Climate Change in the Crown of the Continent Ecosystem: Implications for Fisheries

Clint Muhlfeld
USGS Northern Rocky Mountain Science Center
Glacier National Park
West Glacier, Montana 59936
cmuhlfeld@usgs.gov
http://nrmsc.usgs.gov/staff/muhlfeld

Crown of the Continent Ecosystem

CANADA

Aquatic Habitat

Aquatic Biota

Bull Trout – *A threatened species*

Bull Trout Migratory Life History

Spawning and incubation

Juvenile rearing

Adult movements

Subadult rearing

Westslope Cutthroat Trout – *A Species of Special Concern*

Flathead River near Foisey Creek, BC *M. Ready*

Westslope Cutthroat Trout

Westslope cutthroat trout display both *migratory* and *resident* life history strategies

Flathead River

Commerce Creek, BC

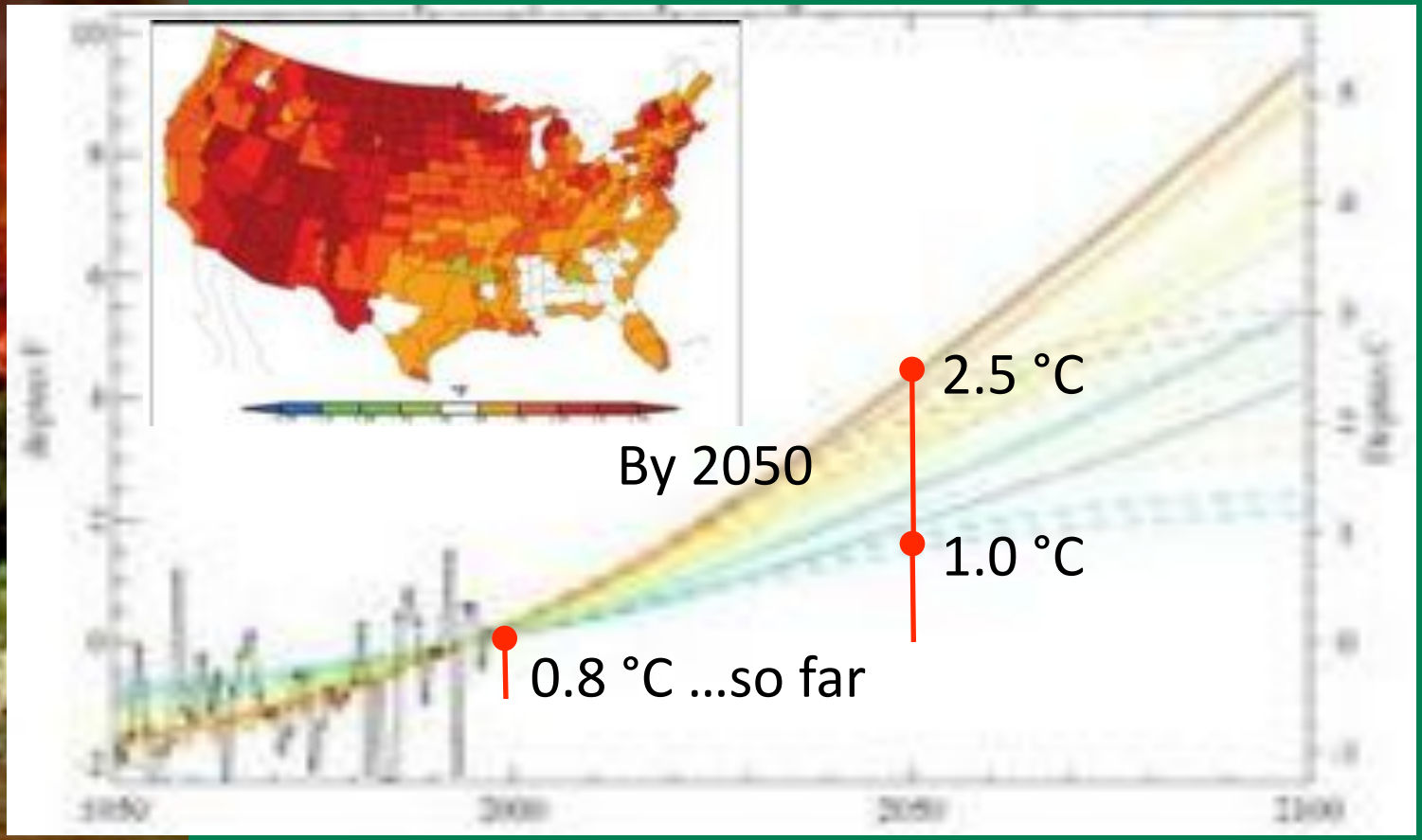
Flathead River: A native species stronghold

Declines of Native Salmonids

Habitat alteration

Invasive species

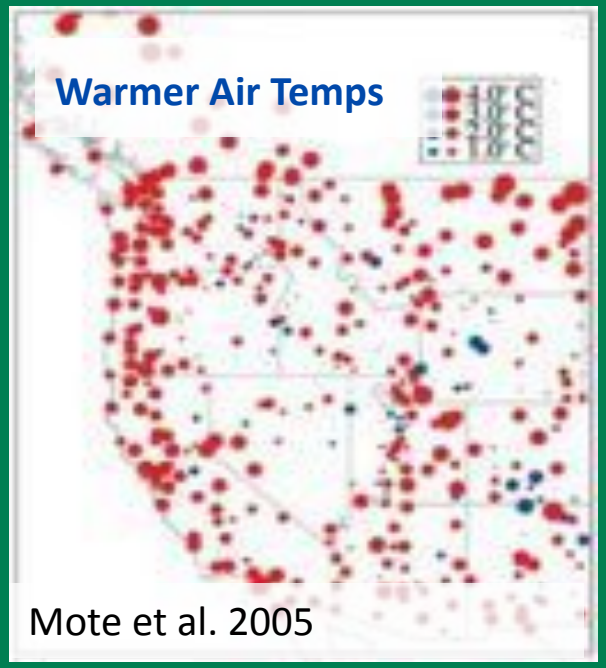
Climate is Changing Fastest in the Interior West

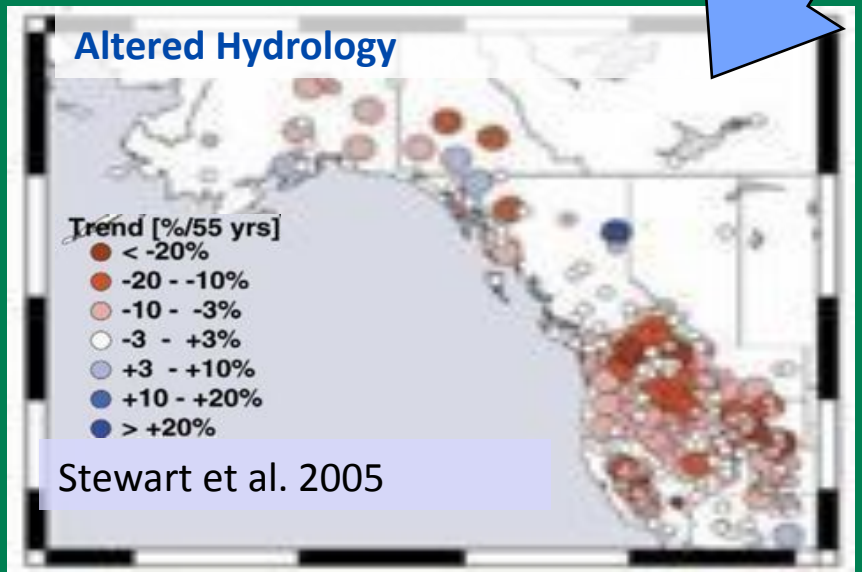


Mote et al. 2008

A Landscape Undergoing Change

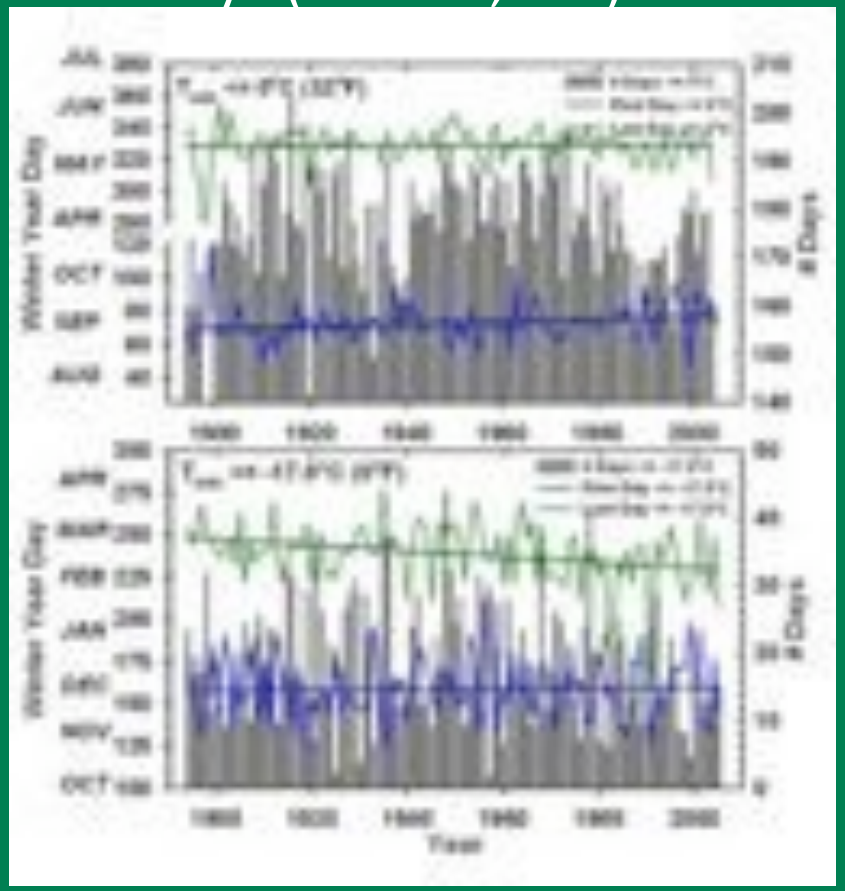
Western US – Observed Trends



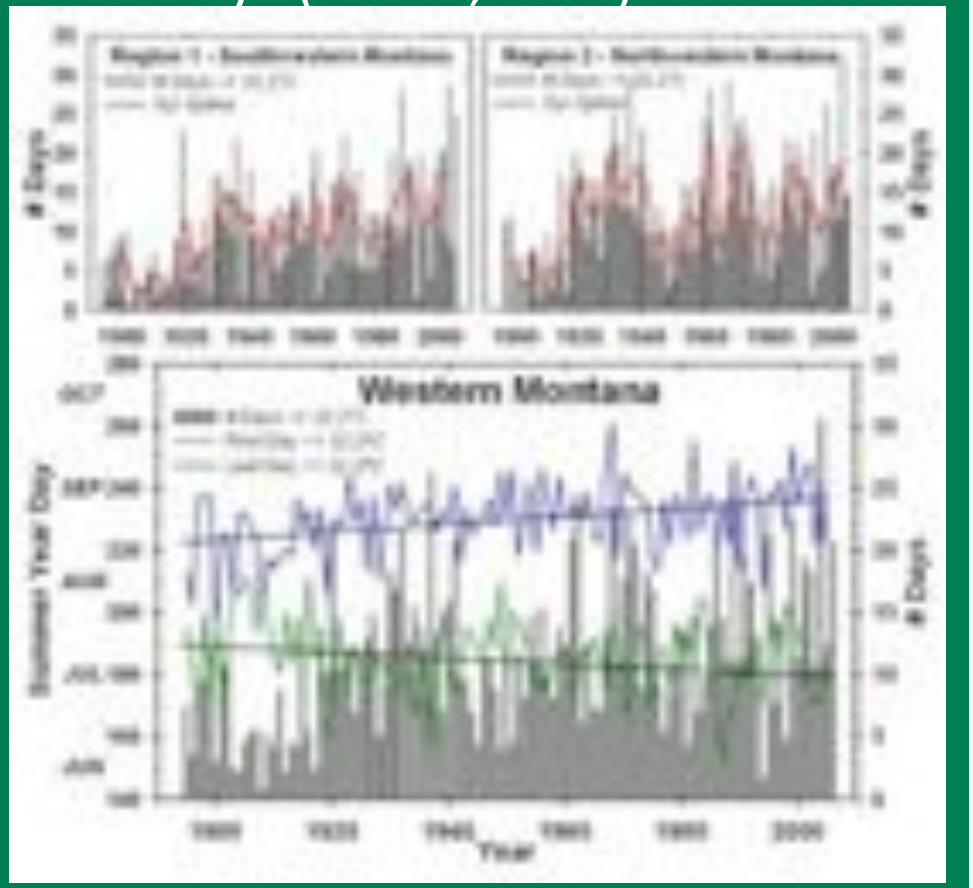


Air Temperature Trends – Western Montana

Loss of ~ month of extremely cold days (< -18°C; 0°F)



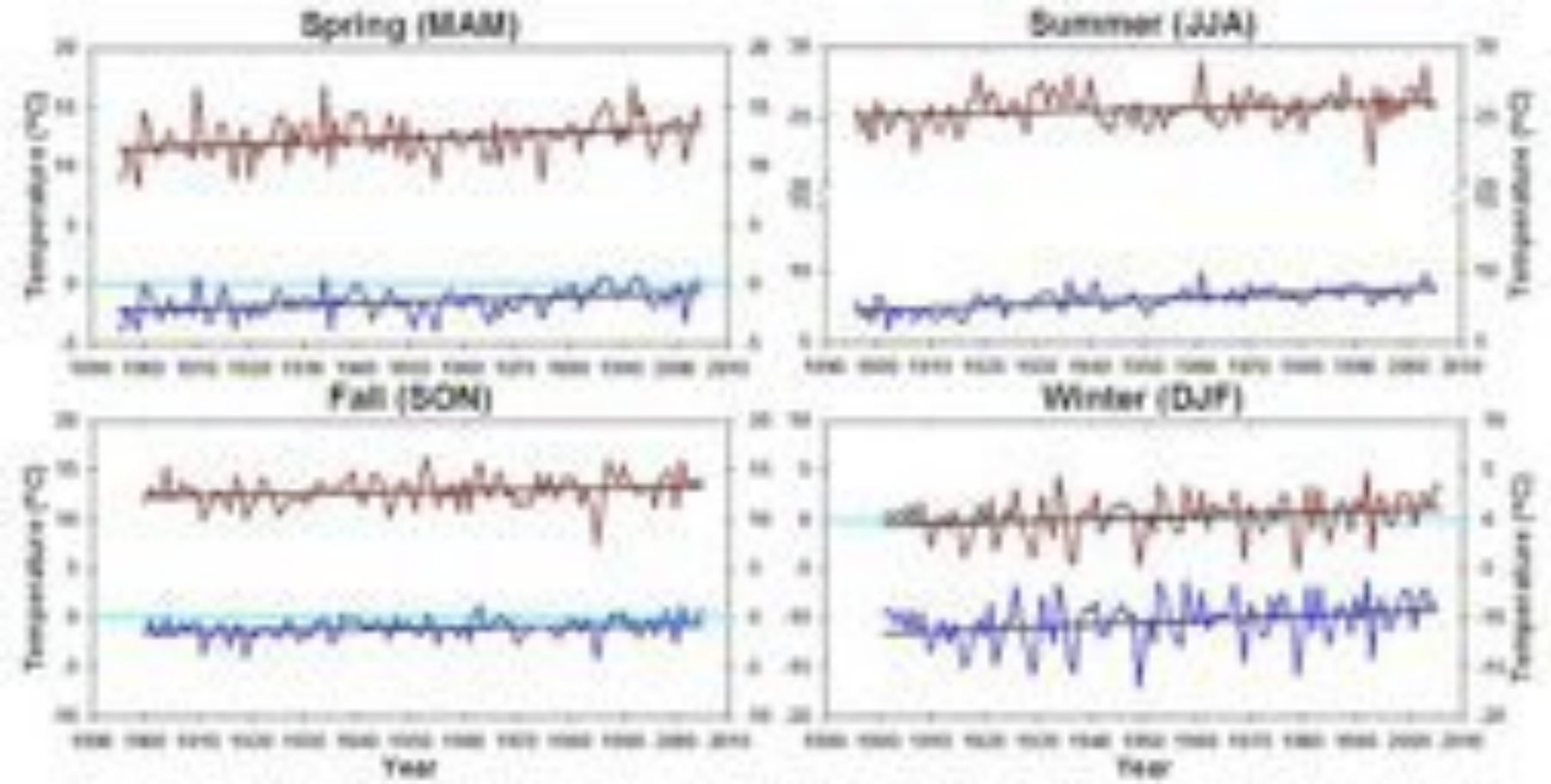
3-fold increase in extremely hot days (>32°C; 90°F)



USGS

Pederson et al. (2010) Climatic Change

Air Temperature Trends – Western Montana

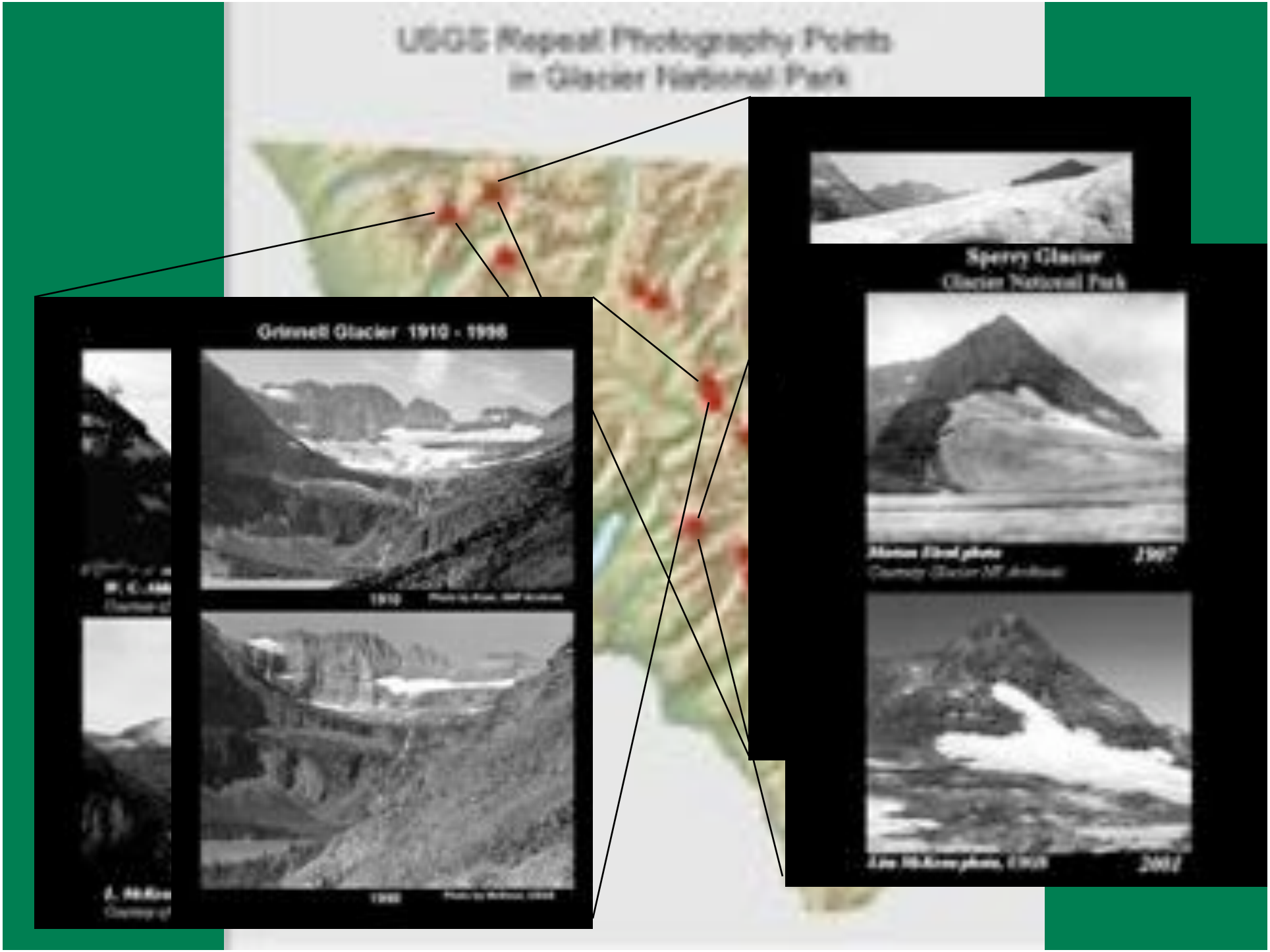


1900-2006

- **+1.33°C rise in annual average temperatures**
- **~1.8 times > +0.74°C rise in Global temperatures**

USGS

Pederson et al. (2010)


USGS Repeat Photography Points
in Glacier National Park
Grinnell Glacier 1910 - 1998
1910
1998
Sperry Glacier
Glacier National Park
1917
2002

Phase I: Broad-scale analysis of climate change and native trout persistence

- What kinds of climate associated stressors are likely to pose the greatest risk for native trout?
- Where are the highest risk impacts likely to occur?
- Where are the lowest risk areas?
- How do these climate-associated stressors interact with existing population status and habitat condition?

