing bull trout populations in a changing climate?

Robert Al-Chokhachy, David Schmetterling, Chris Clancy, Pat Saffel, Ryan Kovach, Leslie Nyce, Brad Liermann, Wade Fredenberg, and Ron Pierce

Abstract: Understanding how climate change may facilitate species turnover is an important step in identifying potential conservation strategies. We used data from 33 sites in western Montana to quantify climate associations with native bull trout (*Salvelinus confluentus*) and non-native brown trout (*Salmo trutta*) abundance and population growth rates (λ). We estimated λ using exponential growth state-space models and delineated study sites based on bull trout use for either spawning and rearing (SR) or foraging, migrating, and overwintering (FMO) habitat. Bull trout abundance was negatively associated with mean August stream temperatures within SR habitat ($r = -0.75$). Brown trout abundance was generally highest at temperatures between 12 and 14 °C. We found bull trout λ were generally stable at sites with mean August temperature below 10 °C but significantly decreasing, rare, or extirpated at 58% of the sites with temperatures exceeding 10 °C. Brown trout λ were highest in SR and sites with temperatures exceeding 12 °C. Declining bull trout λ at sites where brown trout were absent suggest brown trout are likely replacing bull trout in a warming climate.

Résumé : Il importe de comprendre comment le climat pourrait faciliter le renouvellement des espèces pour cerner des stratégies de conservation potentielles. Nous avons utilisé des données de 33 sites de l'ouest du Montana pour quantifier les associations climatiques avec l'abondance et les taux de croissance de populations (λ) d'ombles à tête plate (*Salvelinus confluentus*) indigènes et de truites brunes (*Salmo trutta*) non indigènes. Nous avons estimé λ en utilisant des modèles d'espaces d'états de croissance exponentielle et délimité les sites étudiés selon leur utilisation par l'omble à tête plate soit comme habitat de frai et d'alevinage (SR) ou d'approvisionnement, de migration et d'hivernage (FMO). L'abondance des ombles à tête plate était négativement associée aux températures moyennes des cours d'eau en août dans les habitats SR ($r = -0,75$). L'abondance de la truite brune était généralement maximum à des températures entre 12 et 14 °C. Nous avons constaté que les λ des ombles à tête plate étaient généralement stables aux sites présentant une température moyenne en août inférieure à 10 °C, mais qu'il diminuait significativement, l'espèce y étant rare ou disparue, dans 58 % des sites où cette température dépasse 10 °C. Les λ des truites brunes étaient maximums dans les habitats SR et les sites caractérisés par des températures supérieures à 12 °C. Des λ en baisse des ombles à tête plate dans des sites exempts de truites brunes donnent à penser que ces dernières remplacent probablement les ombles à tête plate dans un climat en réchauffement. [Traduit par la Rédaction]

Introduction

Climate change is likely to substantially alter stream ecosystems with pronounced effects for cold-water fishes such as salmonids (Jonsson and Jonsson 2009; Williams et al. 2009; Elliott and Elliott 2010). Salmonid life histories, vital rates, and demographics are strongly tied to factors influenced by climate, including thermal and hydrologic regimes (Elliott 1994; Lobon-Cervia 2004; Crozier et al. 2008; Warren et al. 2012). With different thermal tolerances and life-history expressions, the effects of changing climatic conditions are likely to differ across species. Understanding how climate, among other factors, may be influencing populations is critical for identifying the potential for effective management and restoration scenarios.

Non-native salmonids are an additional concern for the conservation of native salmonids across North America (Dunham et al. 2002). Widespread introductions for recreation have resulted in naturally producing populations of non-native salmonids in many streams. The mechanistic threats of non-native species to native salmonids, particularly in the context of climate change, are often not well understood (e.g., Rahel and Olden 2008; Lawrence et al. 2014). This uncertainty stems partly from the paucity of situations where changing climatic conditions have been empirically linked with salmonid population and demographic data (Kovach et al. 2016). Likewise, delineating between non-native displacement (i.e., declines in native salmonids due to negative interactions with non-natives) or replacement (i.e., declines in native salmonids due to factors unrelated to non-natives) is an inherent challenge in species turnover studies (Dunham et al. 2002).

Refining our understanding of the influences of climate change and non-native species on extant populations of bull trout (*Salvelinus confluentus*) is essential in designing conservation strategies to enhance long-term persistence. Bull trout are currently listed as "Threatened" in the United States under the Endangered Species Act and ranked "Of Special Concern" or "Threatened" for three of four geographic populations by the Committee on the Status of Endangered Wildlife in Canada. Bull trout are extremely temperature-sensitive

