The New Reality…

1880-2014 Global Air Temperature Trend

2014 Set a New Record
The New Reality...

Atmospheric CO₂ Concentration

+3ppm/year

Foot still on the greenhouse gas pedal...

Plan on continued warming for decades...
Obviously, the Cold-Water Fish World Will End in Immolation...

- Huge declines: 50%-100%

- Meisner 1988
- Keleher & Rahel 1996
- Eaton & Schaller 1996
- Reusch et al. 2012
- Rahel et al. 1996
- Mohseni et al. 2003
- Flebbe et al. 2006
- Rieman et al. 2007
- Kennedy et al. 2008
- Williams et al. 2009
- Wenger et al. 2011
- Almodovar et al. 2011
- Etc.
Obviously, the Cold-Water Fish World Will End in Immolation...

Double-Whammy in Mountain Headwaters!

We’ve been predicting doom for almost 30 years
Climate “Velocity” is What’s Biologically Relevant Rate at Which Isotherms & Thermal Niches Shift

Velocity varies 100x for same warming rate

Stream Application Required Some Data

>200,000,000 hourly records
>20,000 unique stream sites
>100 resource agencies
& Accurate Stream Temperature Scenarios

- $R^2 = 0.91$
- RMSPE = 1.0°C

1-km resolution
1,000,000 kilometers
Stream Warming Rates 1968-2011

923 sites in NorWeST database with >10 year records

+0.10°C/decade
Stream Warming Rates 1968-2011

923 sites in NorWeST database with >10 year records

+0.10°C/decade

Air trend = 0.21°C/decade
Remember... Velocity is What Matters!

Stream Velocity Reference Equations

Stream warming rate
- +0.1 C/decade \( (y = 1.25x^{-1}) \)
- +0.2 C/decade \( (y = 2.50x^{-1}) \)
- +0.3 C/decade \( (y = 3.75x^{-1}) \)
- +0.4 C/decade \( (y = 5.00x^{-1}) \)
- +0.5 C/decade \( (y = 6.25x^{-1}) \)

Stream slope (%)

Climate velocity (km/decade)

Climate Velocity Map for Regional Network

1968-2011 Median Velocity: 1.07 km/decade

>10x Slower Than Velocities of Global Marine & Terrestrial Environments (Burrows et al. 2011)
Where do Those “Doomed” Headwater Species Live?

222,000 kilometer network

Climate scenario & velocity maps

August stream temperature (°C)

Climate velocity (km/decade)

Where do Those “Doomed” Headwater Species Live?

Median velocity: 0.33-0.48 km/decade

BIG biological databases – 1000s of sites

Cold Climates Also Exclude Most Invaders

Proportion of sites species observed

Mean August Stream Temp (°C)

- Cutthroat Trout <125 mm (2269 sites)
- Bull Trout < 150 mm (1102 sites)
- Brook Trout (3061 sites)
- Brown Trout (832 sites)
- Rainbow Trout (1562 sites)

BEWARE THE INVASION
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
Precise Species Distribution Models to Highlight Climate Refugia

BIG FISH DATA

>4,000 sites
>500 streams

Big difference in habitat size

78% classification accuracy

85% classification accuracy
Bull Trout Probability Map

1980s

Stream population scale predictions

5,332 >0.1 habitats
1,325 >0.5 habitats
348 >0.9 habitats
Bull Trout Probability Map

2080s

North Cascades

Metolius

Walla Walla

Flathead

Upper Salmon

Extreme scenario! +5°C

2,712 >0.1 habitats
460 >0.5 habitats
62 >0.9 habitats
Cutthroat Probability Map

- 9,219 >0.1 habitats
- 8,519 >0.5 habitats
- 3,089 >0.9 habitats
Cutthroat Probability Map 2040s

7,914 >0.1 habitats
7,153 >0.5 habitats
2,179 >0.9 habitats
Cutthroat Probability Map

2080s

6,489 >0.1 habitats
5,181 >0.5 habitats
1,559 >0.9 habitats
About that Brook Trout Effect...

Number & Size of Refugia >0.9

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<th></th>
<th>Period</th>
<th>Median size (km)</th>
<th>Refugia</th>
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<td>Cutthroat Trout</td>
<td>1980s</td>
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2x larger

...but steeper streams are also invasion resistant
Website Provides Information in User-Friendly Digital Formats

Just Google “Climate shield trout”

File formats:
- ArcGIS files
- pdf files

15 Scenarios:
- 3 climate periods
- 5 Brook invasion levels
High-quality Spatial Information Empowers the Aquatic Conservation Army...

Occupancy Probability
- > 0.90
- > 0.75 to < 0.90
- > 0.50 to < 0.75
- > 0.25 to < 0.50
- < 0.25

Slope = 10% to 15%

West Fork Clearwater River
Jocko River
East Fork Finley Creek
Finley Creek
Agency Creek
South Fork SP

Highest priority conservation investment!
Uses for Climate Shield Information

1. Designing and implementing climate-smart conservation networks
2. Identifying candidate streams for assisted migrations and founding new populations
3. Informing decisions about the locations (or need) for fish barriers, projects to eradicate non-native species, or habitat restoration
4. Quantifying amount of native trout habitat and potential changes this century
5. Designing efficient biological monitoring programs (e.g., eDNA)
Consistent for all Rocky Mountain Streams
CRCT Cutthroat Probability Poster

a) 1980s

Climate Shield Refuge Streams for Colorado River Cutthroat Trout

Occupancy Probability
- > 0.9
- > 0.5 to < 0.9
- > 0.1 to < 0.5

Climate Shield

b) 2040s
Cautions With Use of Climate Shield

Geologic barriers

NHD stream layer inaccuracies (intermittent reaches: Fcode = 46003)

USGS NHD Data Stewardship Program: http://nhd.usgs.gov/index.html
Fish Data Acknowledgements:
John Chatel & Scott Vuono - Sawtooth National Forest; Ralph Mitchell, Herb Roerick, & Mike Kellett - Boise National Forest; Bart Gamett - Salmon-Challis National Forest; James Brammer & Steven Kujala - Beaverhead-Deerlodge National Forest; Joan Louie - Lolo National Forest; Leslie Nyce - Montana Fish, Wildlife and Parks; Seth Wenger – University of Georgia; Kevin Meyer – Idaho Fish & Game
Map & Protect Climate Refugia for Many Aquatic Critters...
Partners have sampled >8,000 sites already…
Goal: Precise Models & Databases for All Species

High-resolution landscape models

I’m going to invest here...

...instead of here