USGS

Focal species

Haak et al. *In-review*

Increased summer temperatures

Used trout historic distribution to define suitable temperatures for each fish based on PRISM temperature data

Applied 3°C increase to PRISM data

Categorized risk

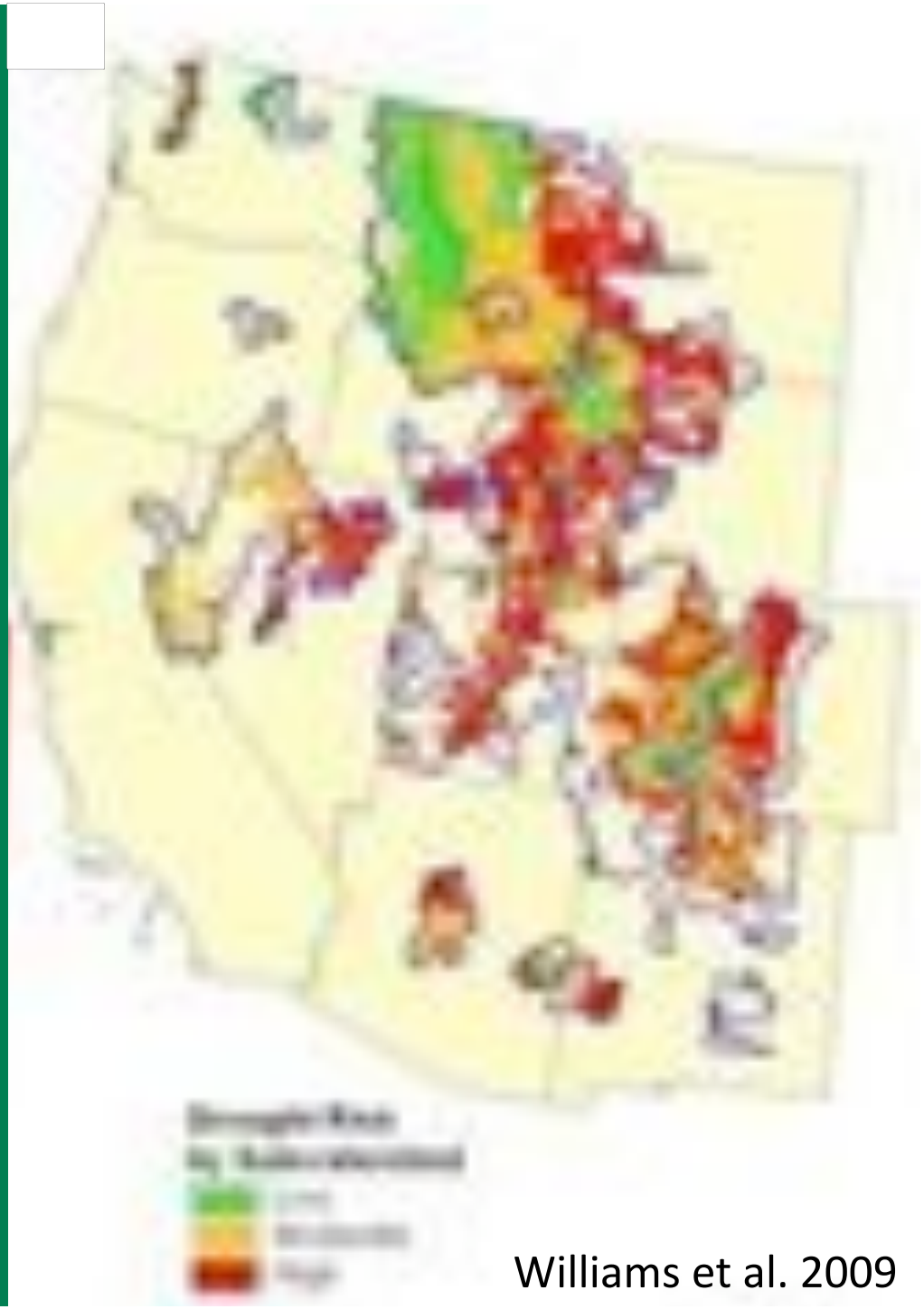
USGS

Drought

Hoerling and Eischeid (2007) applied the Palmer Drought Severity Index to project drought 2035-2060

PDSI developed for plains states: does not capture the regional microclimates associated with mountainous terrain in the West

Used elevation (snowpack) and mean annual precipitation to mitigate



Williams et al. 2009

Uncharacteristic flooding

Areas transitioning from snow to rain experiencing uncharacteristic flooding events in west

Followed Hamlet and Lettenmaier (2007) to categorize basins as:

- Snow dominant
- Rain dominant
- Transient

Applied 3° C increase and re-categorized

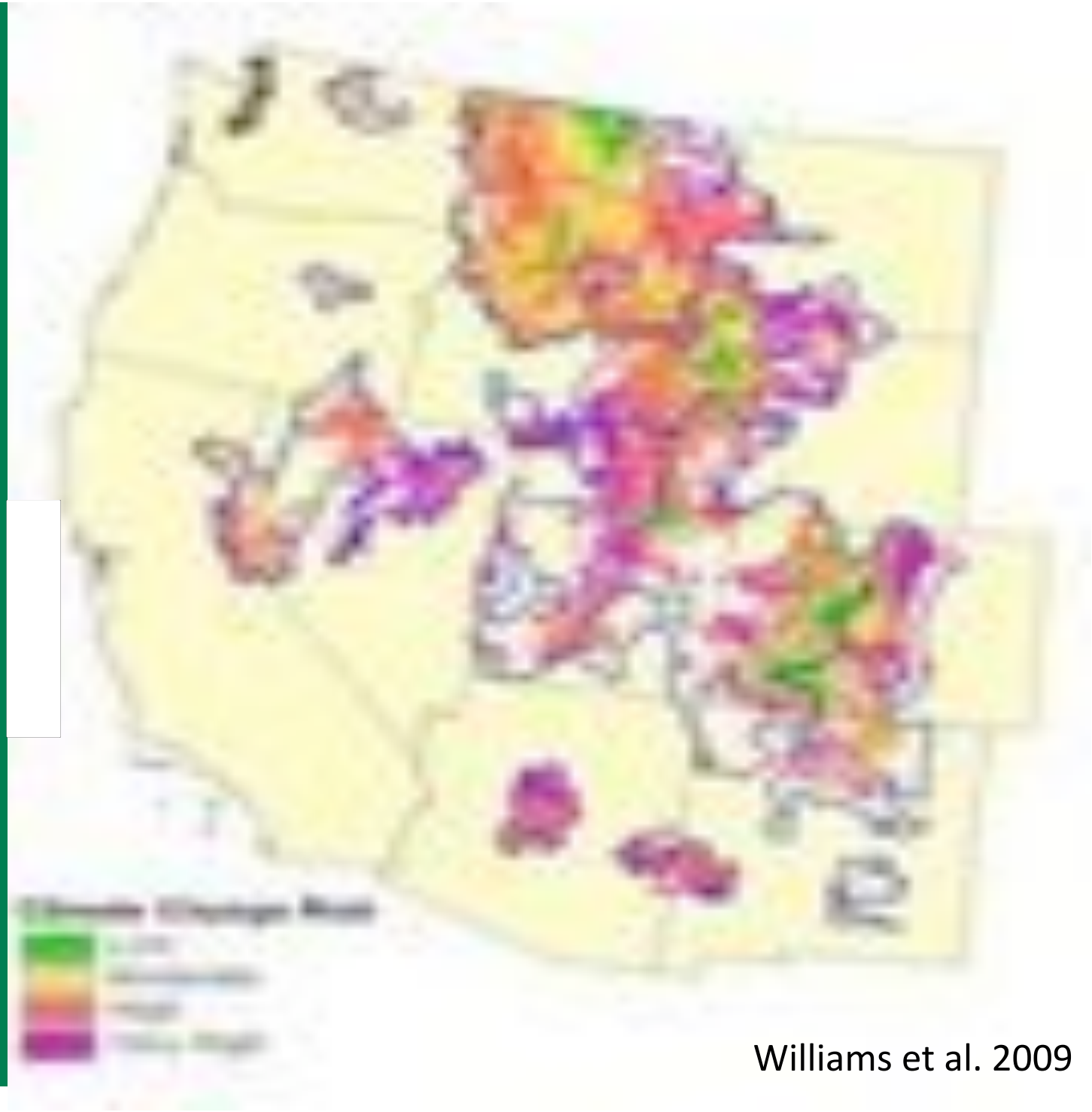
USGS

Williams et al. 2009

Increased risk of fire

- Westerling et al (2006) found fires in west associated with timing of snow melt
- Earlier melt = more fires/ longer season due to increased drying
- Topographic zone of 1680 – 2690 m
- Within topographic zone, further classified based on fuel types using Anderson Fire Behavior Fuel Model (Anderson 1982)

Composite Climate Change Risk



Williams et al. 2009

Risks vary substantially from one species or subspecies to the next

- 39% of Bonneville cutthroat habitat at high risk of fire
- 17% of Colorado River cutthroat habitat at high risk

Coarse-scale Evaluation

As much as 65% of the habitat currently occupied by WCT will be at high risk due to climate change (warmer water, winter flooding, and increased wildfires) over the next 50 years…..

USGS

Williams et al. (2009)

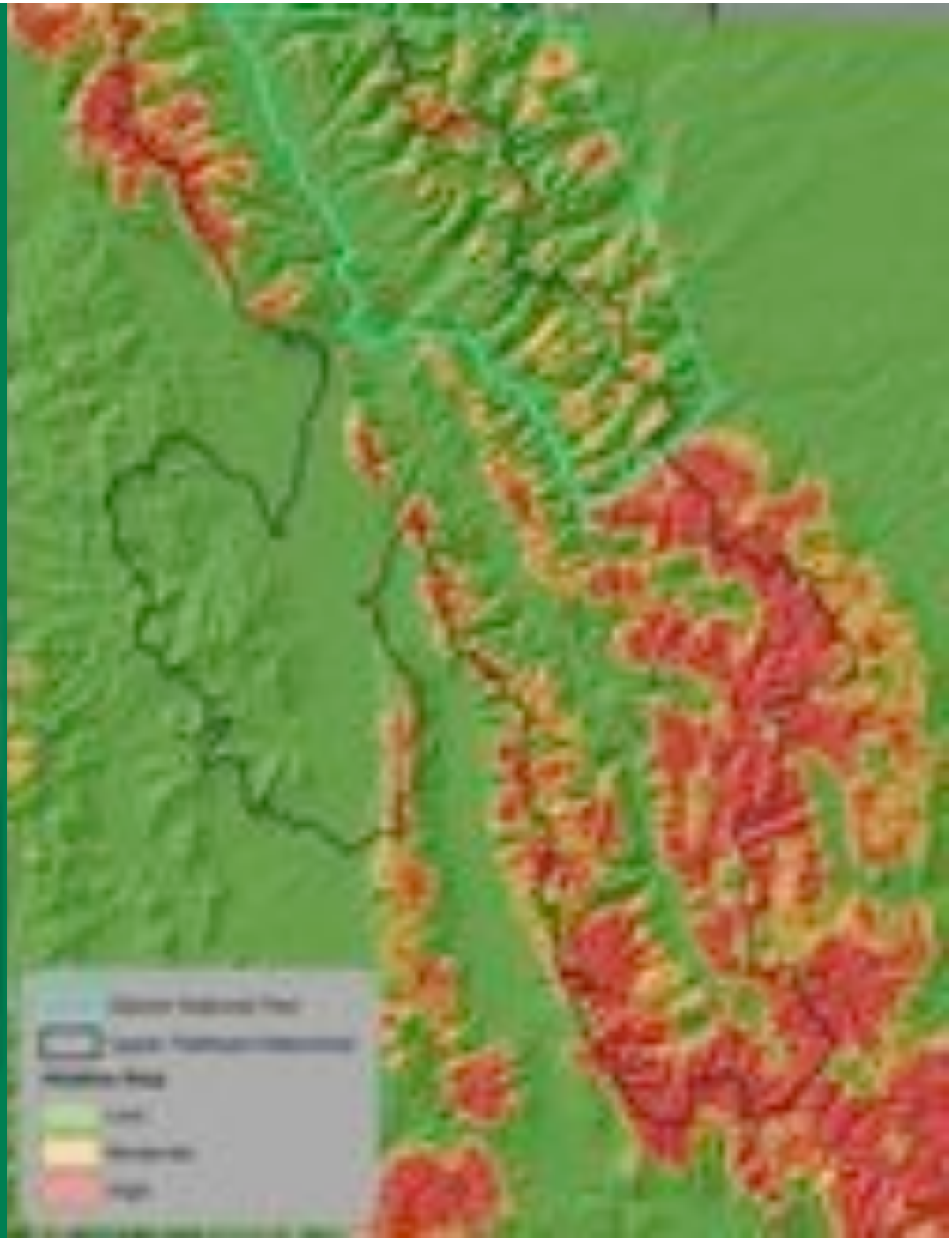
Winter Flood Risk

to native Westslope cutthroat trout in Glacier National Park

USGS

Wildfire risk to native Westslope cutthroat trout in Glacier National Park

USGS

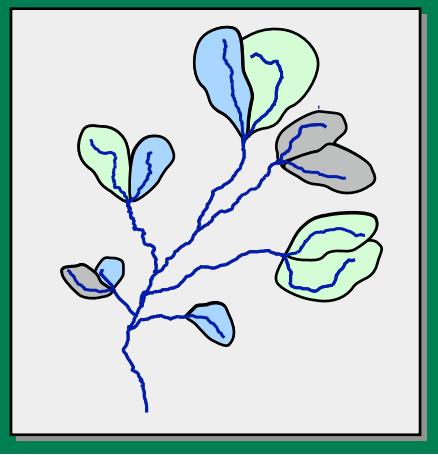


Drought risk to native Westslope cutthroat trout in Glacier National Park

USGS

Better Downscaling Needed

How will global trends affect my stream?



USGS

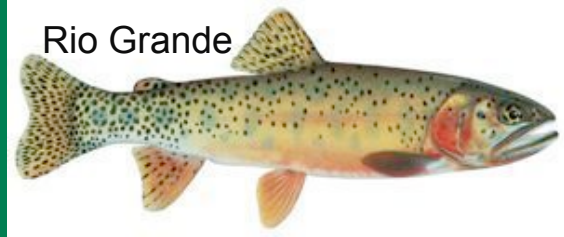
Phase II: moving it to the ground:
fine-scale evaluation of broad-scale findings