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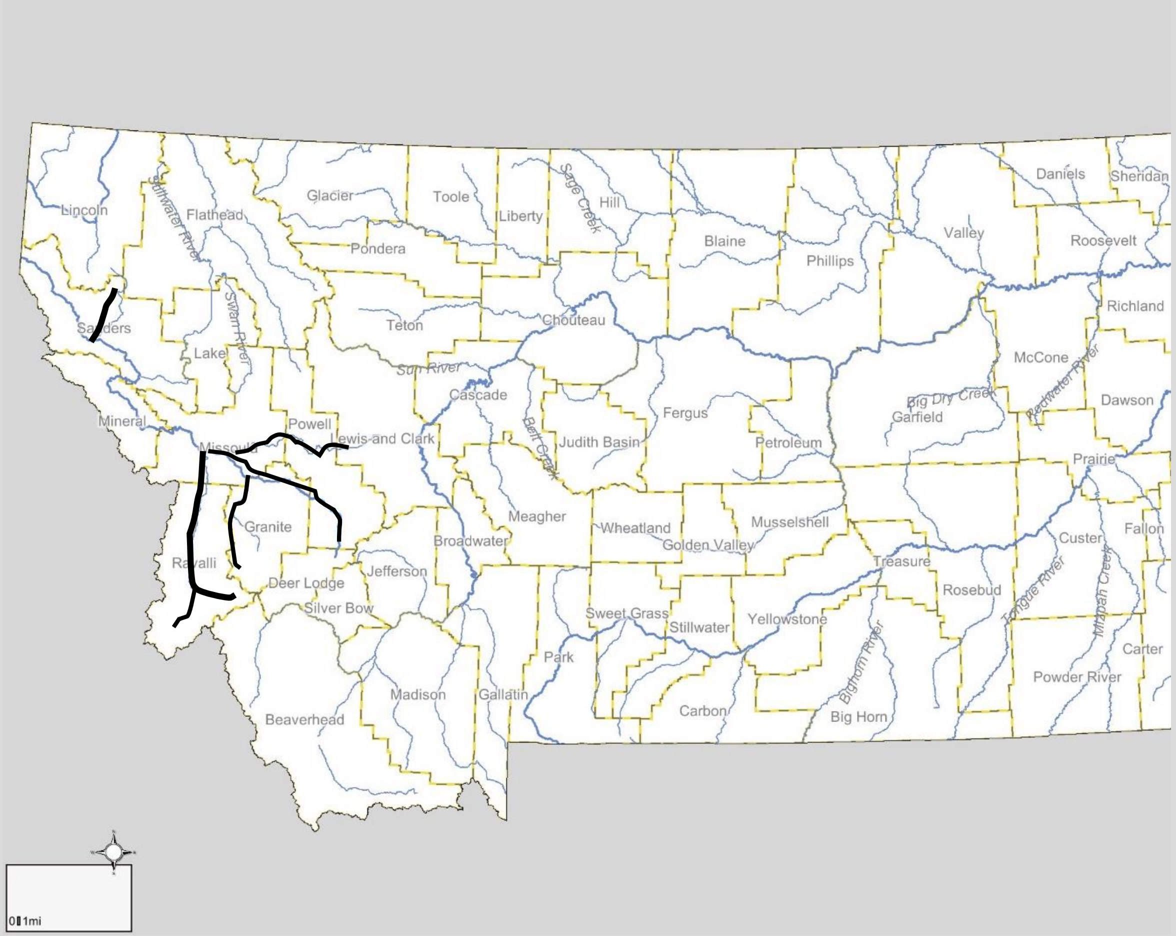
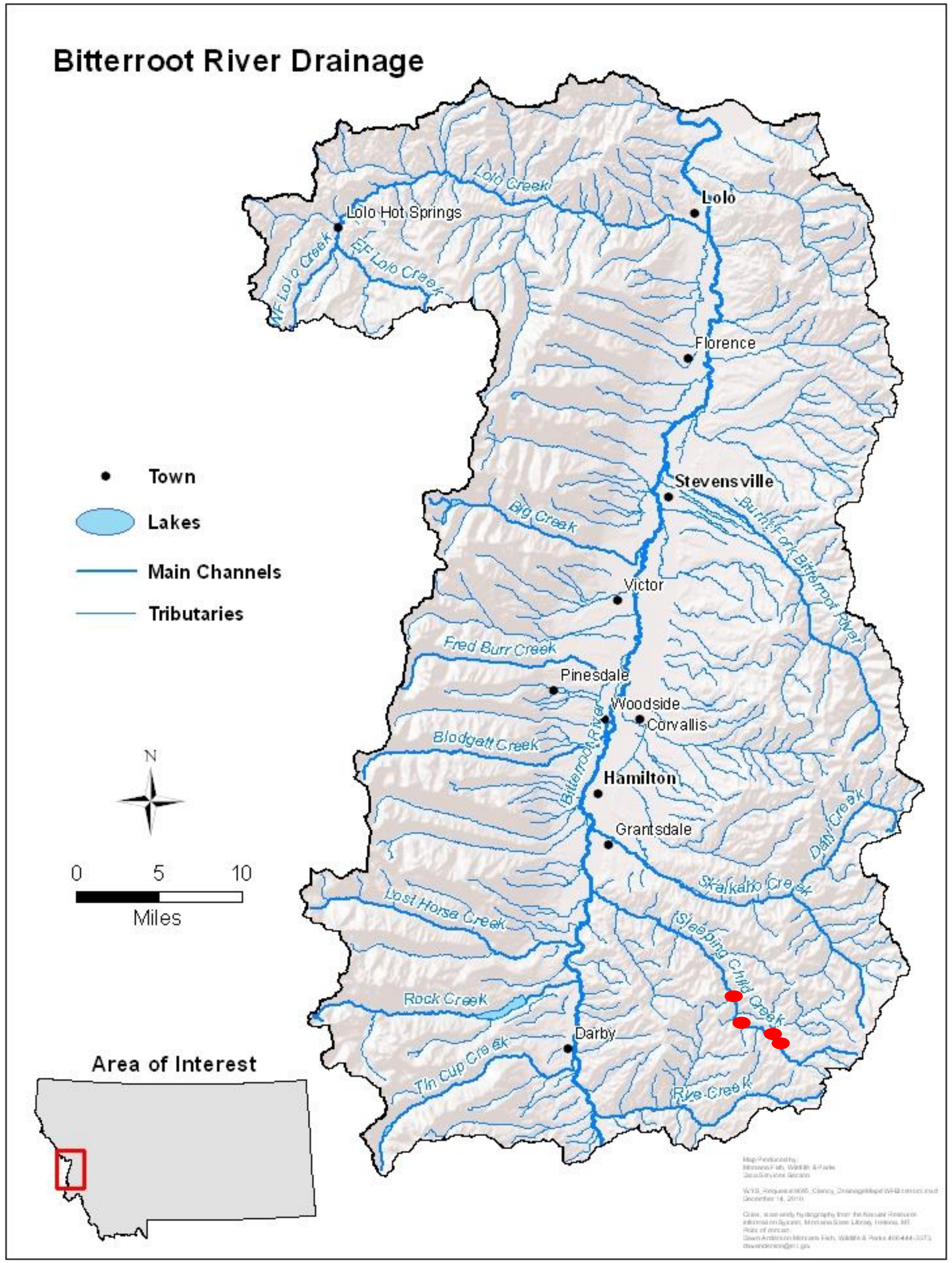
C. Clancy and L. Nyce. Montana Fish, Wildlife and Parks, 1801 North 1st Street, Hamilton, MO 59840, USA.
R. Kovach. US Geological Survey, Northern Rocky Mountain Science Center, Glacier Field Station, West Glacier, MT 59936, USA.
W. Fredenberg. US Fish and Wildlife Service, Creston Fish & Wildlife Center, Kalispell, MT 59901, USA.
Corresponding author: Robert Al-Chokhachy (email: ral-chokhachy@usgs.gov).

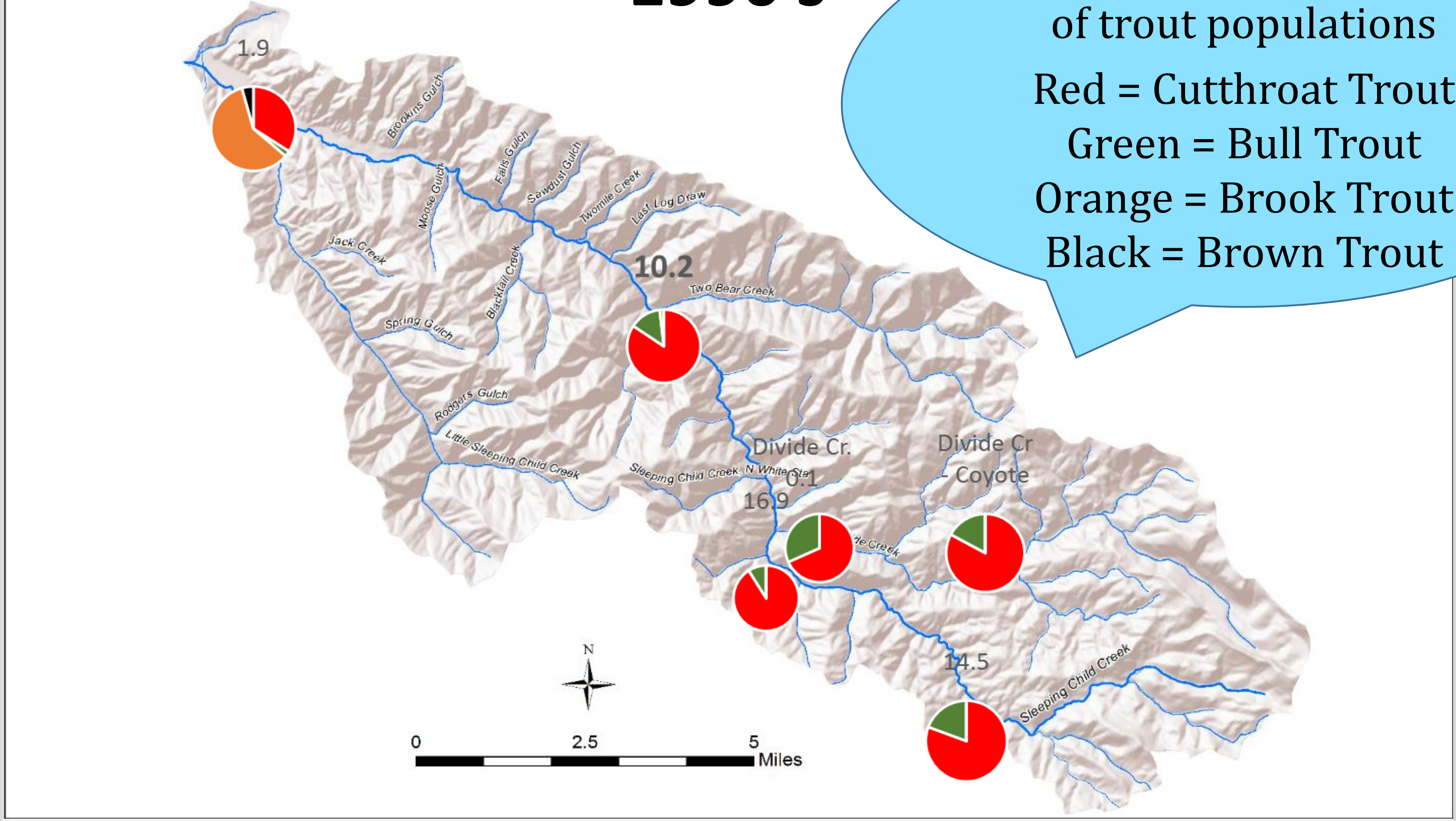



Bitterroot River Drainage
Town
Lakes
Main Channels
Tributaries
N
0 5 10
Miles
Area of Interest
Lolo Creek
Lolo Hot Springs
Lolo
WF Lolo Creek
EF Lolo Creek
Florence
Stevensville
Big Creek
Burnt Fork Bitterroot River
Victor
Fred Burr Creek
Pinesdale
Woodside
Corvallis
Blodgett Creek
Bitterroot River
Hamilton
Grantsdale
Daly Creek
Skalkaho Creek
Lost Horse Creek
Sleeping Child Creek
Rock Creek
Darby
Tin Cup Creek
Rye Creek

1990’s

Pie Charts show breakdown of trout populations

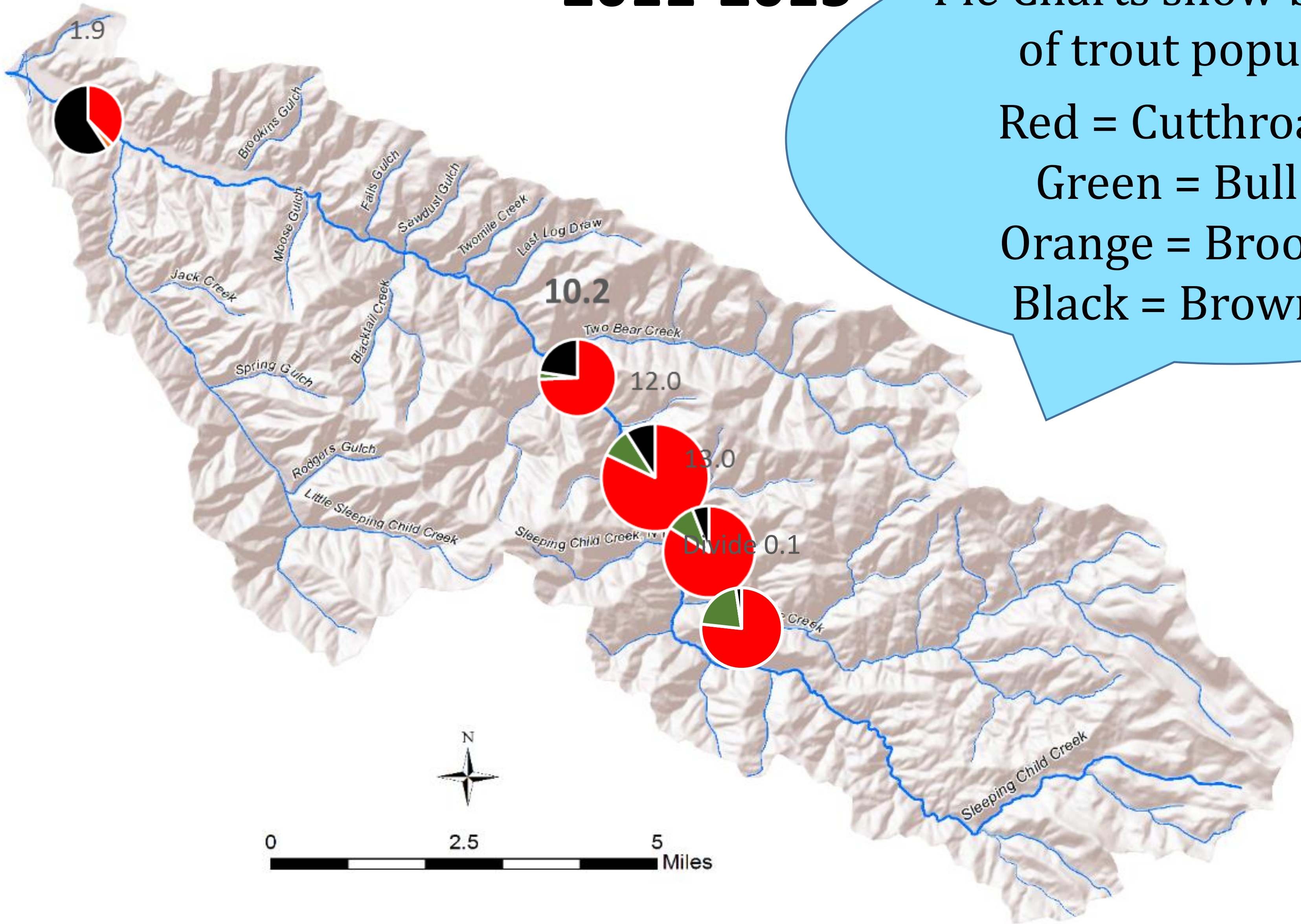
Red = Cutthroat Trout
Green = Bull Trout
Orange = Brook Trout
Black = Brown Trout

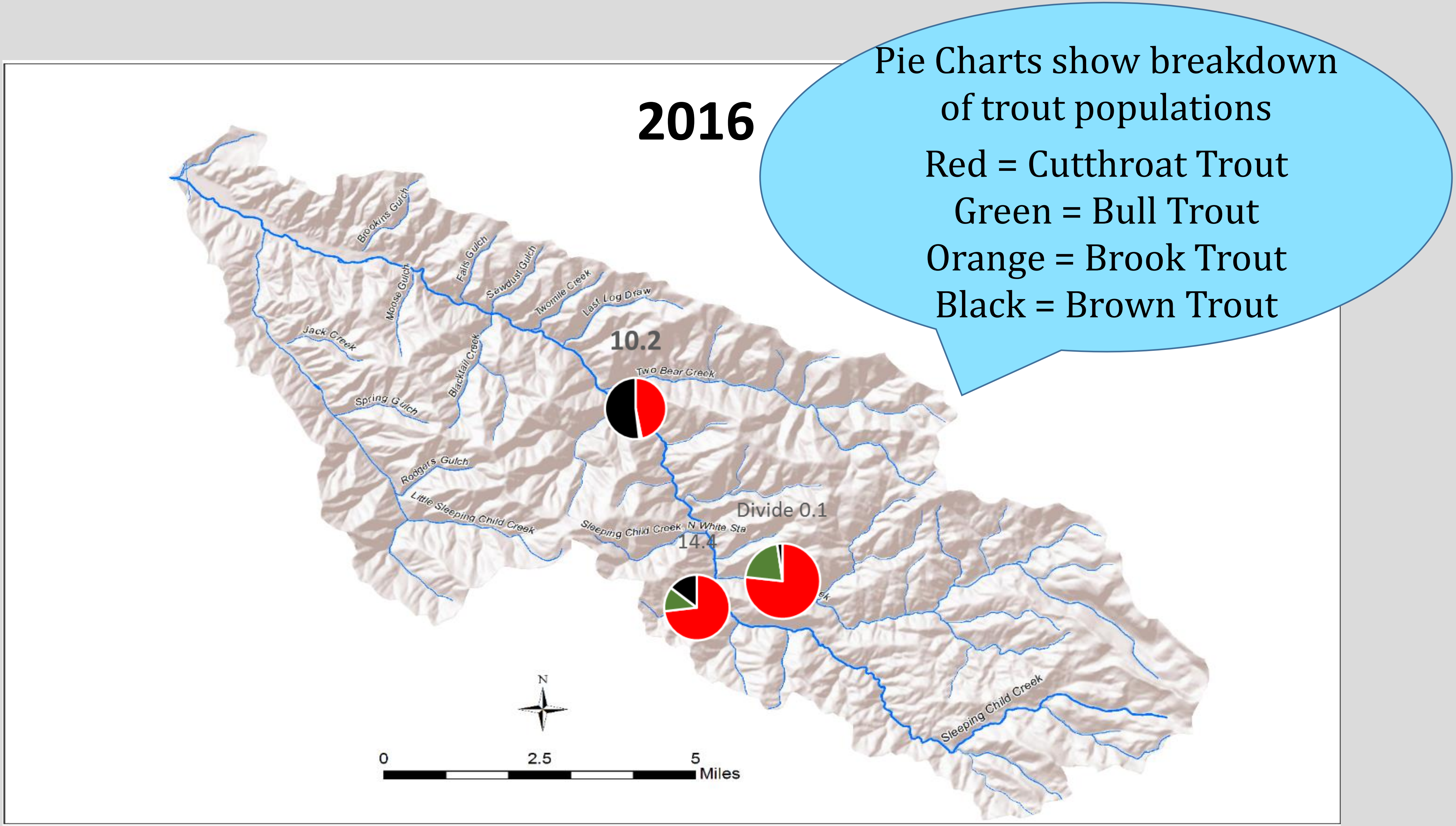


2011-2015

Pie Charts show breakdown of trout populations

Red = Cutthroat Trout
Green = Bull Trout
Orange = Brook Trout
Black = Brown Trout