Yellowstone

Westslope

Colorado

Rio Grande



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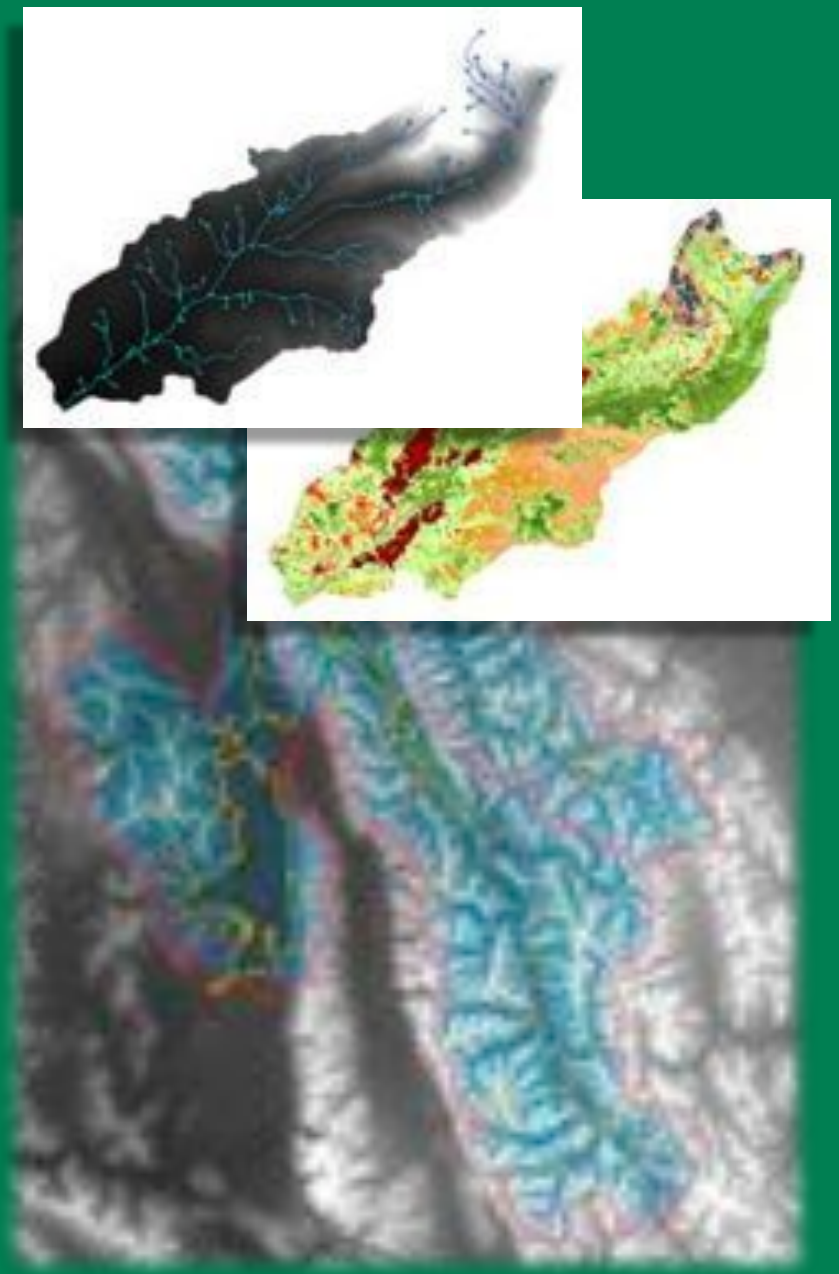
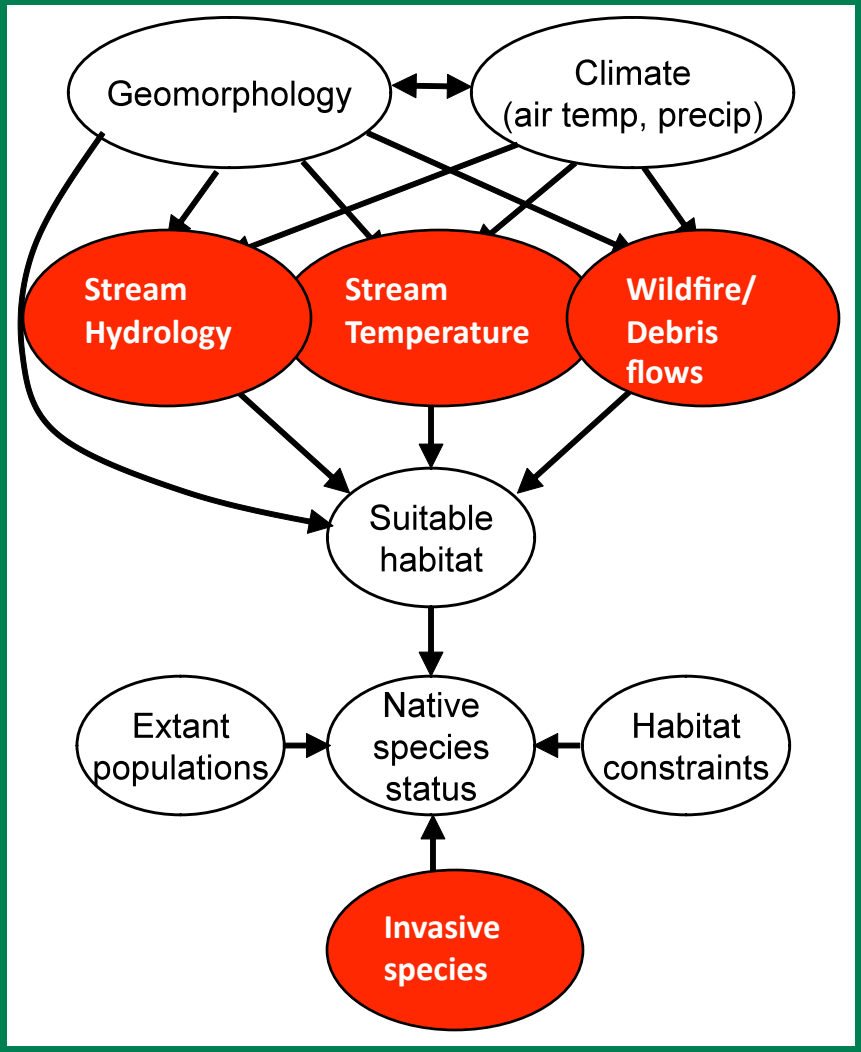
Fine-scale Approach

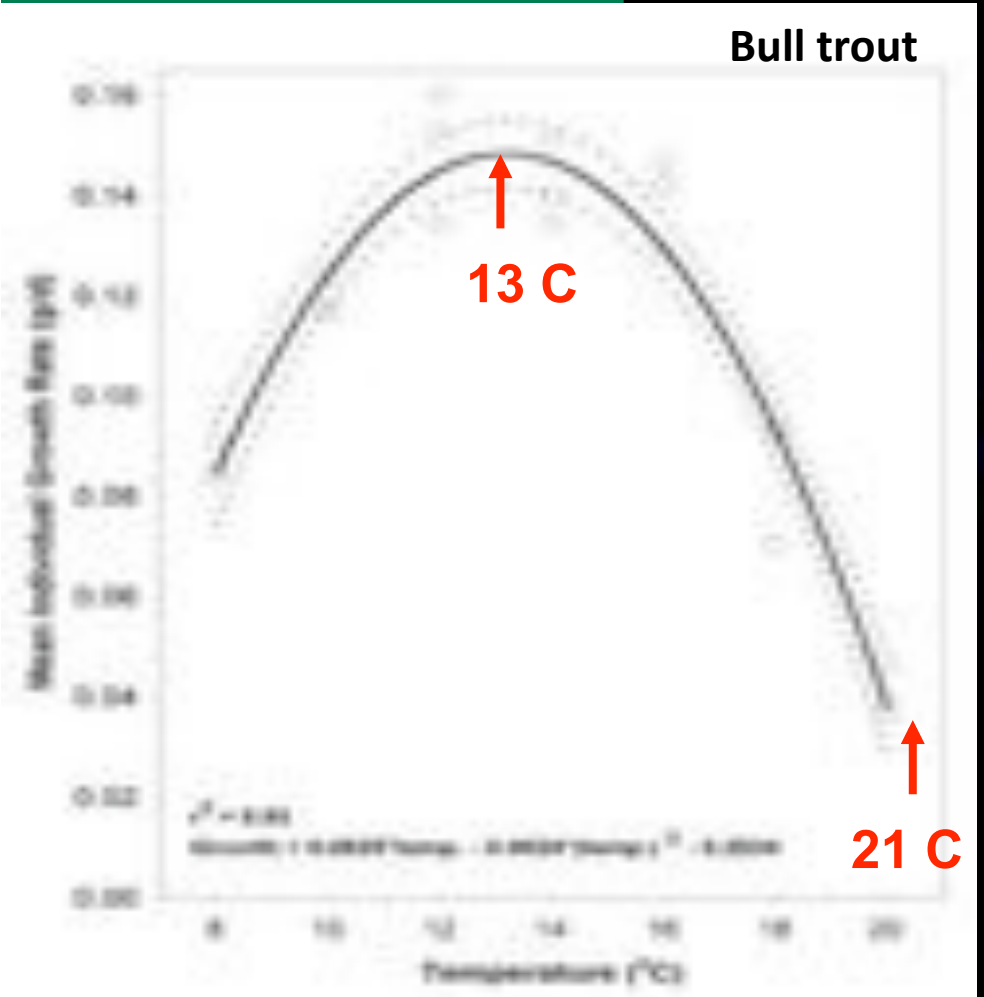


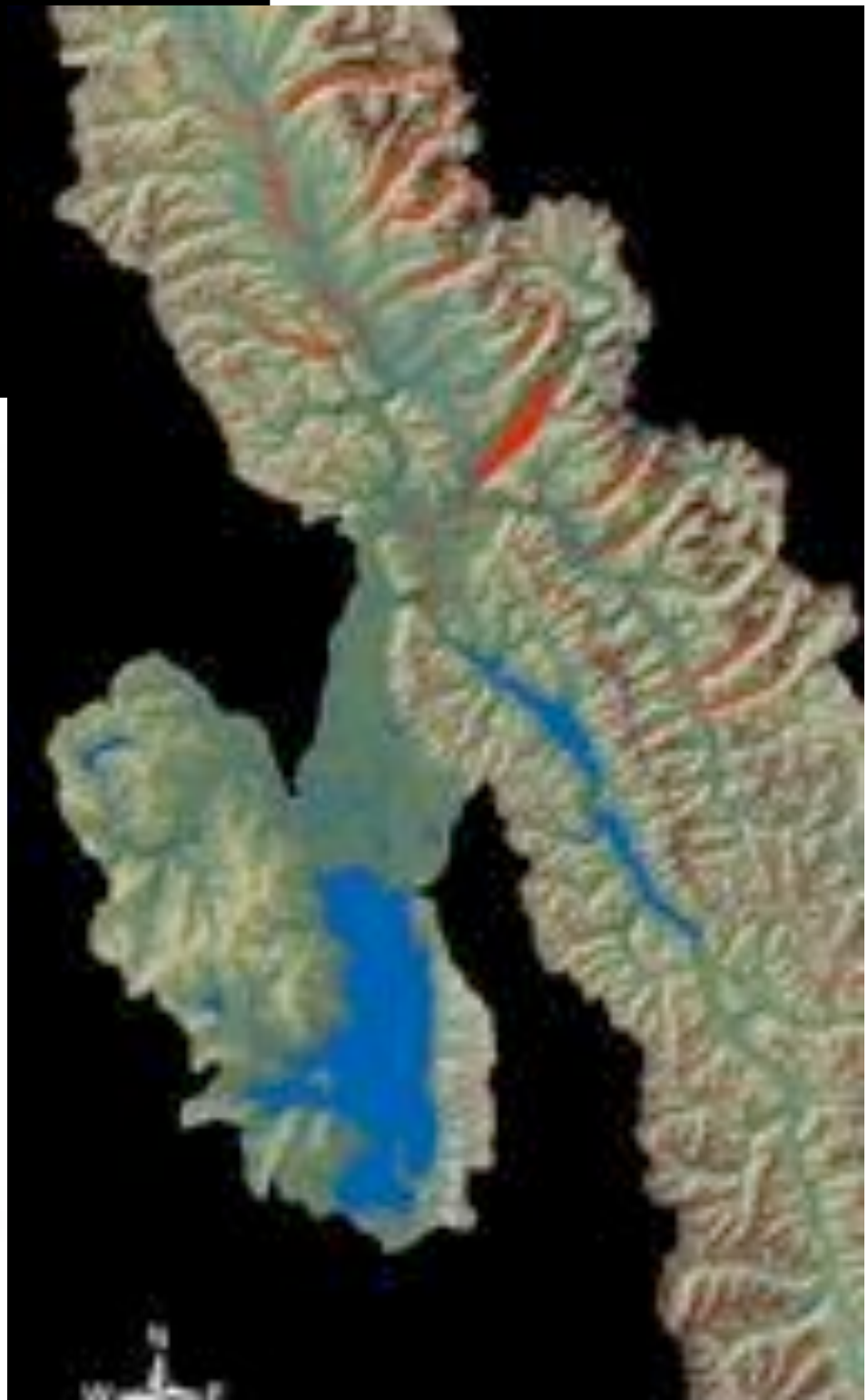
Model

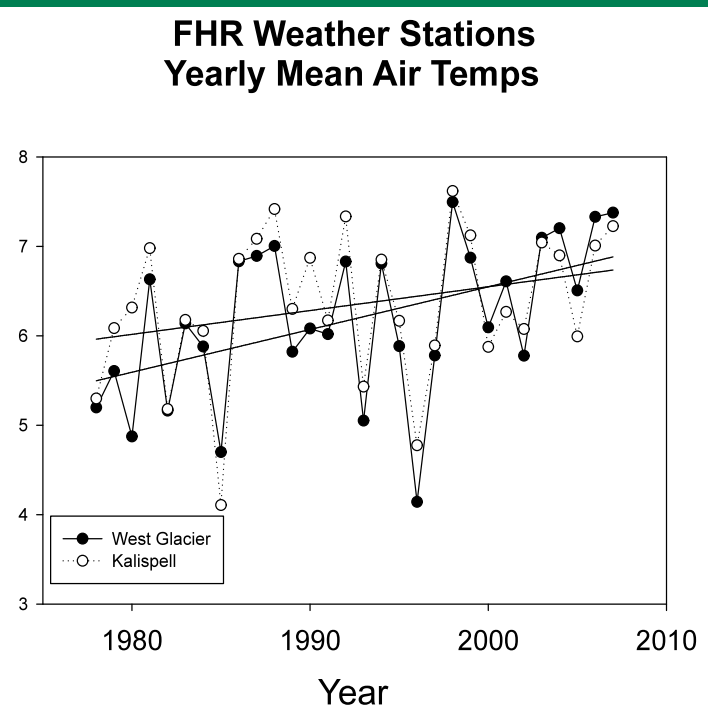


Temperature Optima and Tolerance

Fish distributions and habitat suitability



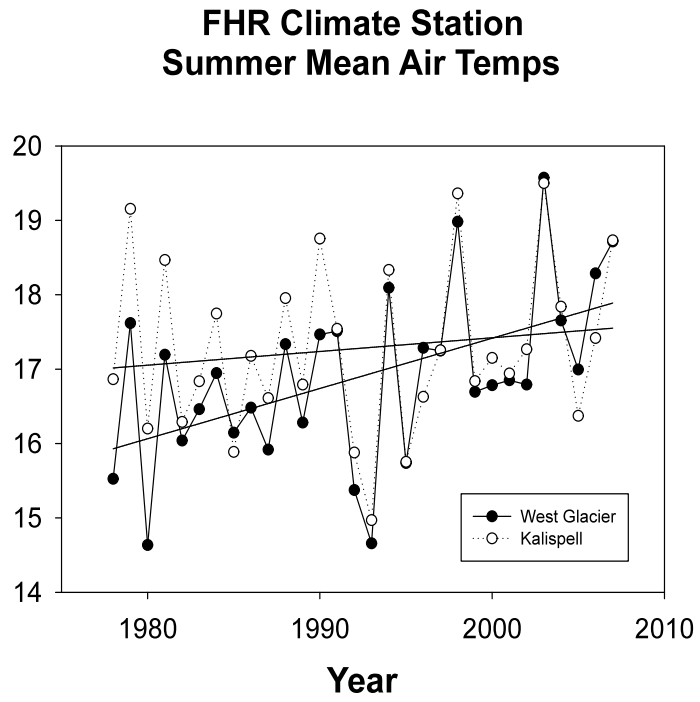


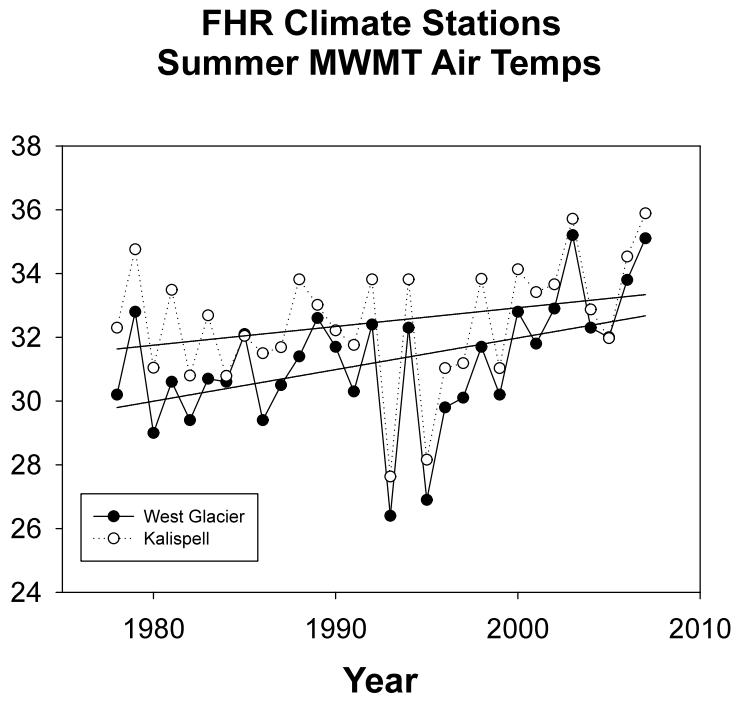


Retrospective analysis:

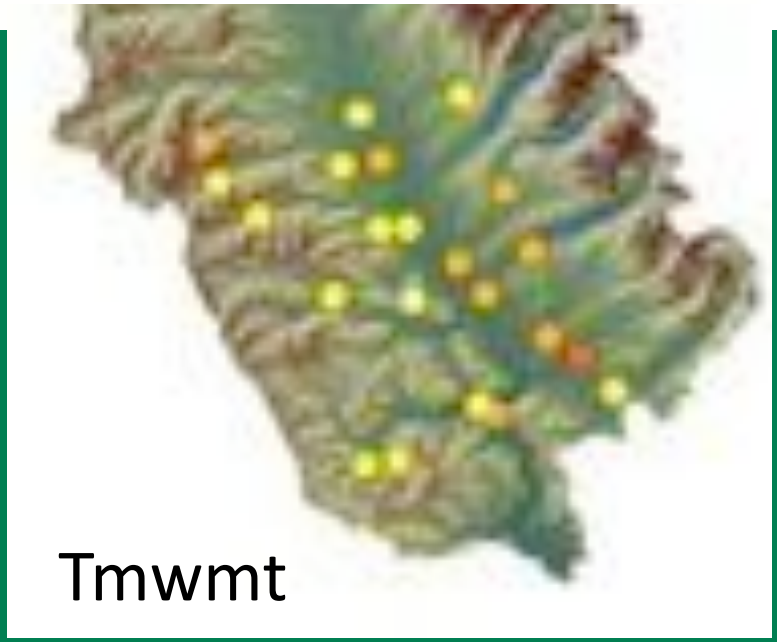
1978-2007 Flathead

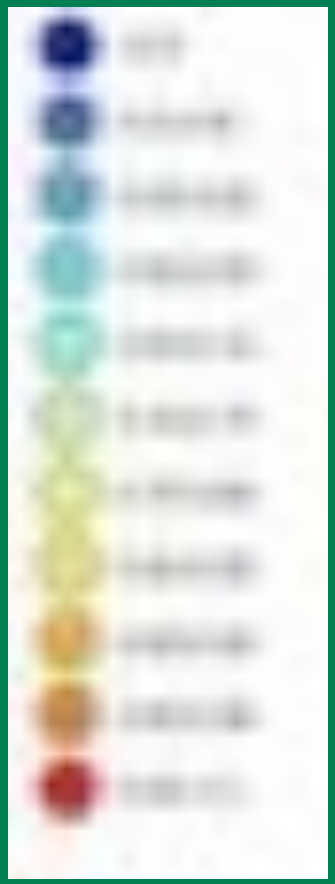
- ~1°C increase in annual air temps
- ~1.25°C for summer