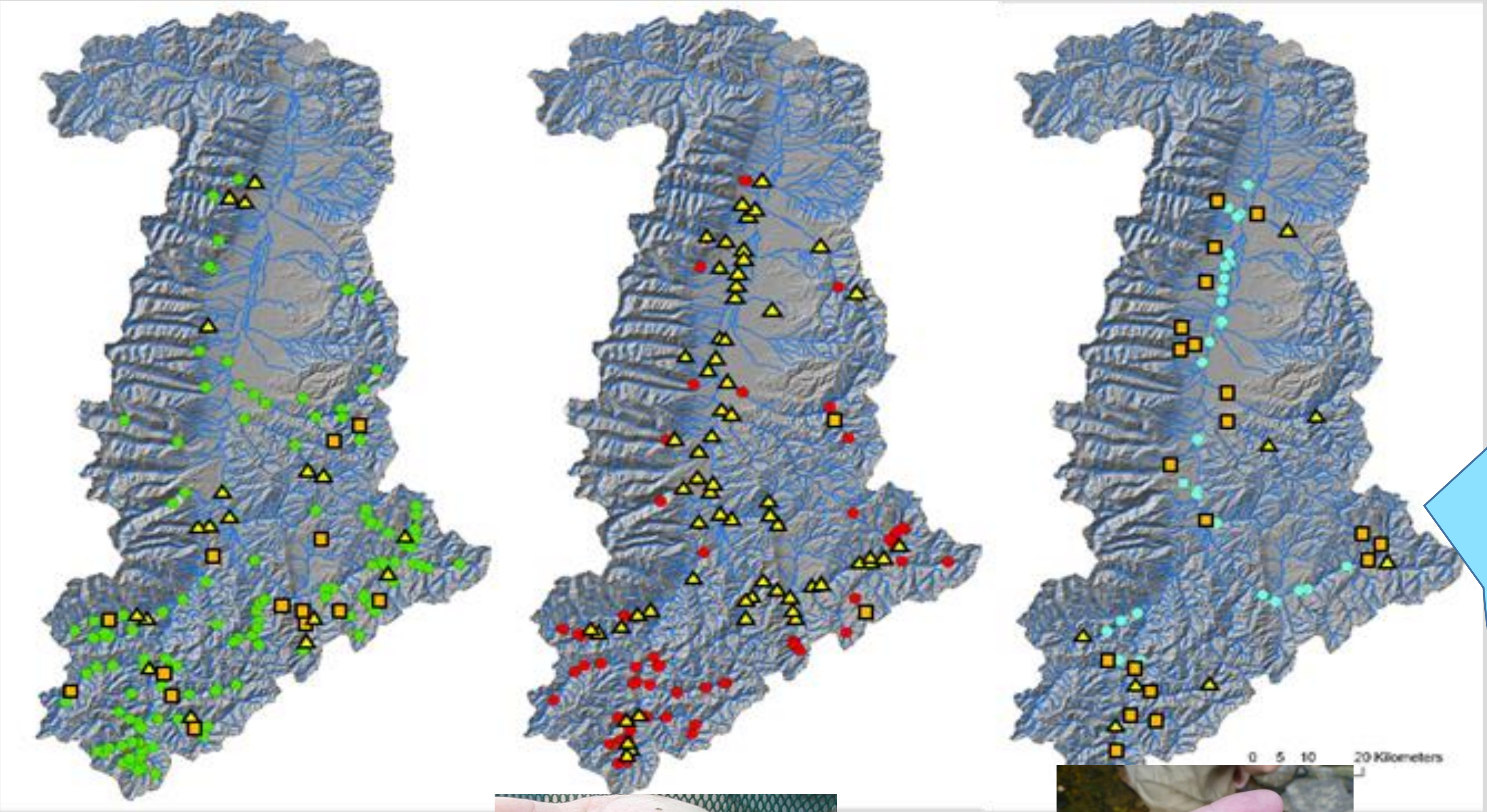

2016
Pie Charts show breakdown of trout populations
Red = Cutthroat Trout
Green = Bull Trout
Orange = Brook Trout
Black = Brown Trout
Brookins Gulch
Falls Gulch
Sawdust Gulch
Moose Gulch
Twomile Creek
Last Log Draw
Jack Creek
Blacktail Creek
10.2
Two Bear Creek
Spring Gulch
Rodgers Gulch
Little Sleeping Child Creek
Sleeping Child Creek
N White Sta
Divide 0.1
14.4
Sleeping Child Creek
N
0
2.5
5
Miles

Longnose Dace replacing Sculpin spp.

Similar thing happening with two native species. The Longnose Dace (tolerant of warmer temperatures) is filling in habitats that the Sculpin is abandoning.

Brown Trout "Scouts"

Longnose Dace replacing Sculpin spp.



Bull Trout

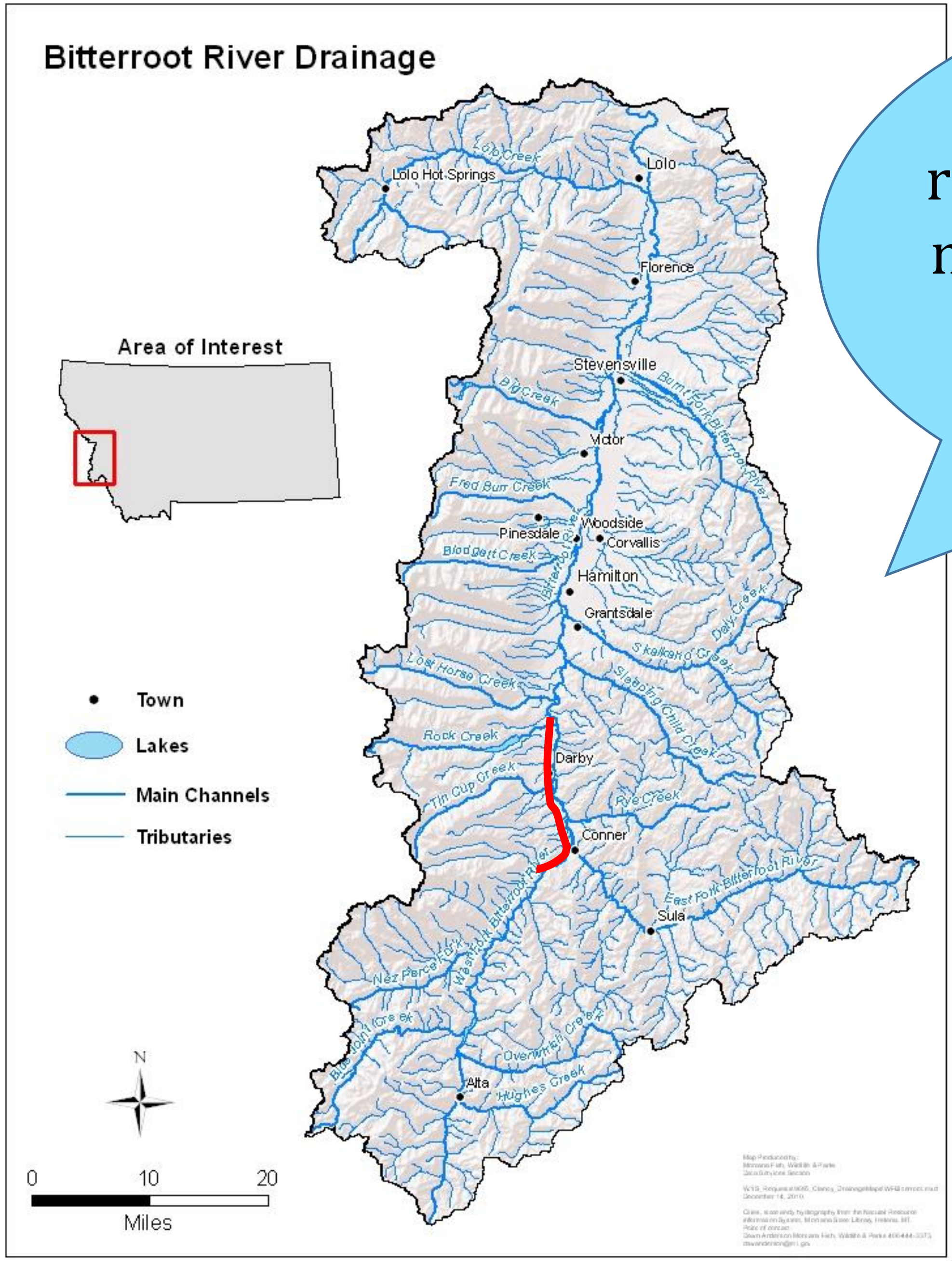
Yellow triangles indicate a spot that used to have Sculpin but they are no longer present.

Orange squares are locations that did not have Longnose Dace in the past and now do.

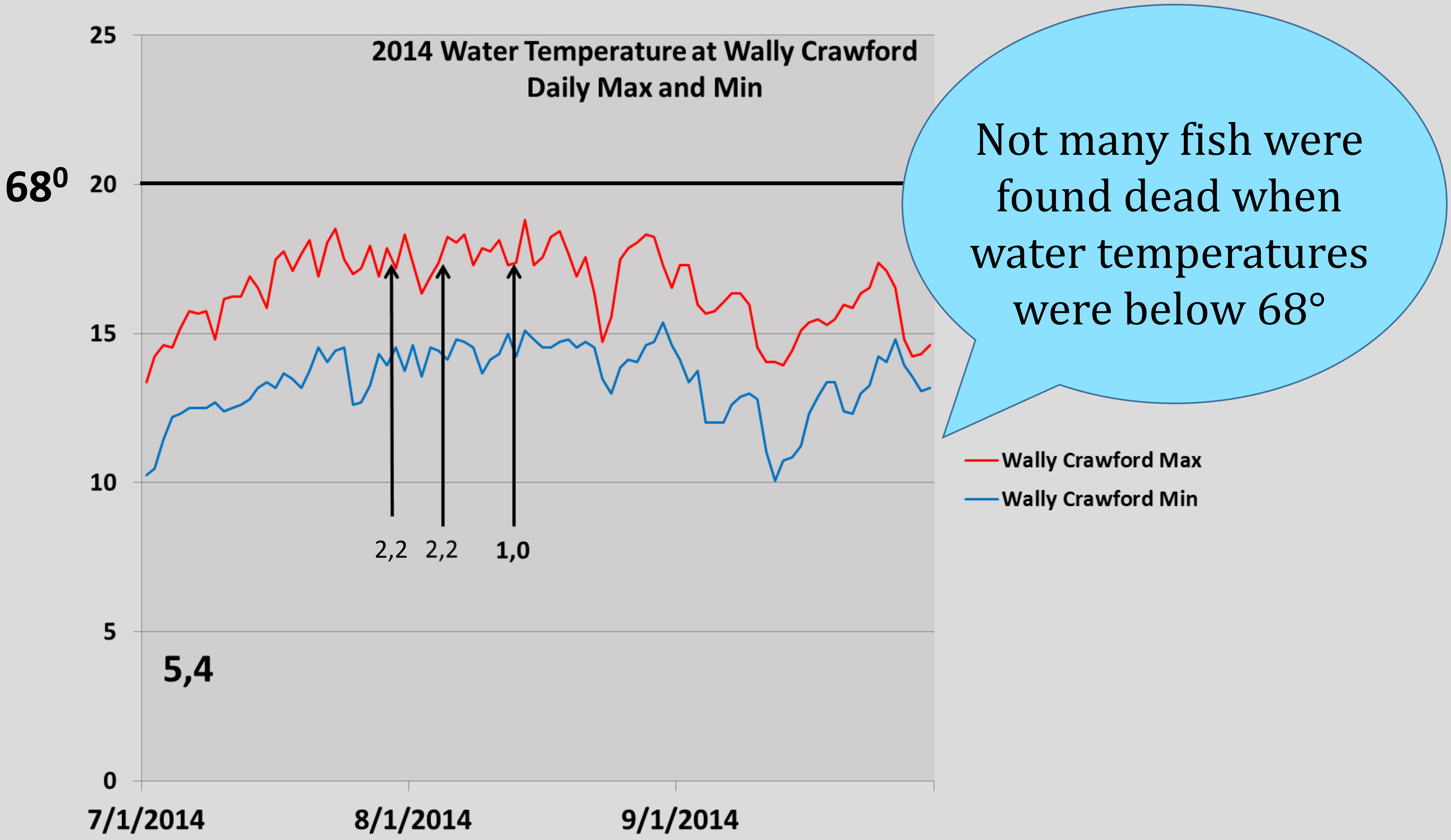
site extirpations (yellow triangles) and site colonizations (orange squares).