Air and Stream Temperature Relationships





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Flathead River Watershed

Stream Temperature Database

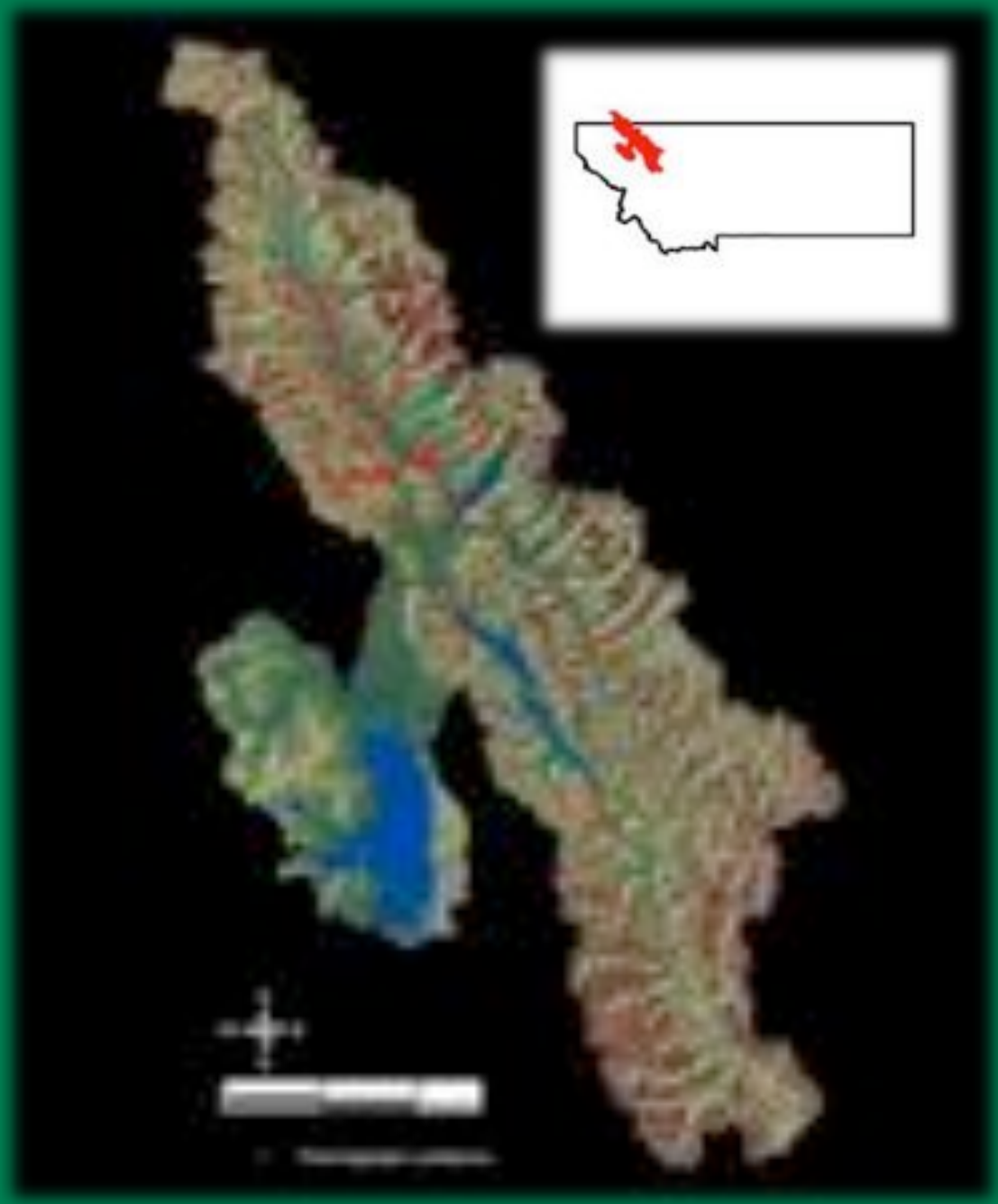
250 unique locations

12 year period (1998 – 2009)

Watershed Characteristics

Elevation range 880 – 3,080 m

Watershed area = 14,300 km^2



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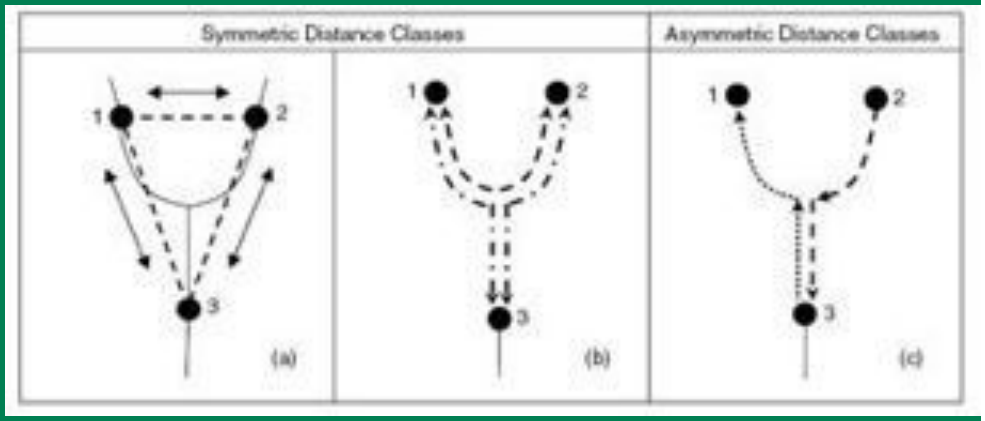
Stream Temperature Model

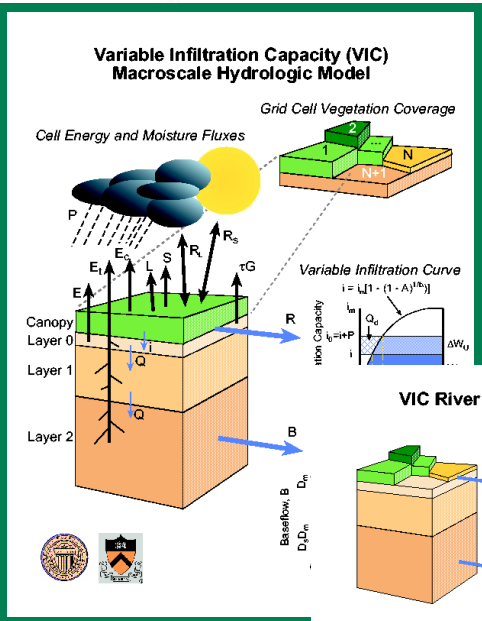
Model Parameters

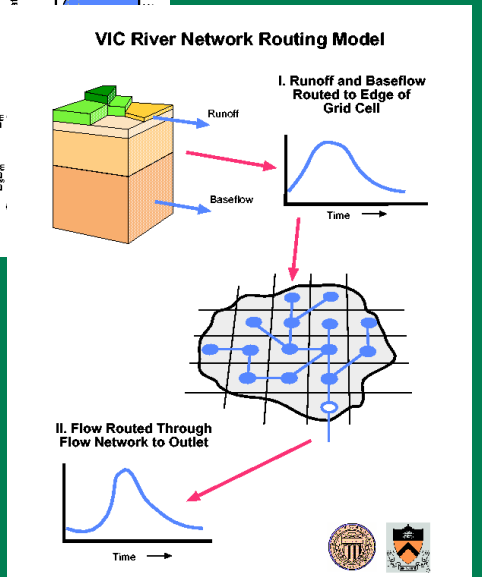
Slope
Elevation
Lake Influence
Drainage Area
Latitude
Fire
Discharge
Snow/Ice

Hydrology

Spatial Statistical Models for Stream Networks







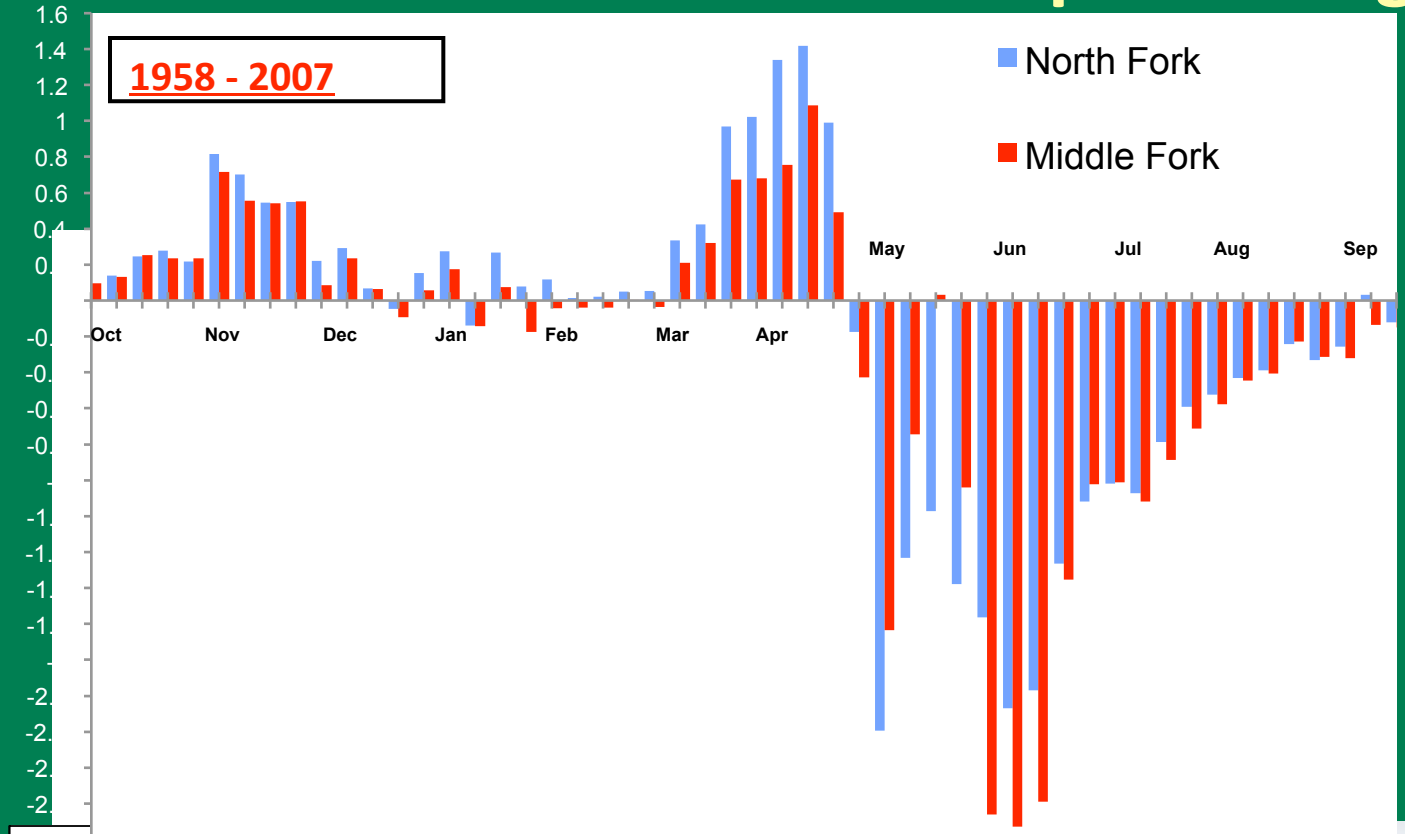
USGS

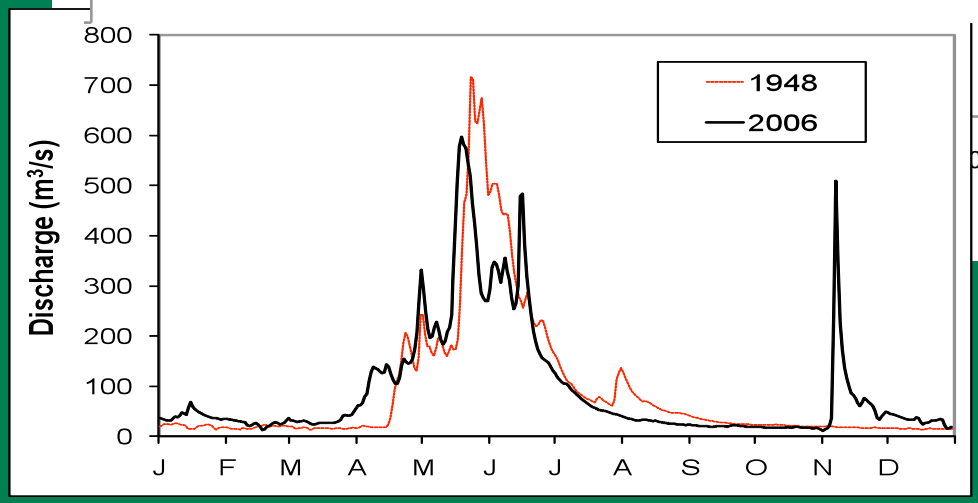
Projected climate changes to the hydrologic cycle in the Rocky Mountains