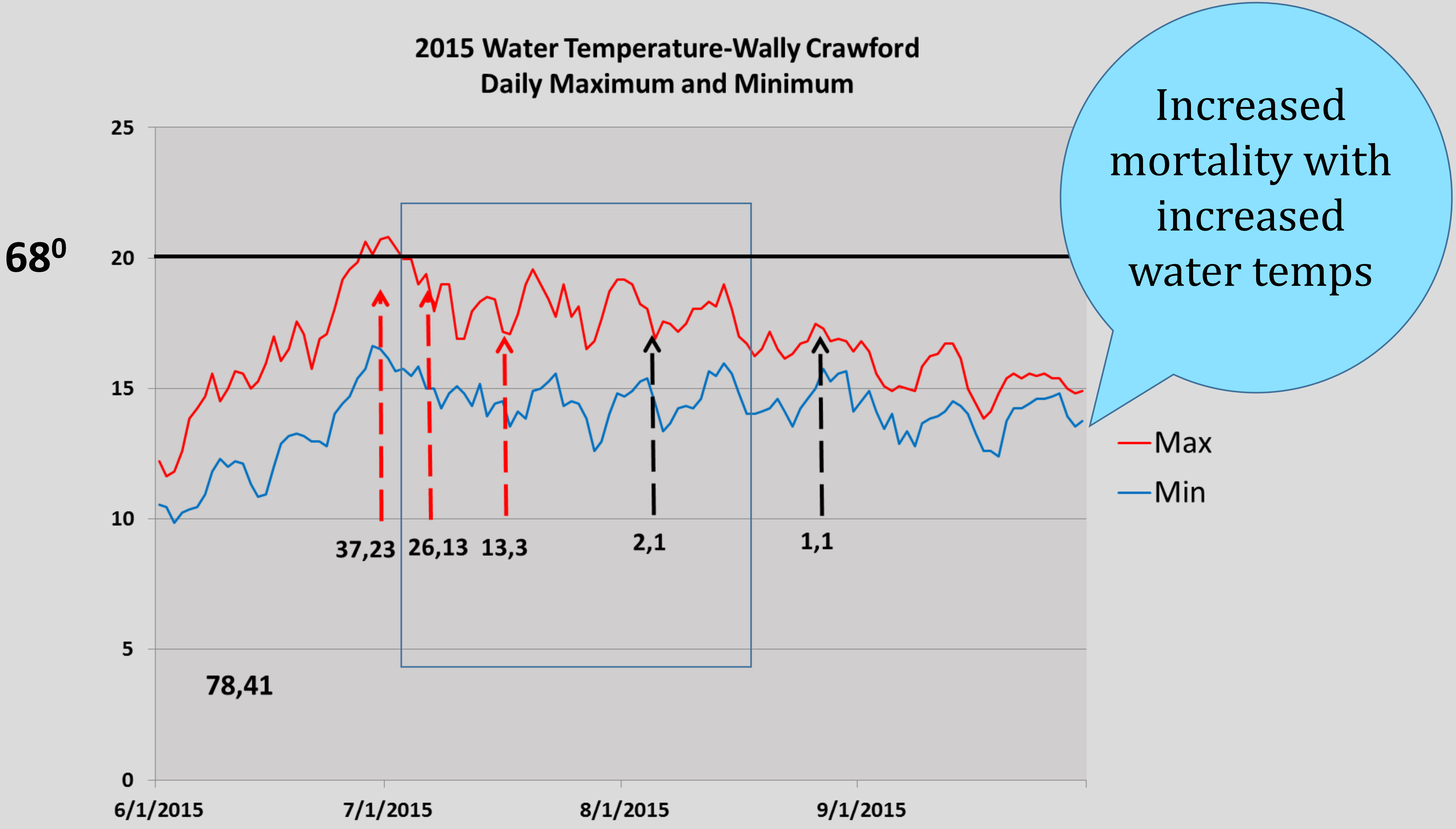
Mike Lemoine,
Lisa Eby
U of M

"Mort Floats"
2012-2016

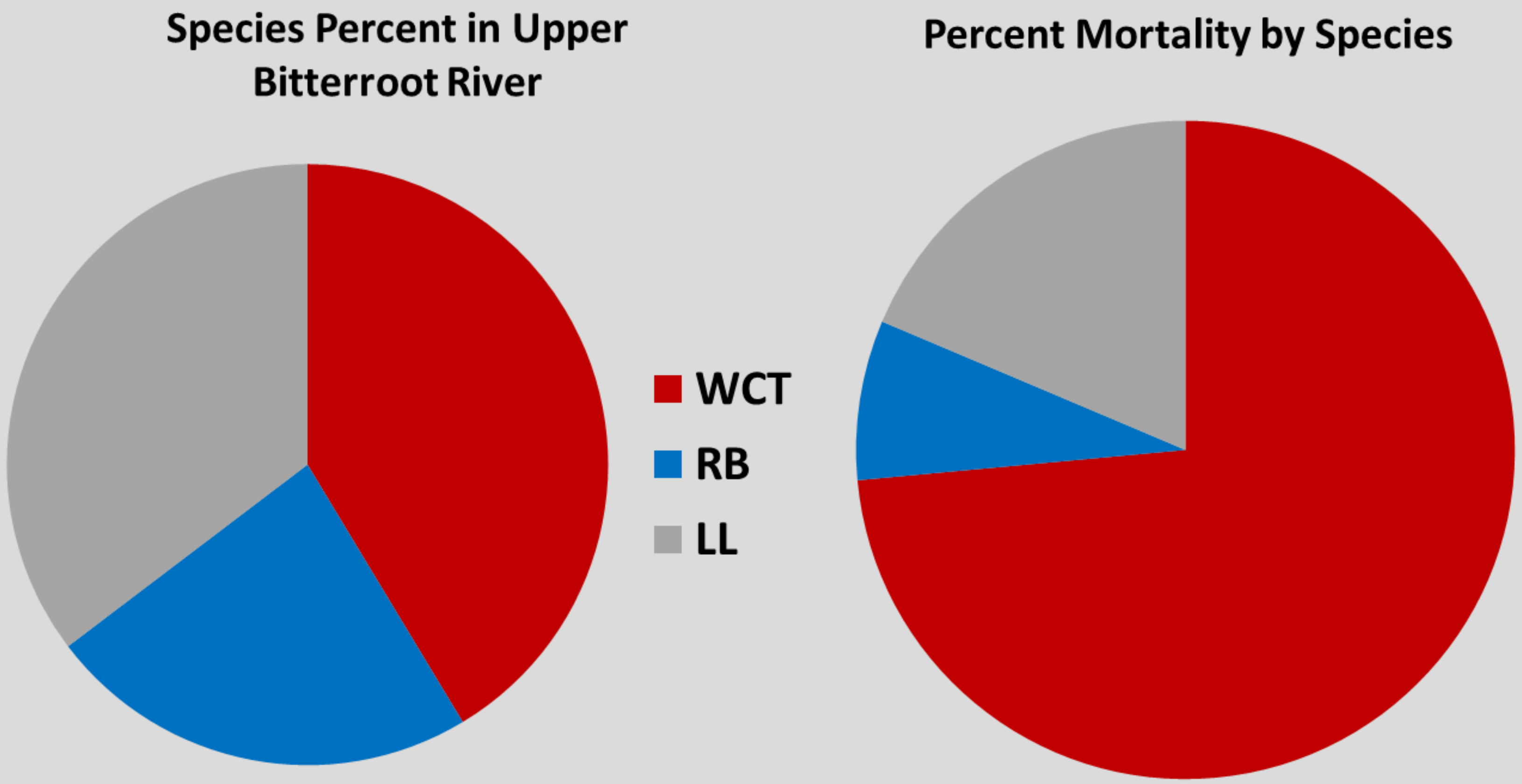


When guides were reporting seeing increased numbers of dead fish FWP did mortality floats to assess conditions


2014 Water Temperature at Wally Crawford
Daily Max and Min
68^0
25
20
15
10
5
0
2,2
2,2
1,0
5,4
7/1/2014
8/1/2014
9/1/2014
Wally Crawford Max
Wally Crawford Min
Not many fish were found dead when water temperatures were below 68°


2015 Water Temperature-Wally Crawford
Daily Maximum and Minimum
68^0
25
20
15
10
5
0
6/1/2015
7/1/2015
8/1/2015
9/1/2015
37,23
26,13
13,3
2,1
1,1
78,41
Max
Min
Increased mortality with increased water temps

2012-2015



Disproportionate number of Westslope Cutthroat trout dead as compared to overall population.

Two theories are

1) Cutthroat are less tolerant of warmer temperatures than the non-native rainbow and brown trout
2) Cutthroat get handled more often as an easier fish to catch.

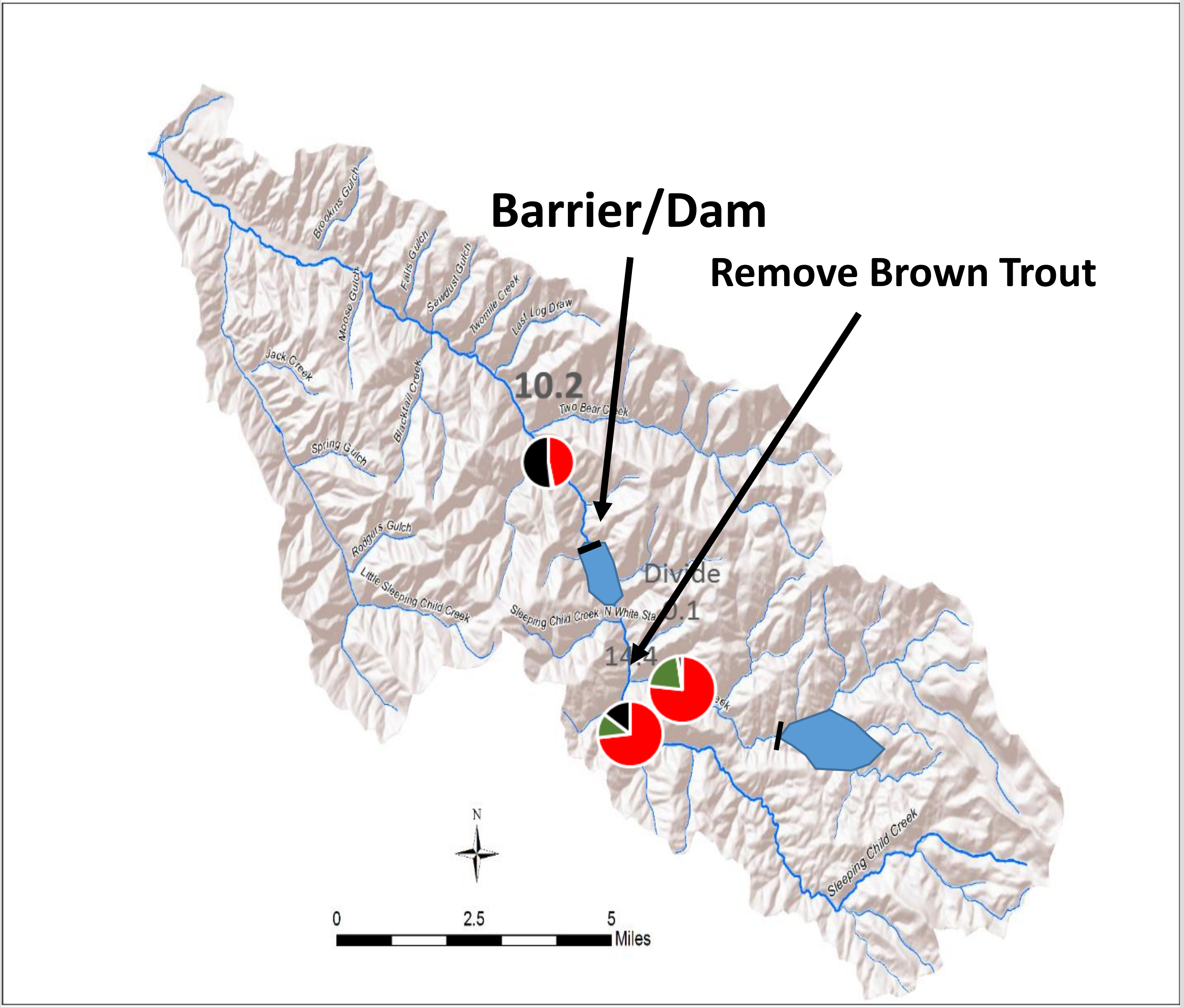
What Should We Do?

The Usual Suspects!

- **Healthy riparian, clean, abundant water, etc, will still be priorities (Plant cottonwoods in with those willows!)**
- **Invasive species – building barriers in some places**
- Summer flows – **agriculture!!**
  - **Anglers and Irrigators are facing the same problems**
  - **Storage will be promoted by irrigators – anglers need to be part of the conversation**

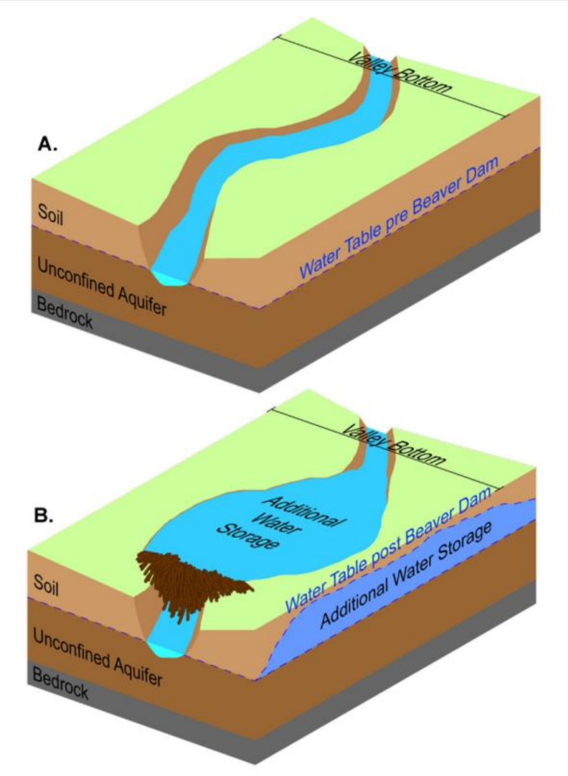
Climate, invasive species and land use drive population dynamics of a cold-water specialist
Ryan P. Kovach1*, Robert Al-Chokhachy2, Diane C. Whited3, David A. Schmetterling4,
Andrew M. Dux5 and Clint C. Muhlfeld1,3