USGS

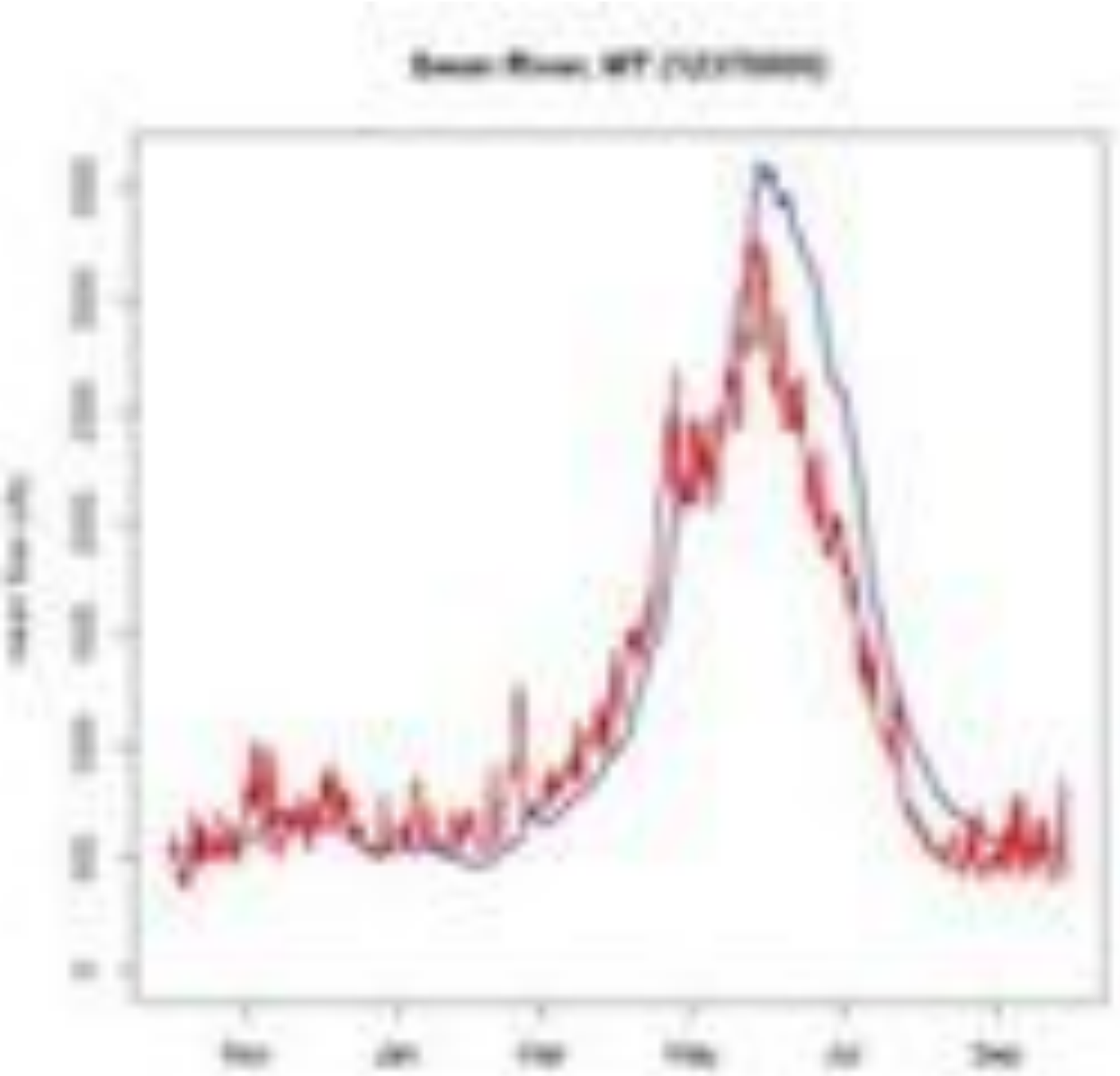
Ashton and Ostermann-Kelm *In-review*

Flathead River Discharge A Landscape Undergoing Change

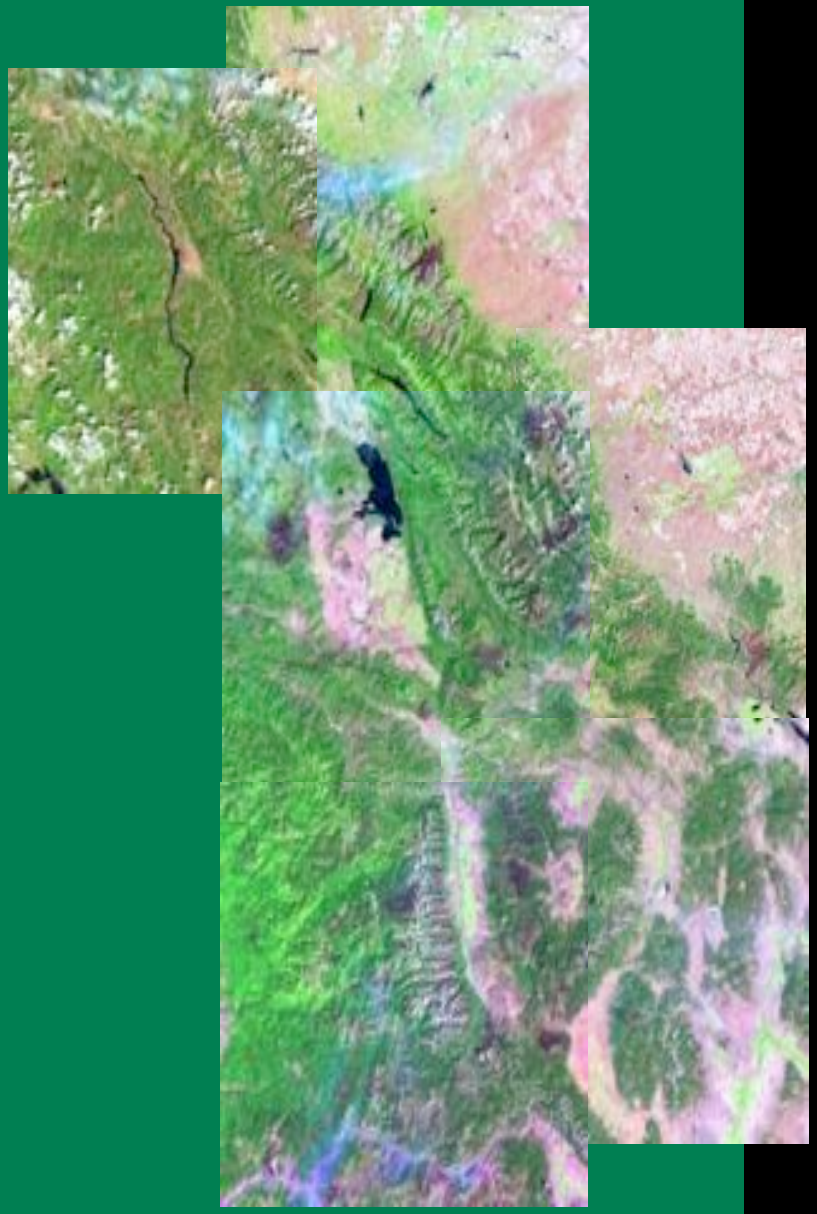


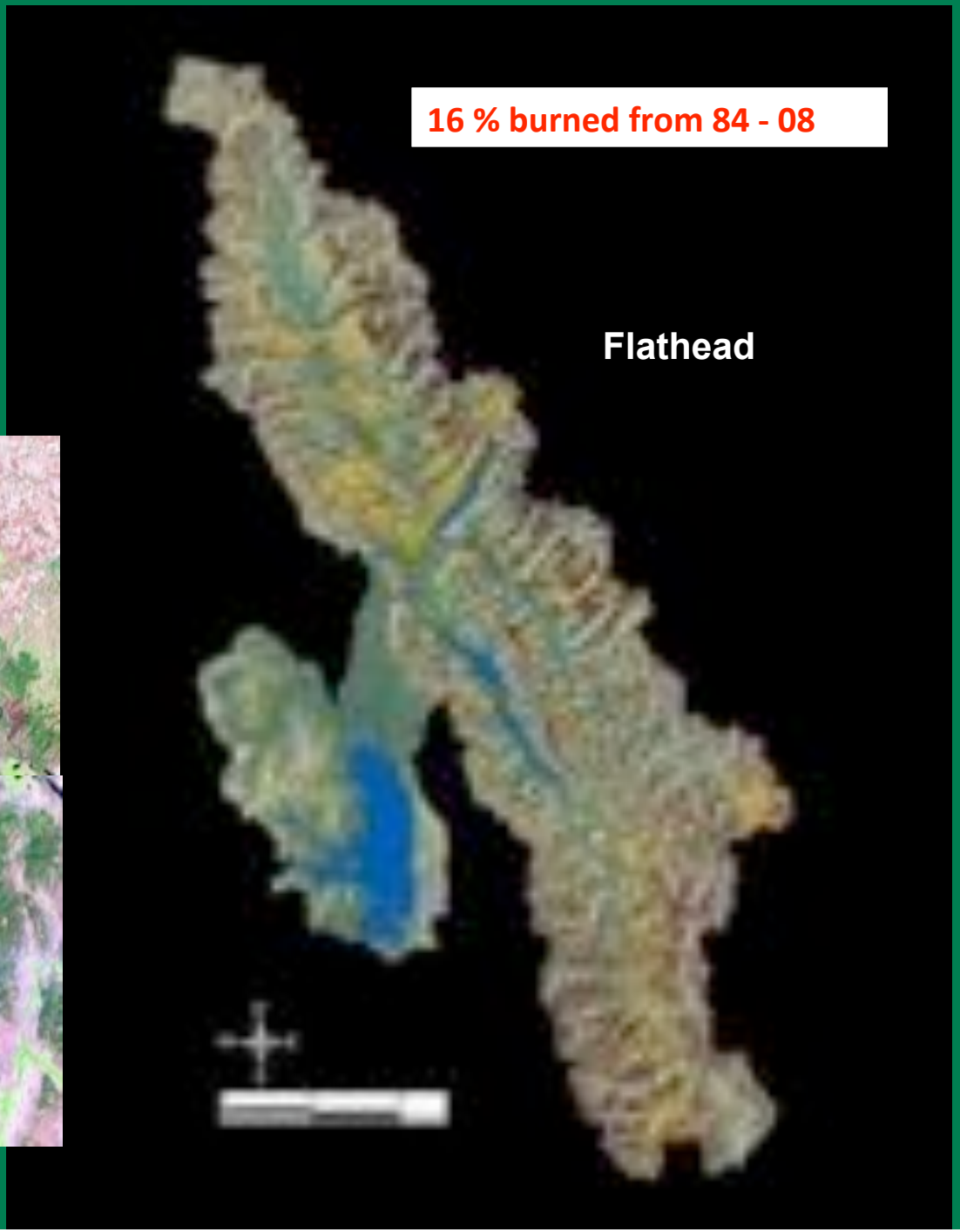


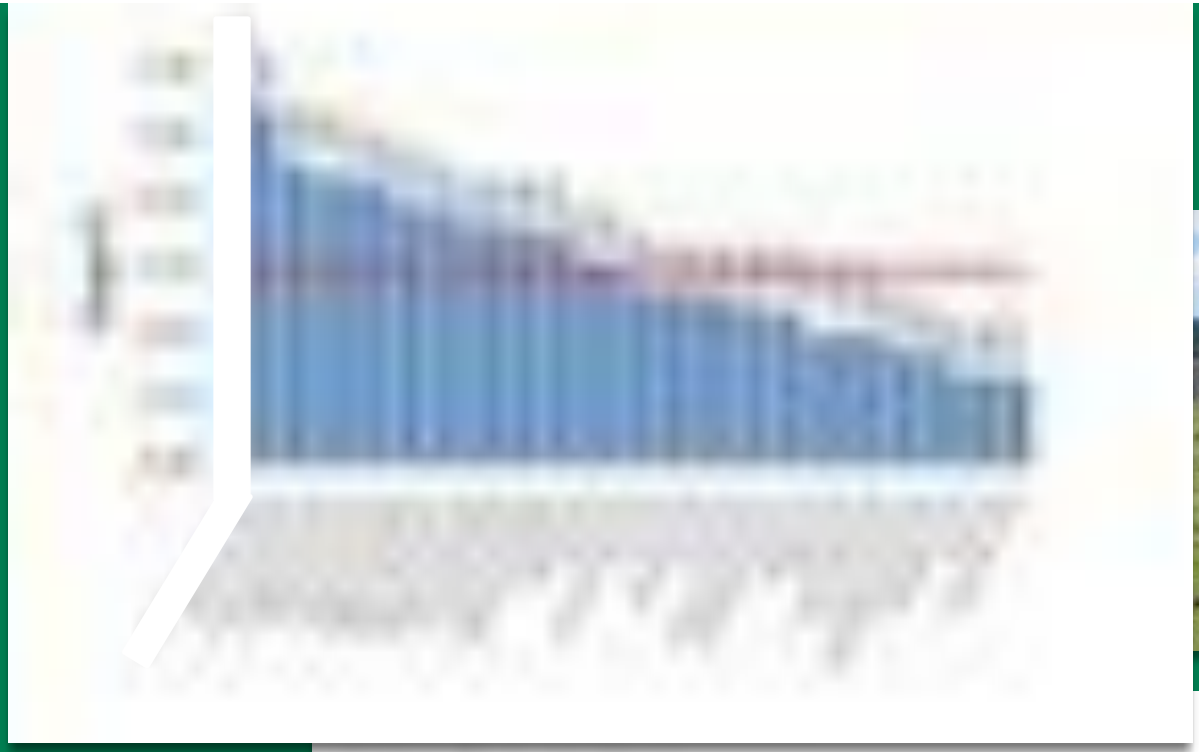
VIC Output



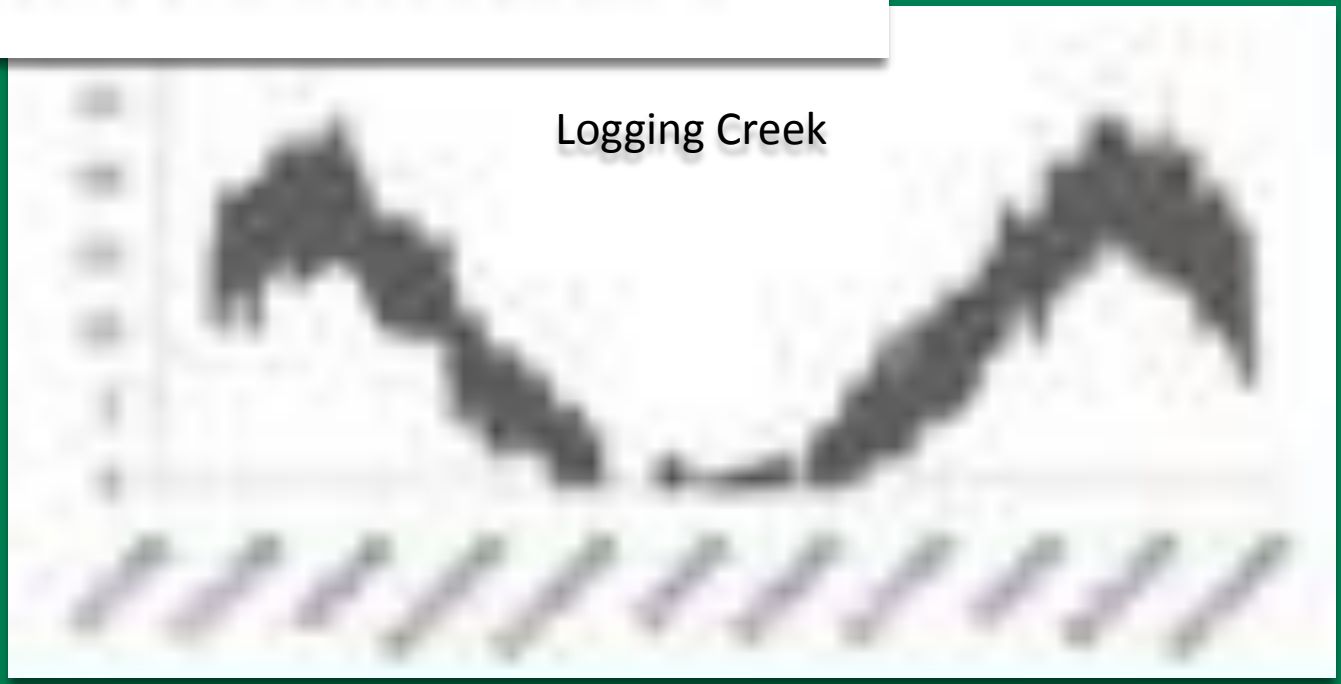
Wildfire







Logging Creek



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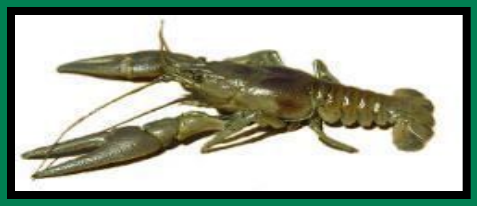
Invasive Species



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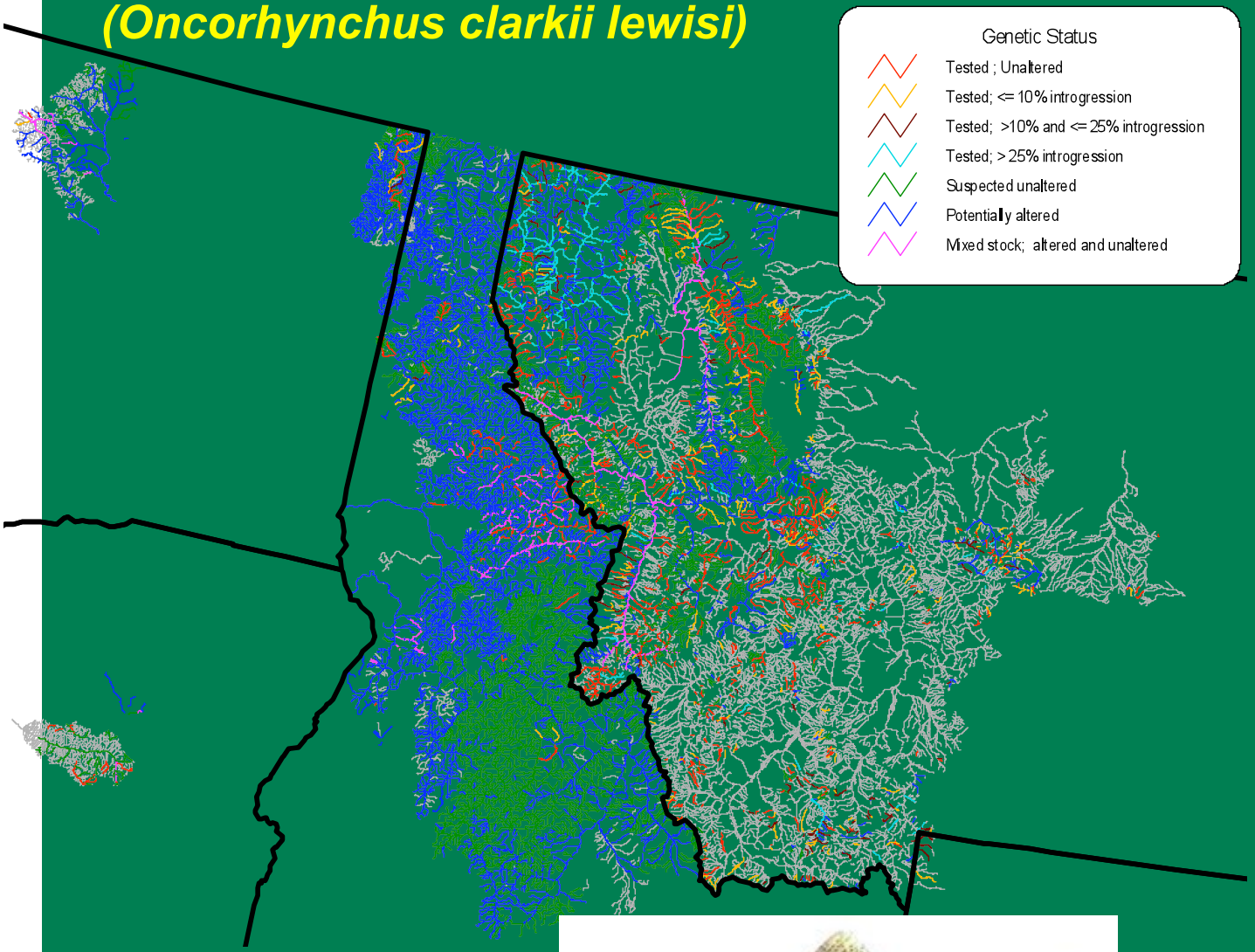
Hybridization

- Loss of co-adapted gene complexes and ecological adaptations
- Threatens the persistence of many rare and endangered species

USGS

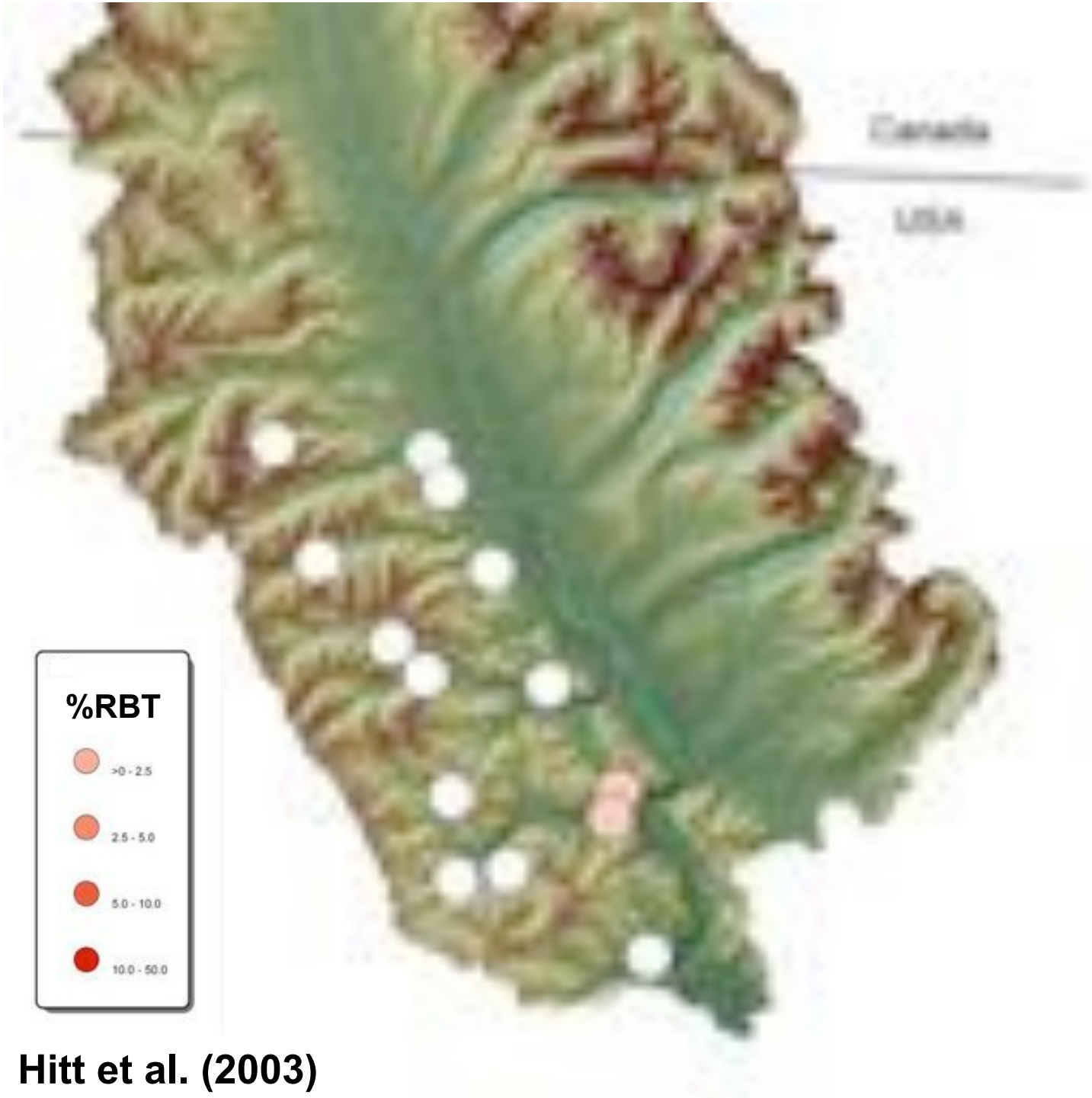
Westslope Cutthroat Trout
(Oncorhynchus clarkii lewisi)



- One of four major subspecies of cutthroat trout
- Distribution: Columbia, Fraser, Missouri, and Hudson Bay drainages of the US and Canada
- Non-hybridized (red) populations occupy <10% of their historic range in the USA
- Hybridization with introduced rainbow trout is the leading factor in their decline