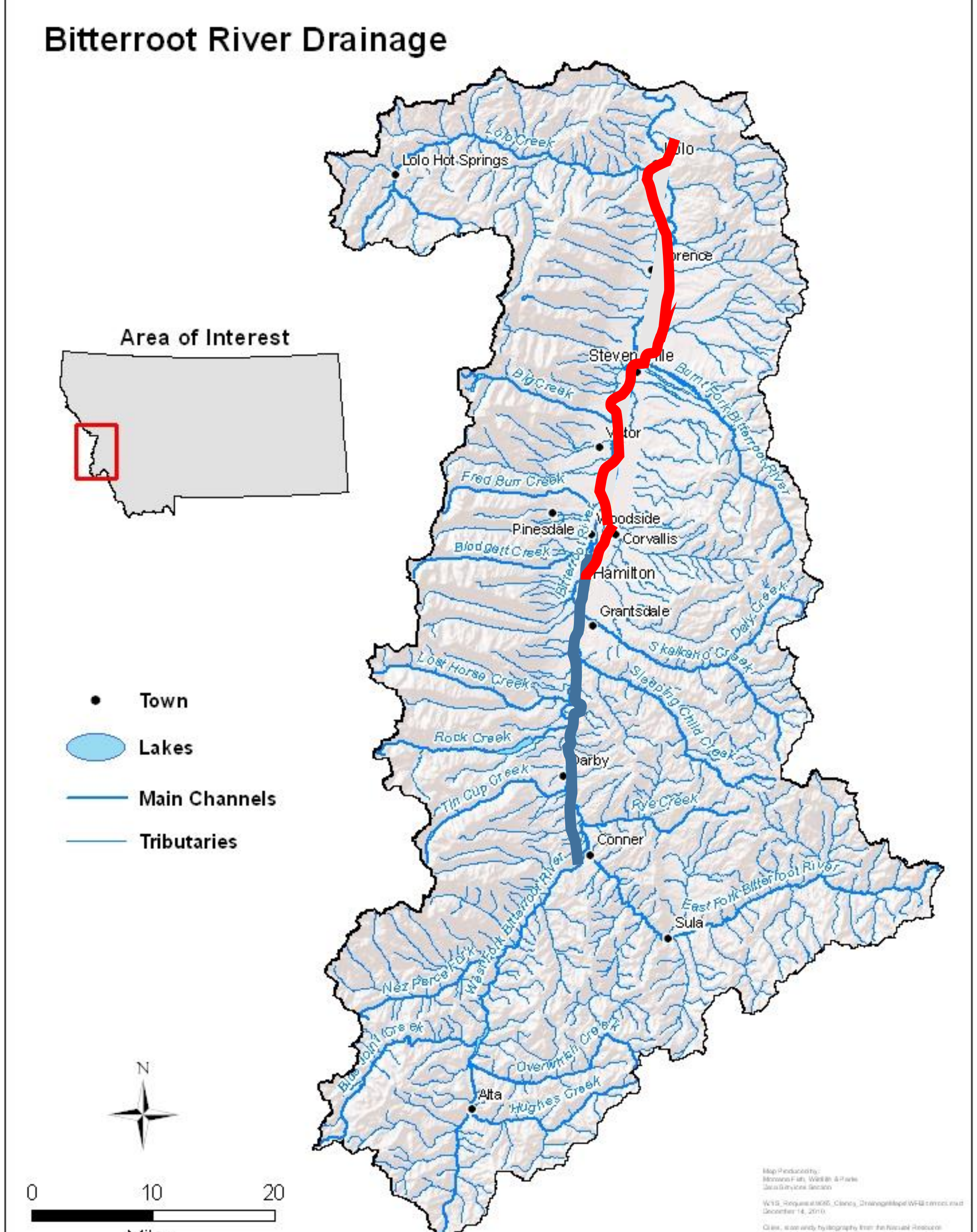
Painted Rocks Dam Raise

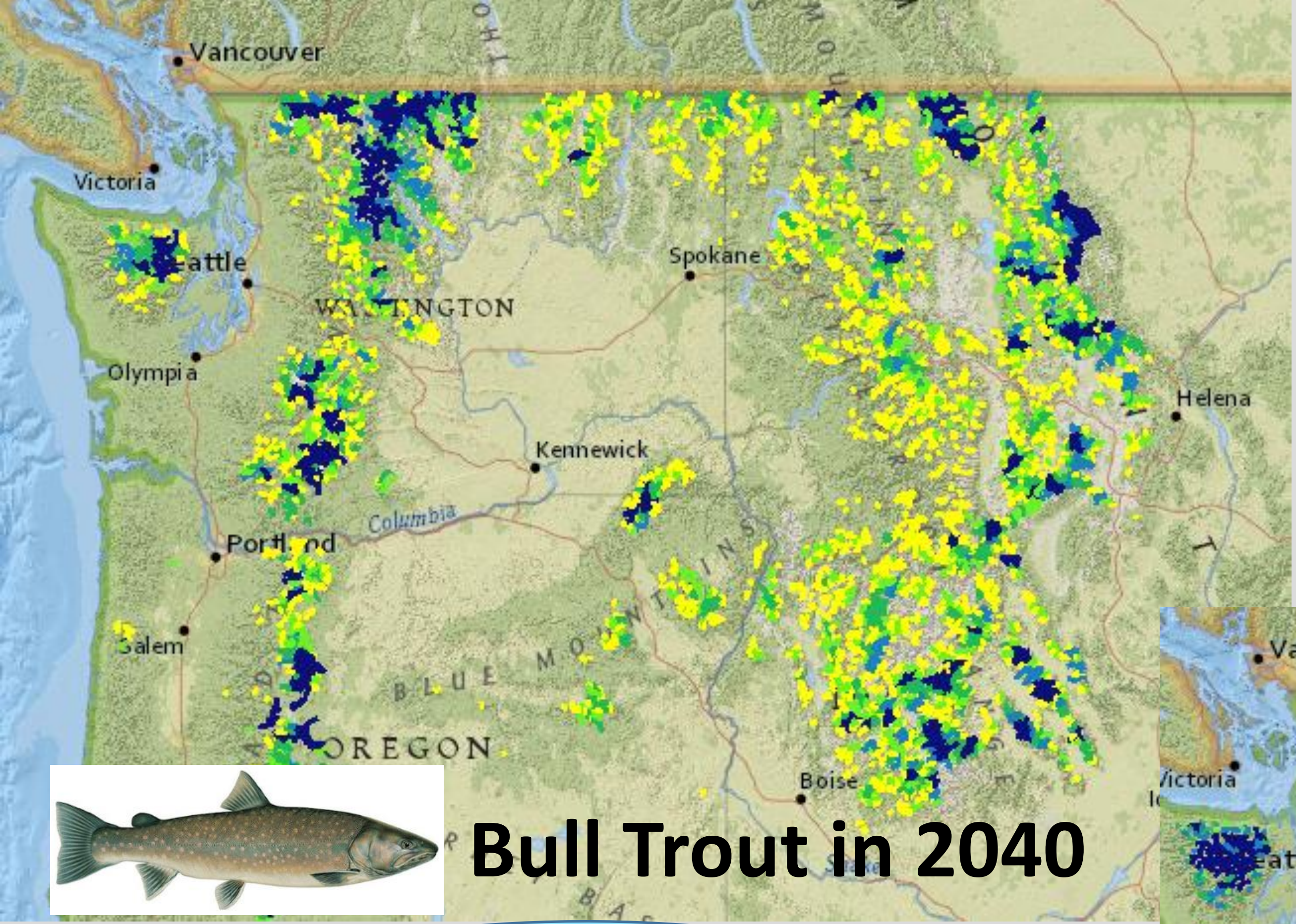


Can Beaver Dams Mitigate Water Scarcity Caused by Climate Change and Population Growth?

Konrad Hafen , William W. Macfarlane *Utah State University*





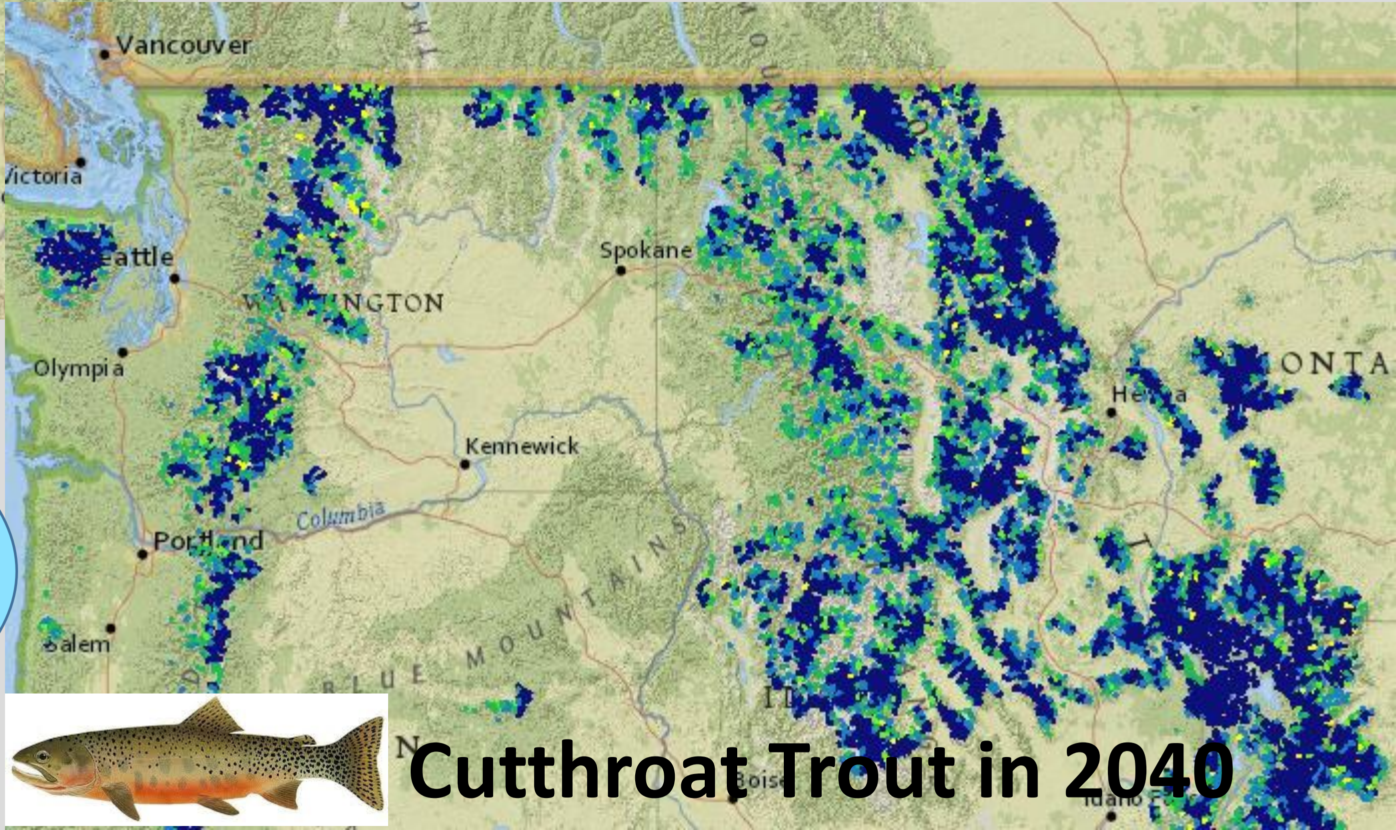


Bull Trout in 2040

Isaak, D., M. Young, D. Nagel, D. Horan, M. Groce, and S. Parkes. 2017. Climate Shield bull trout and cutthroat trout population occurrence scenarios for the western U.S. Rocky Mountain Research Station, U.S. Forest Service Data Archive, Fort Collins, CO. DOI: pending.

Blue indicates habitable by each species.

We need to be thoughtful about the places we're focusing restoration. Some areas will get too warm for Bull and Cutthroat Trout in the future.



Cutthroat Trout in 2040

Human Adaptation in Future Decades