USGS

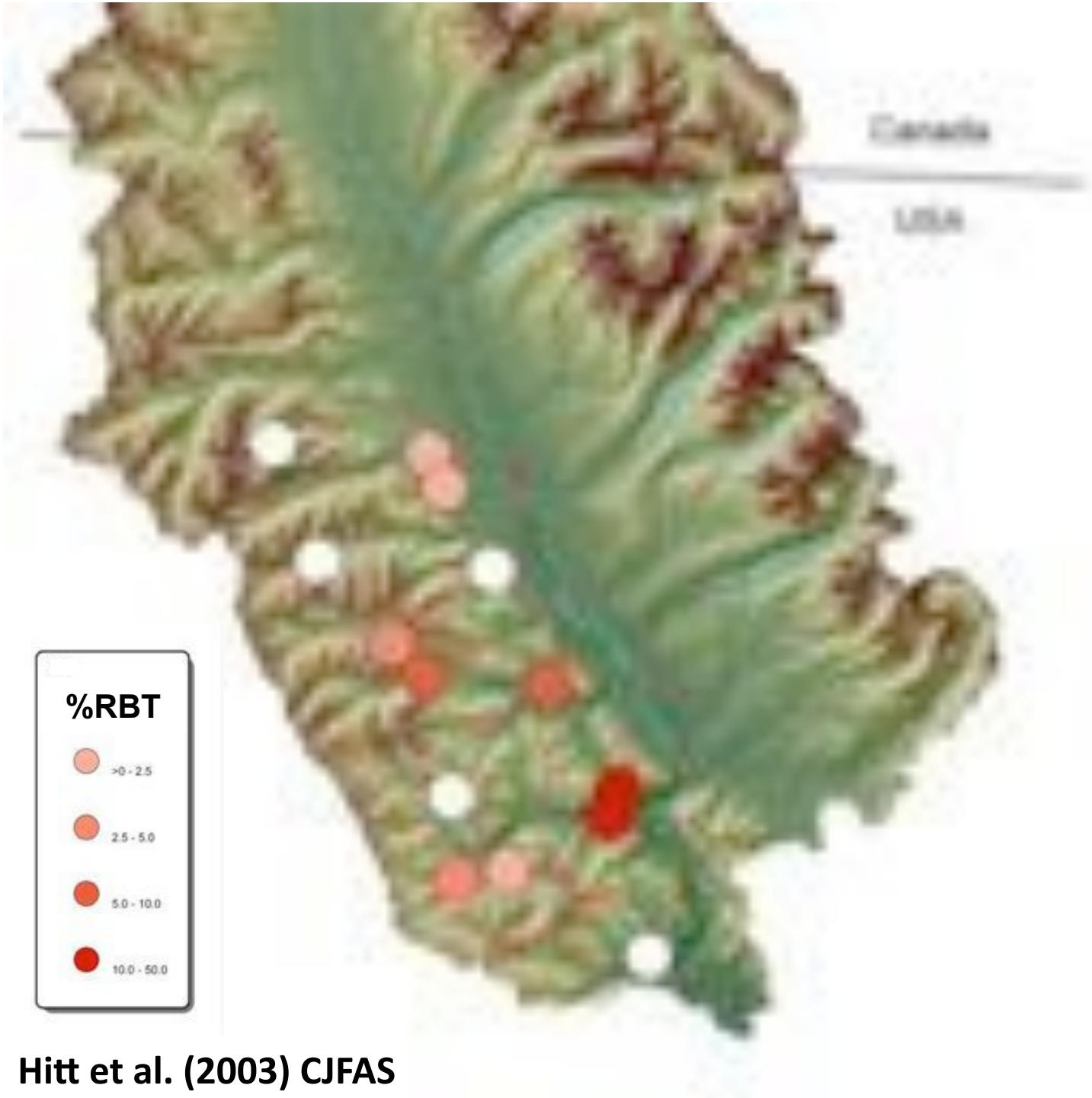
Shepard et al. (2005)



Hitt et al. (2003)

1984

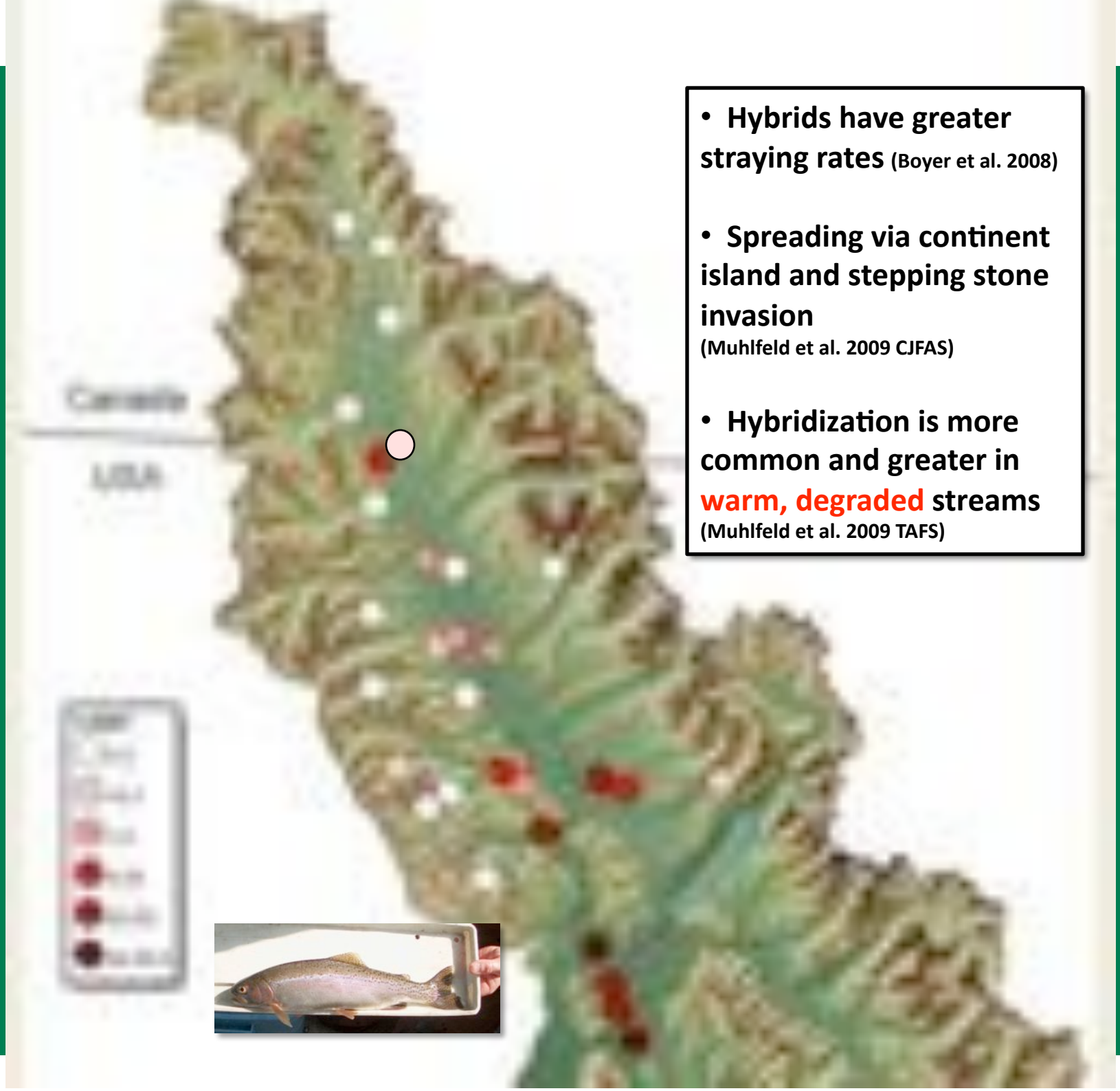
- Low levels of introgression in 2 of 14 sites (14%)



Hitt et al. (2003) CJFAS

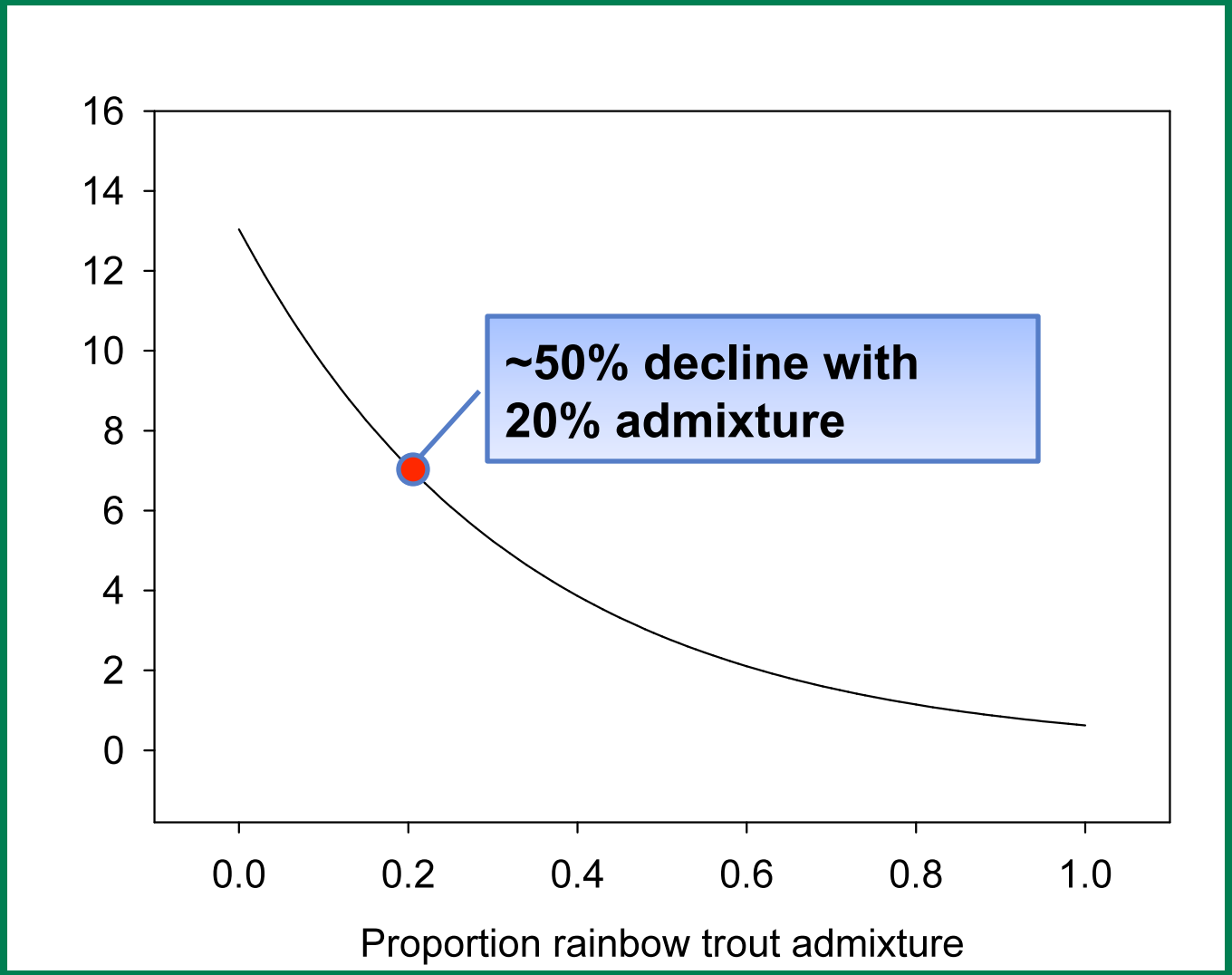
2002

- New introgression in 7 of 12 sites (58%)



- **Hybrids have greater straying rates** (Boyer et al. 2008)
- **Spreading via continent island and stepping stone invasion** (Muhlfeld et al. 2009 CJFAS)
- **Hybridization is more common and greater in warm, degraded streams** (Muhlfeld et al. 2009 TAFS)

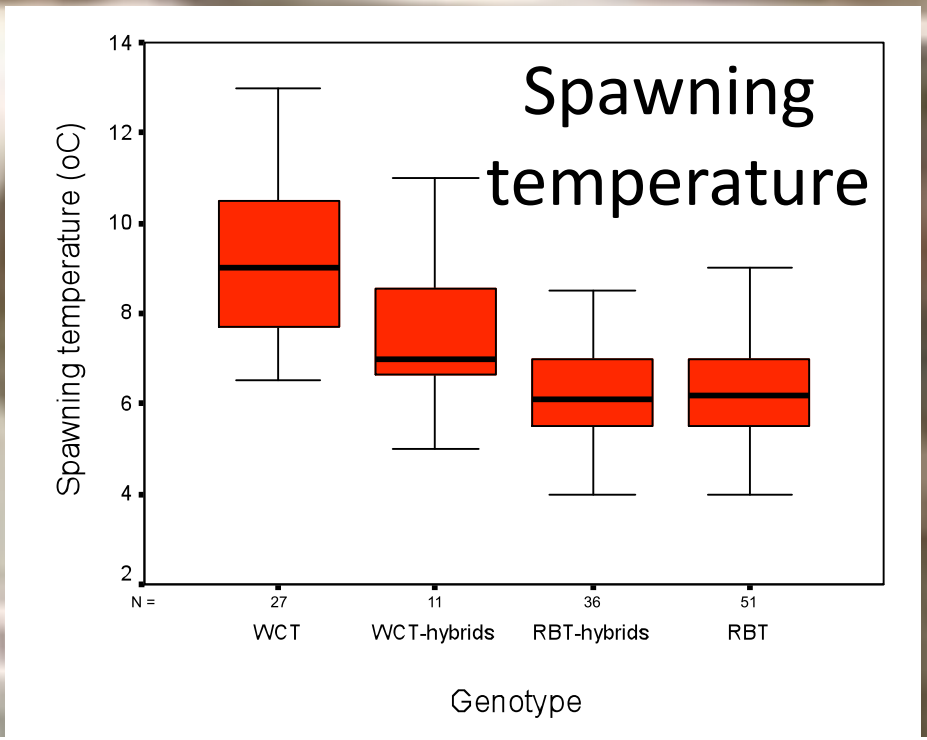
Hybridization Rapidly Reduces Fitness

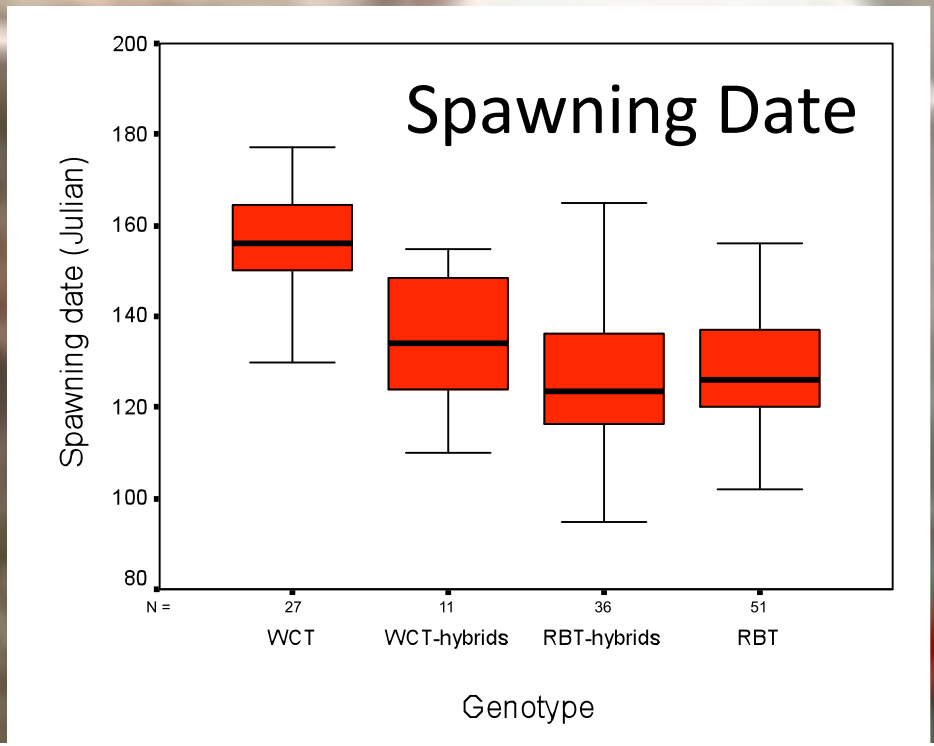


Muhlfeld et al. (2009) *Biology Letters*

Hybridization Changes Behavioral Characteristics

Muhlfeld et al. (2009) CJFAS





Model Results

Distribution

Logistic regression (AIC):

Variables	B	S.E.
Model 1		
Mean temperature	**0.955**	**0.56**
Distance to source	**-0.103**	**0.043**
Number of road crossings	**0.128**	**0.086**
Constant	-3.532	4.64
Model 2		
Mean temperature	1.104	0.584
Distance to source	-0.099	0.047
Constant	-4.131	4.518

Proportion Admixture

Linear regression (AIC):

Variables	B	S.E.
Model 1		
Mean temperature	**0.242**	**0.121**
Distance to source	**-0.072**	**0.009**
Constant	-1.39	1.559
Model 2		
Mean temperature	**0.251**	**0.111**
Distance to source	**-0.065**	**0.009**
Density	**6.376**	**3.422**
Constant	-2.512	1.551
Model 3		
Distance to source	-0.077	0.009
Constant	1.586	0.506
Model 4		
Distance to source	-0.071	0.01
Density	6.017	3.923
Constant	0.639	0.784

USGS

Muhlfeld et al. (2009) *TAFS*

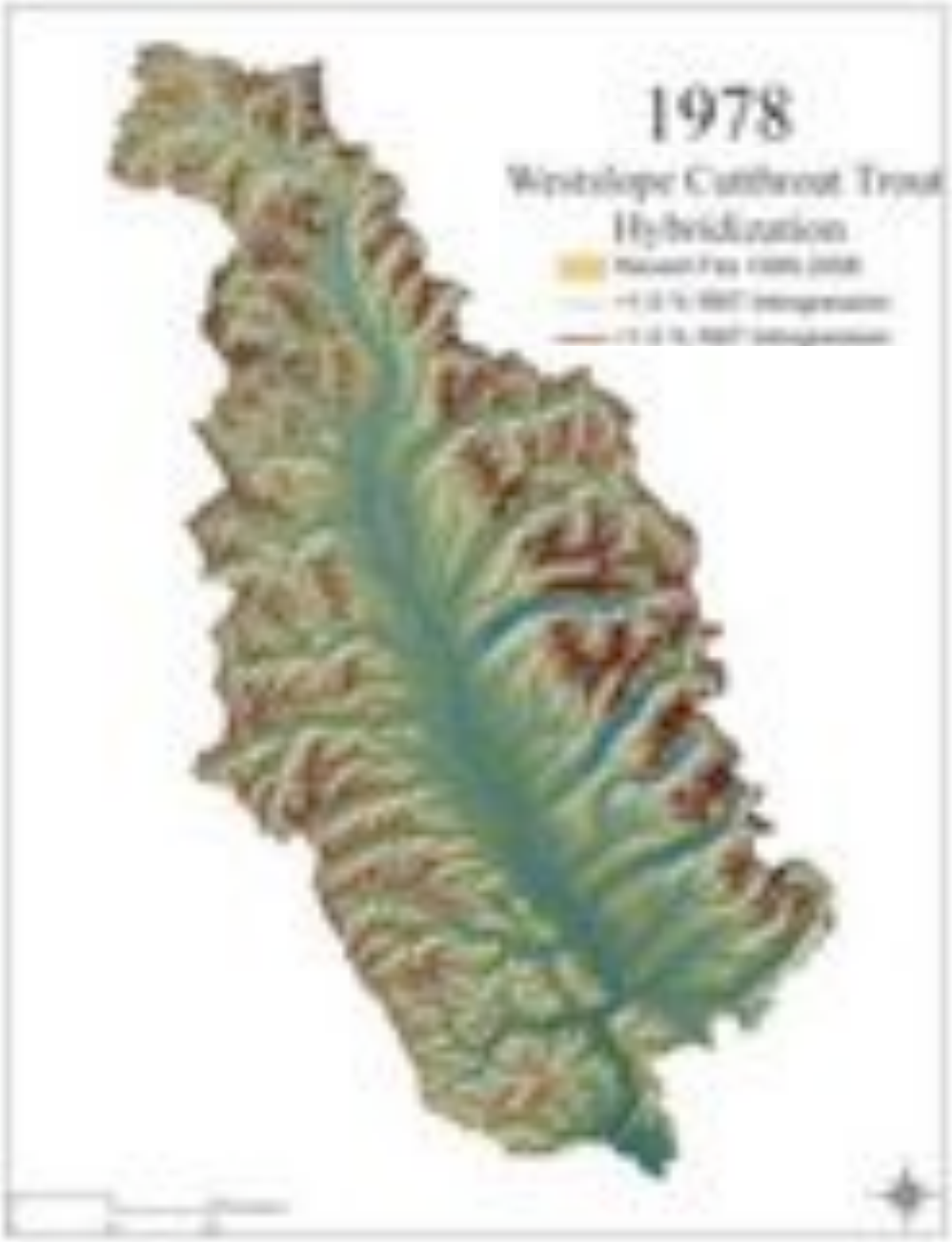
Stream Temperature Model

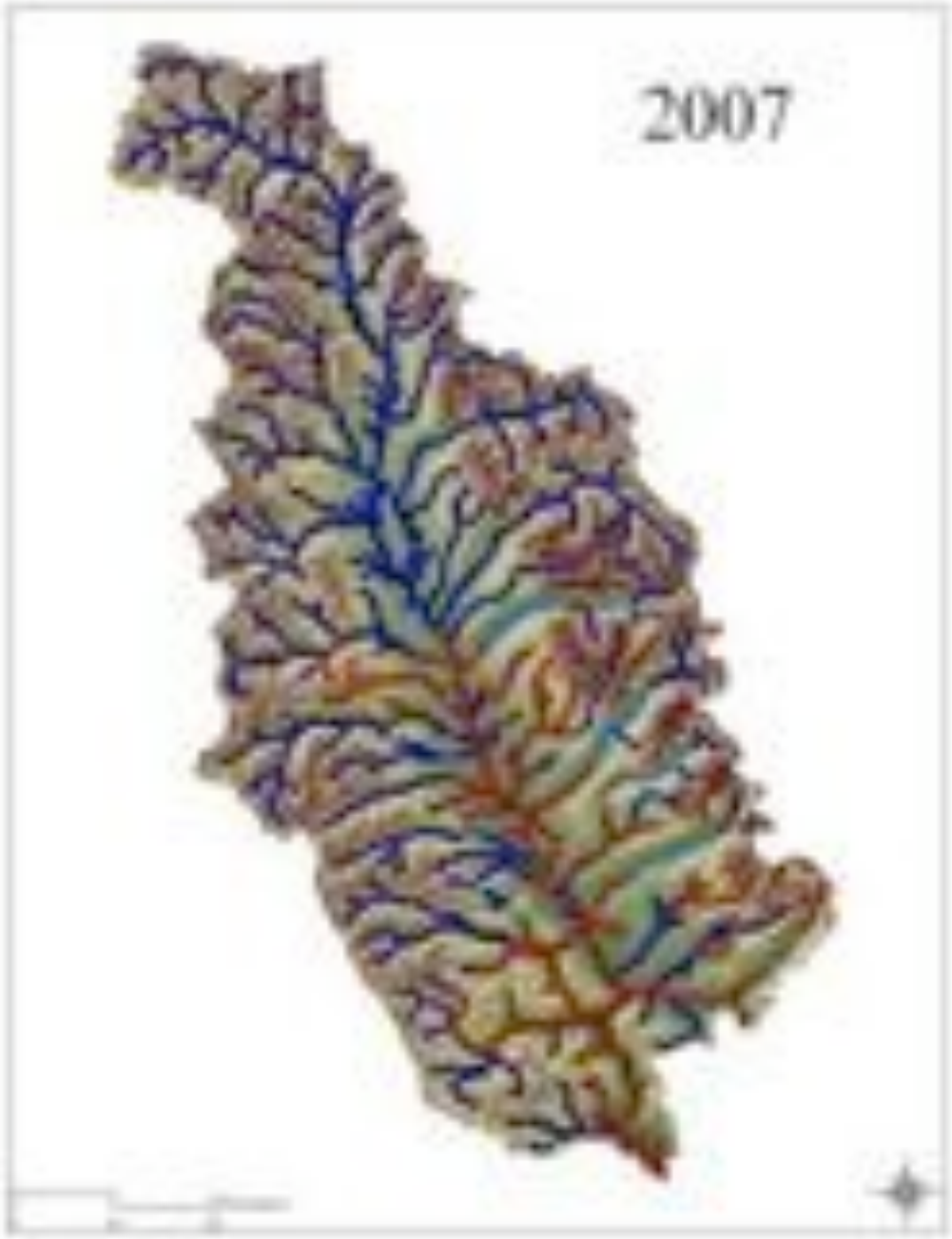
Predictor variables:

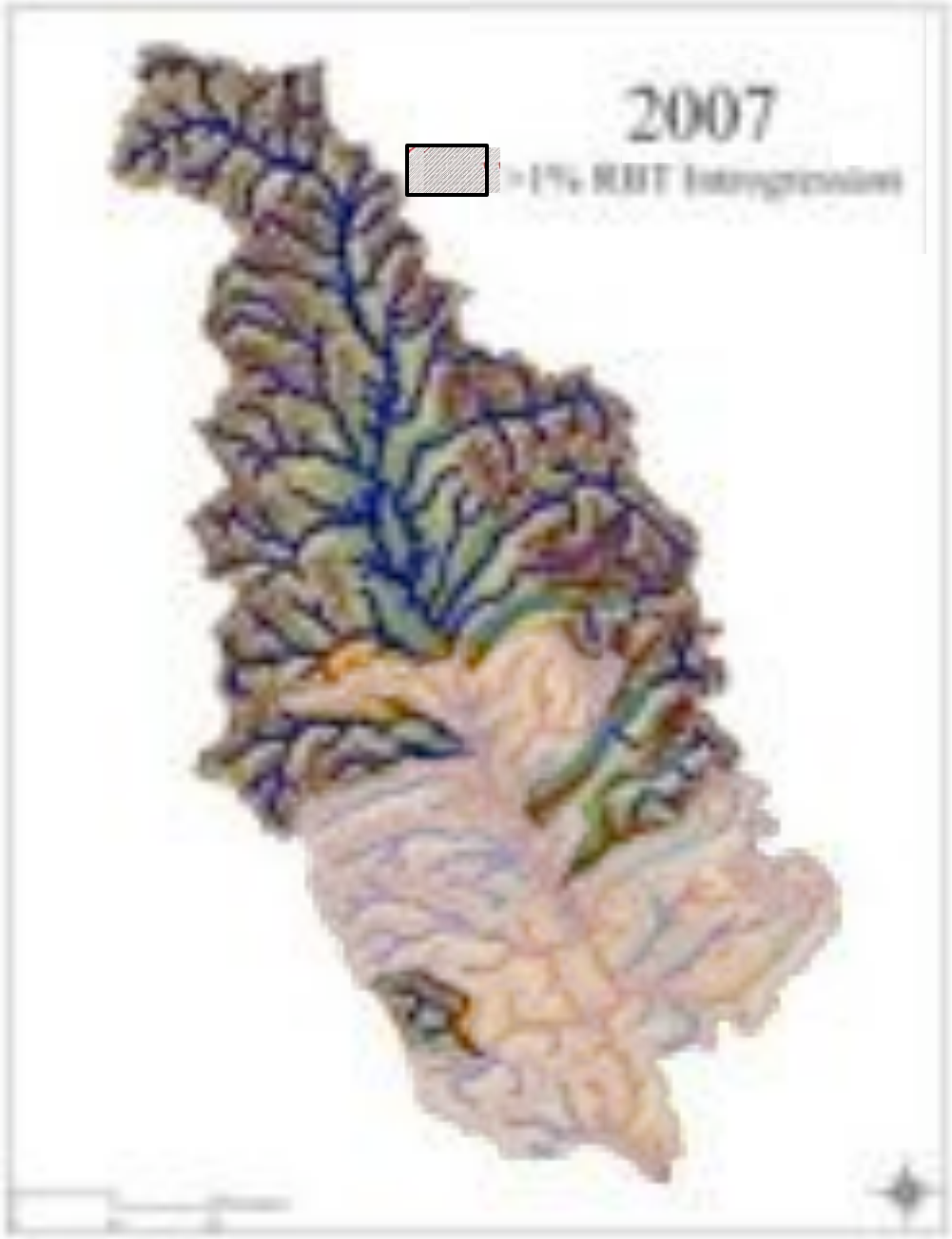
- Fire
- Lake
- Air temp
- Area
- Elevation
- Solar radiation

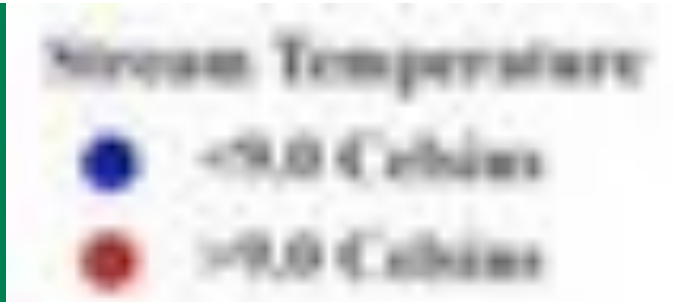
USGS

1978
Stream Temperature
<9.0 Celsius
>9.0 Celsius


1978
Westslope Cutthroat Trout
Hybridization


2007
Stream Temperature
<9.0 Celsius
>9.0 Celsius


2007

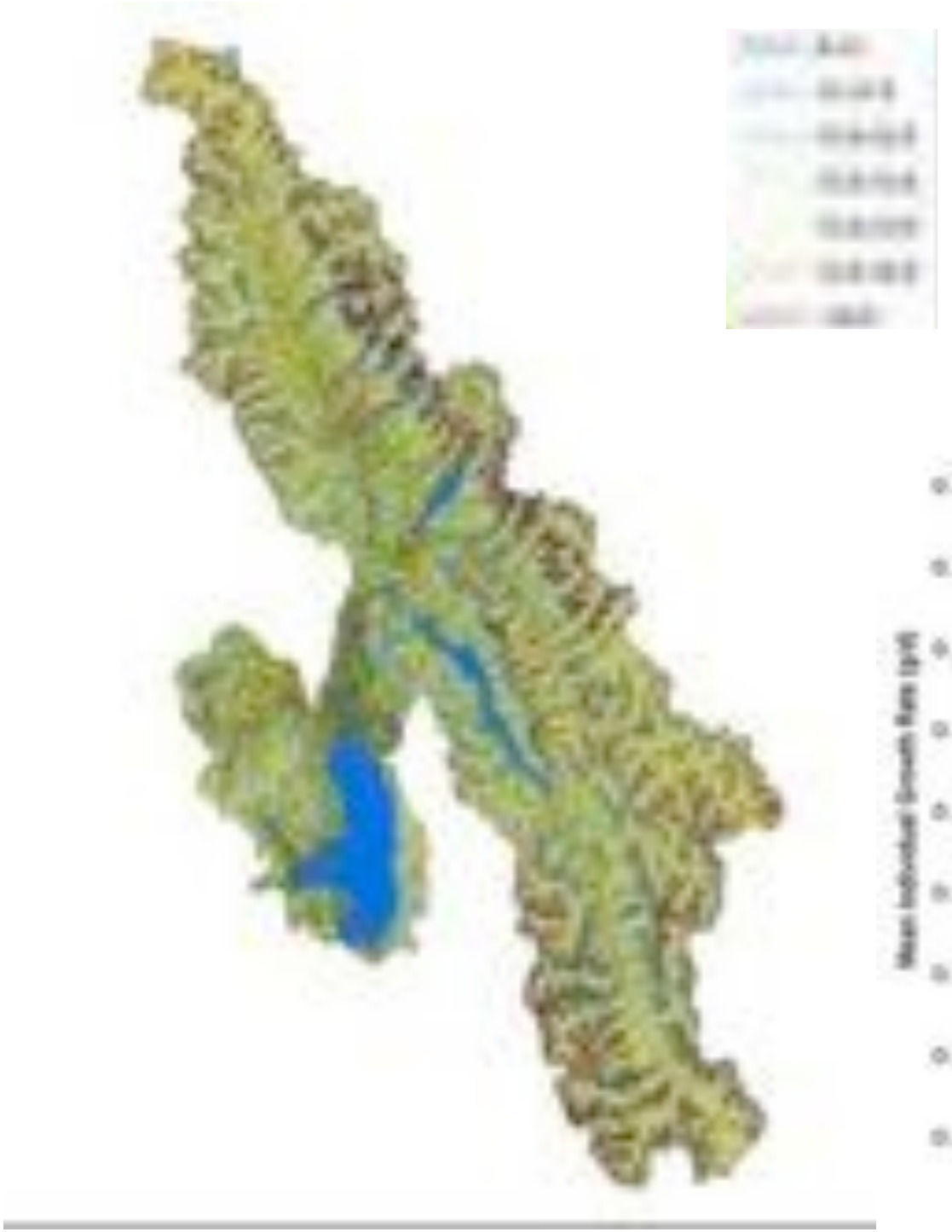

Stream Temperature

Stream Temperature

<9.0 Celsius

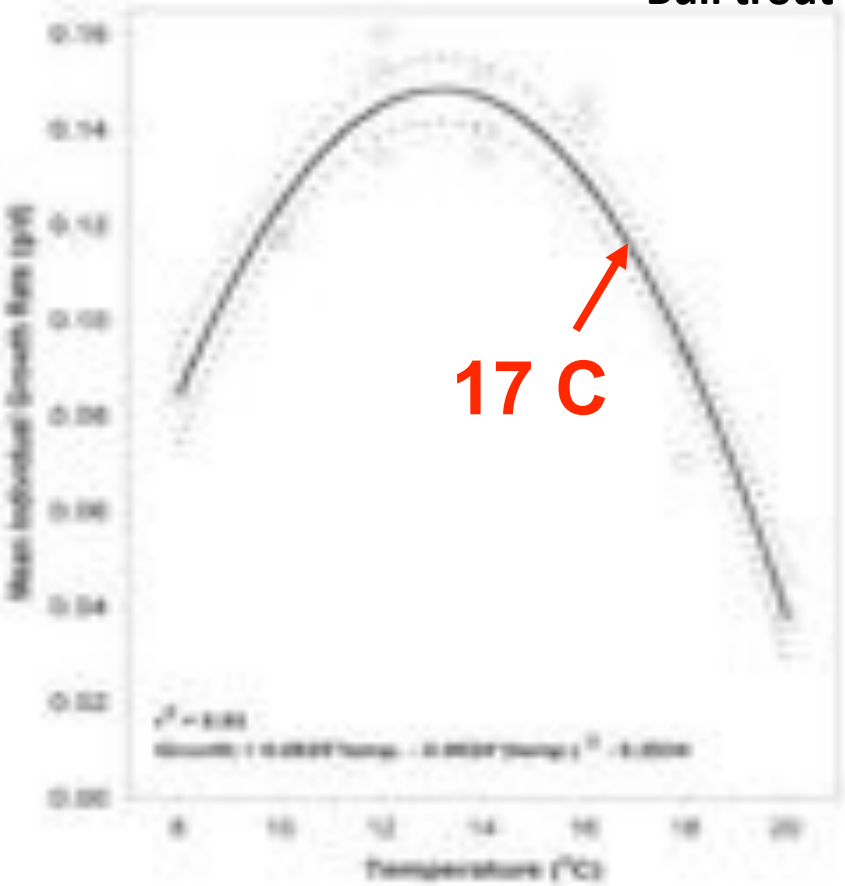
>9.0 Celsius

Bull Trout Habitat 2008
Spawning/Rearing
Unspecified Occupancy
Foraging, Migrating, Overwintering



Stream Temperature Model

Bull trout



Days Tmax > 17 C
1-5
5-10
10-20
20-30
30-41
Fire (1986-2008)

Days Tmax > 20 C
1-5
5-10
10-20
20-30
30-40
Fire (1986-2008)

2008

Percent habitat
>17°C MWMT
(15 Jul – 15 Sep)

13%

1°C increase

Percent habitat
>17°C MWMT
(15 Jul – 15 Sep)

39%

2°C increase

Percent habitat
>17°C MWMT
(15 Jul – 15 Sep)

45%

3°C increase

Percent habitat
>17°C MWMT
(15 Jul – 15 Sep)

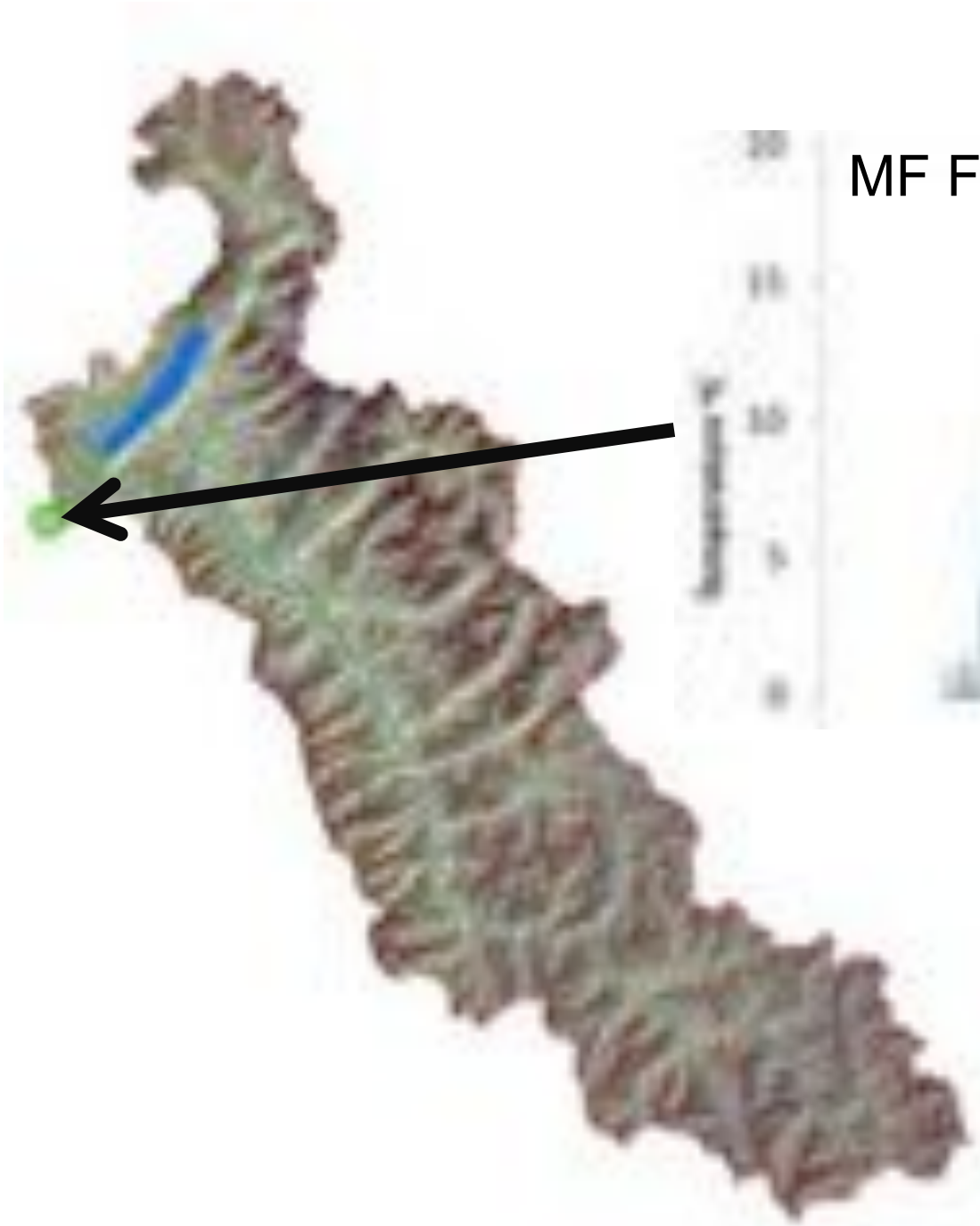
63%

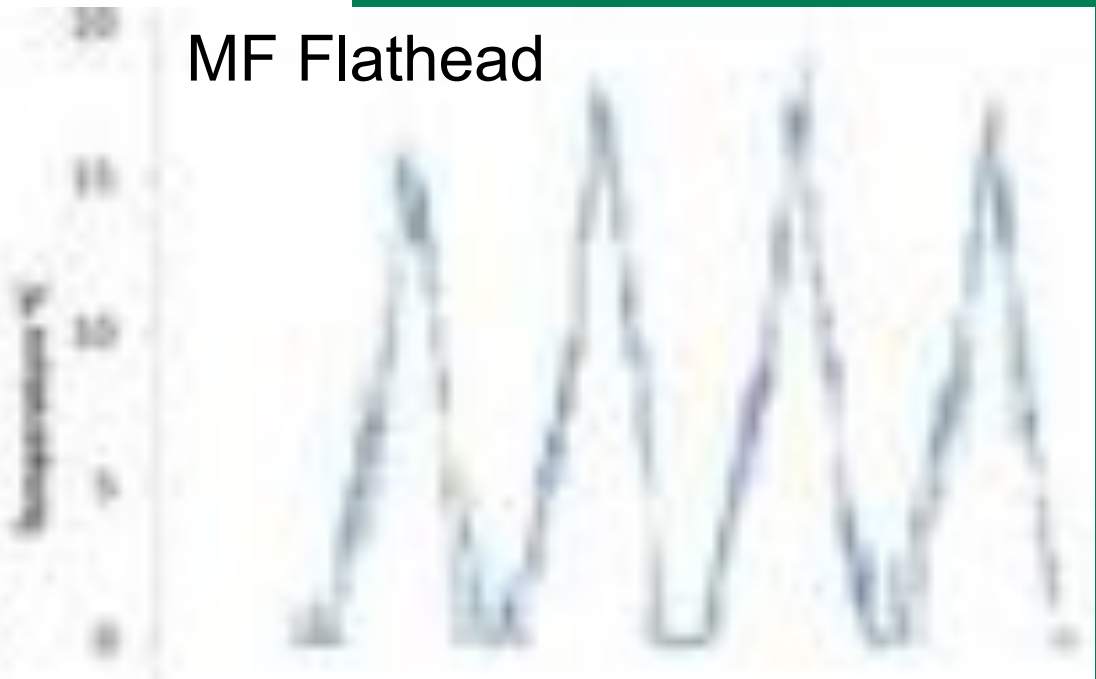
4°C increase

Percent habitat
>17°C MWMT
(15 Jul – 15 Sep)

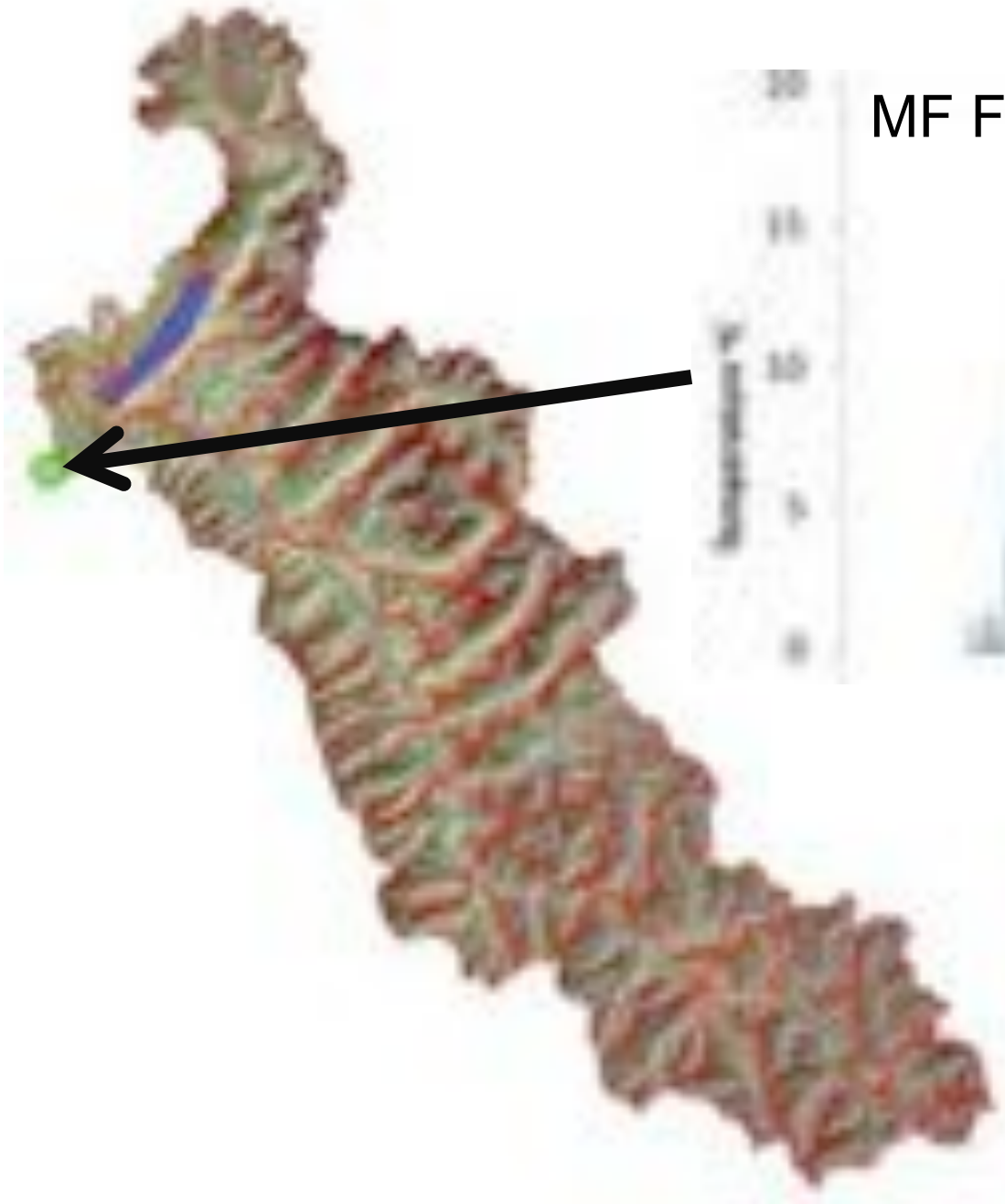
80%

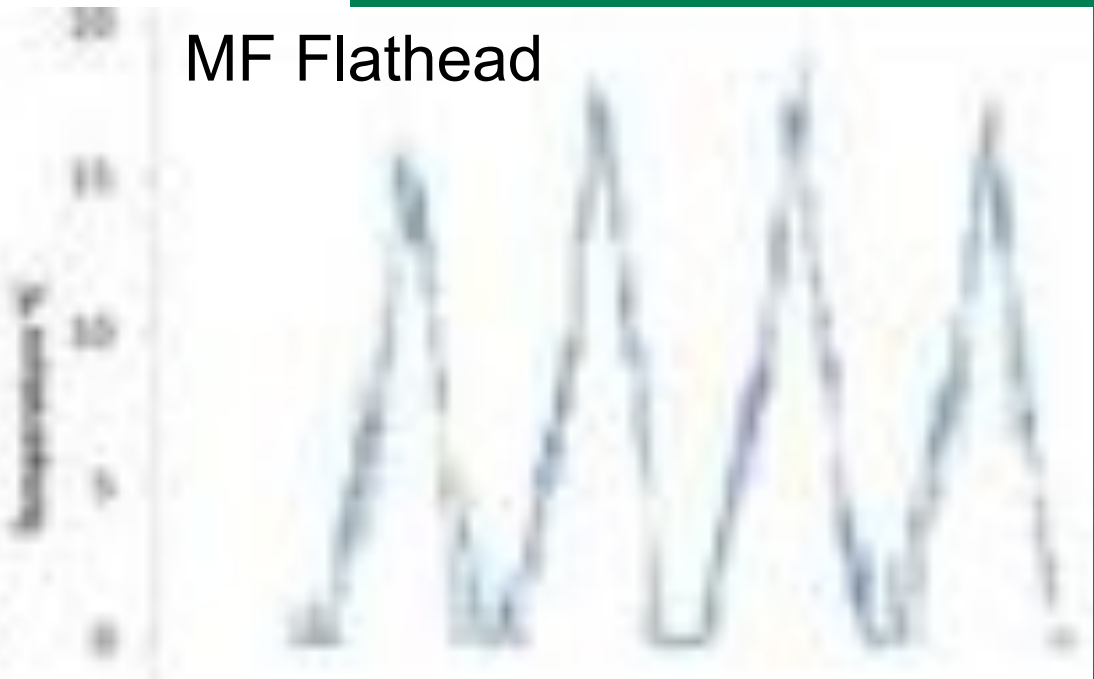
MF Flathead

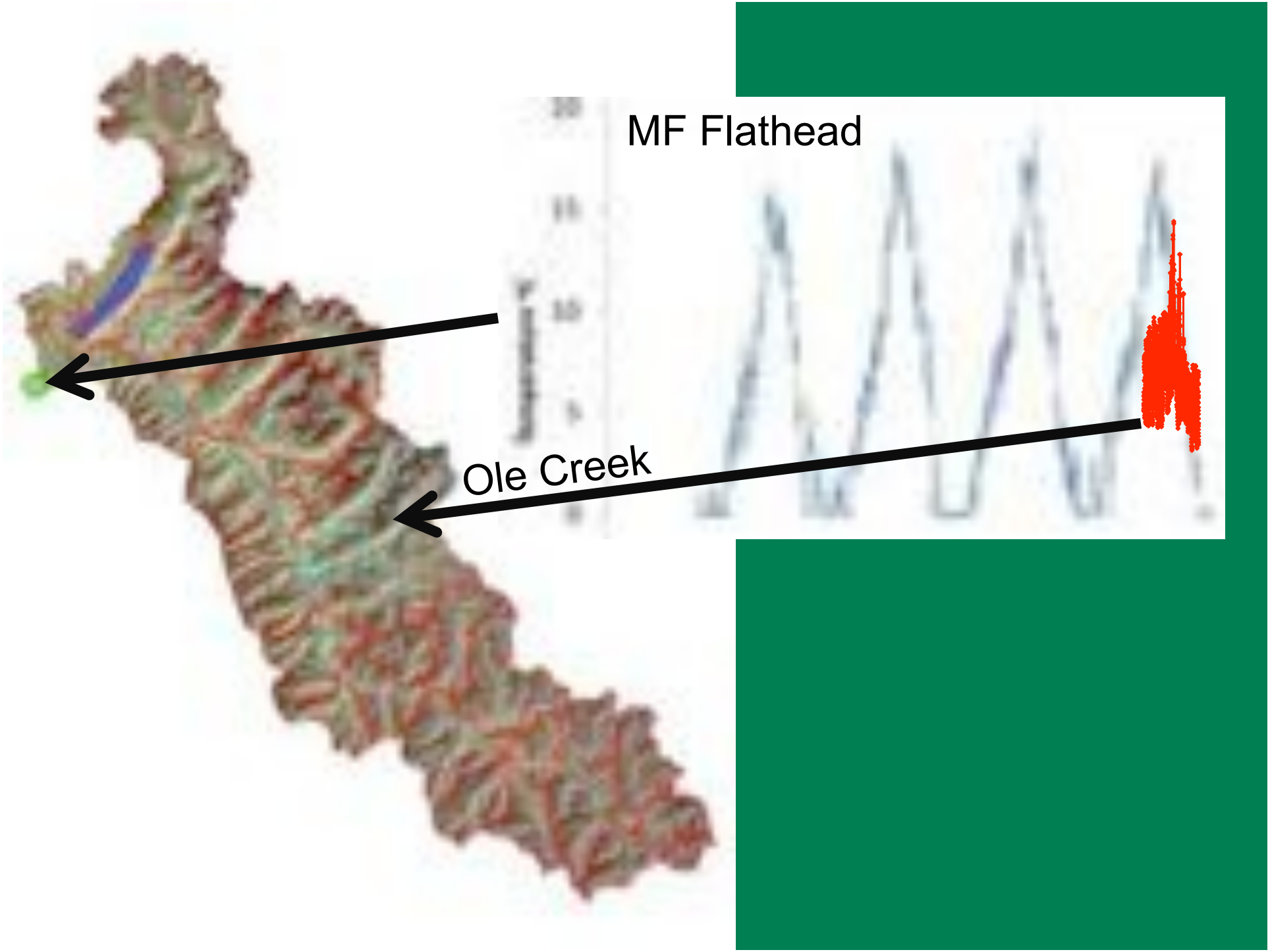




MF Flathead






MF Flathead
Ole Creek

°C

Bull Trout Habitat
Spawning/Rearing
Unspecified Occupancy
Foraging, Migrating, Overwintering
Unoccupied/Unsurveyed

°C

Bull Trout Habitat
Spawning/Rearing
Unspecified Occupancy
Foraging, Migrating, Overwintering
Unoccupied/Unsurveyed
Fish Barriers

°C

Bull Trout Habitat
Spawning/Rearing
Unspecified Occupancy
Foraging, Migrating, Overwintering
Unoccupied/Unsurveyed
Fish Barriers
Redd Counts
2005

°C

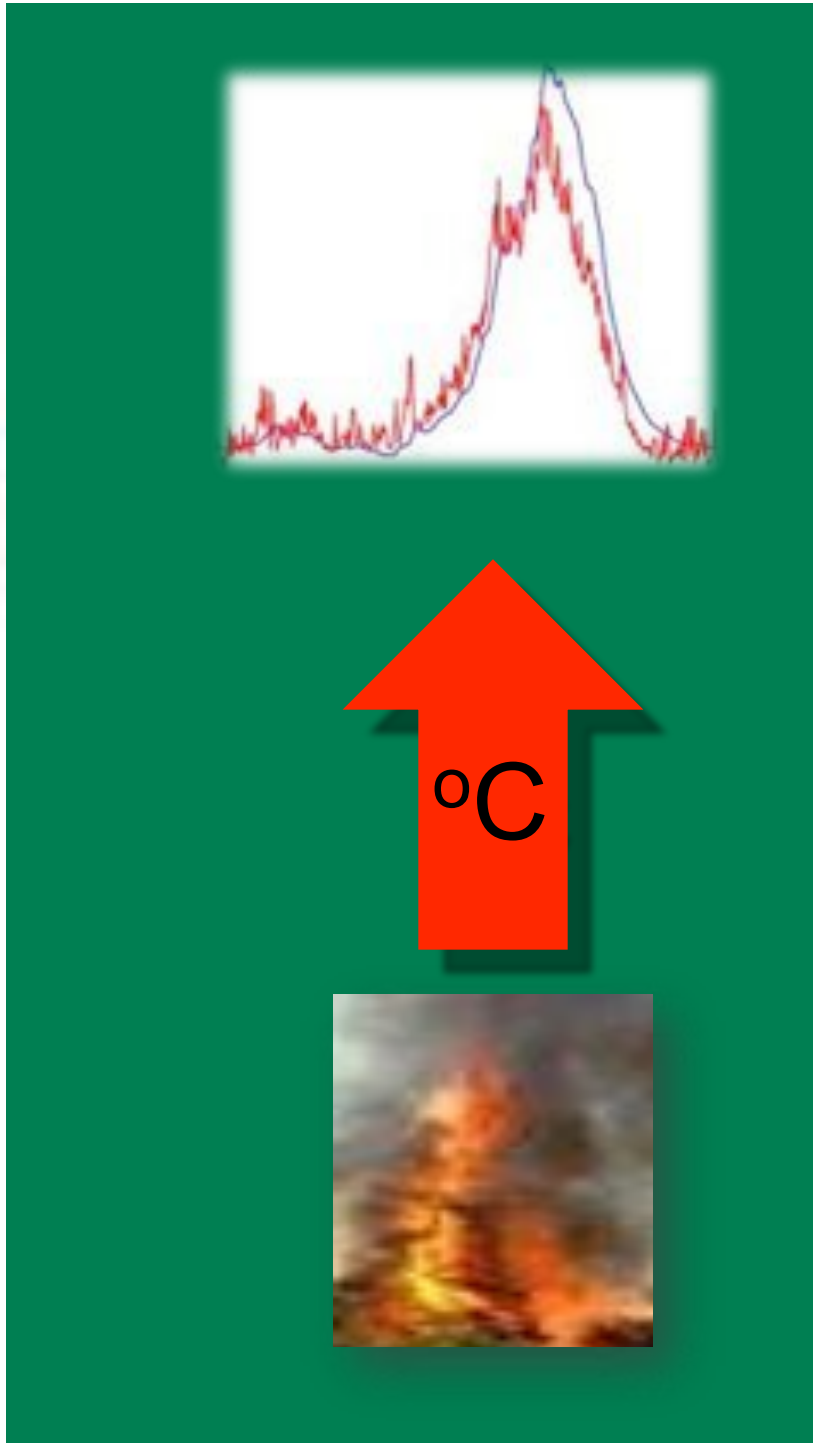
Bull Trout Habitat
Redd Counts

°C

Bull Trout Habitat
Spawning/Rearing
Unspecified Occupancy
Foraging, Migrating, Overwintering
Unoccupied/Unsurveyed
Fish Barriers
Redd Counts
2006
Fire Simulation

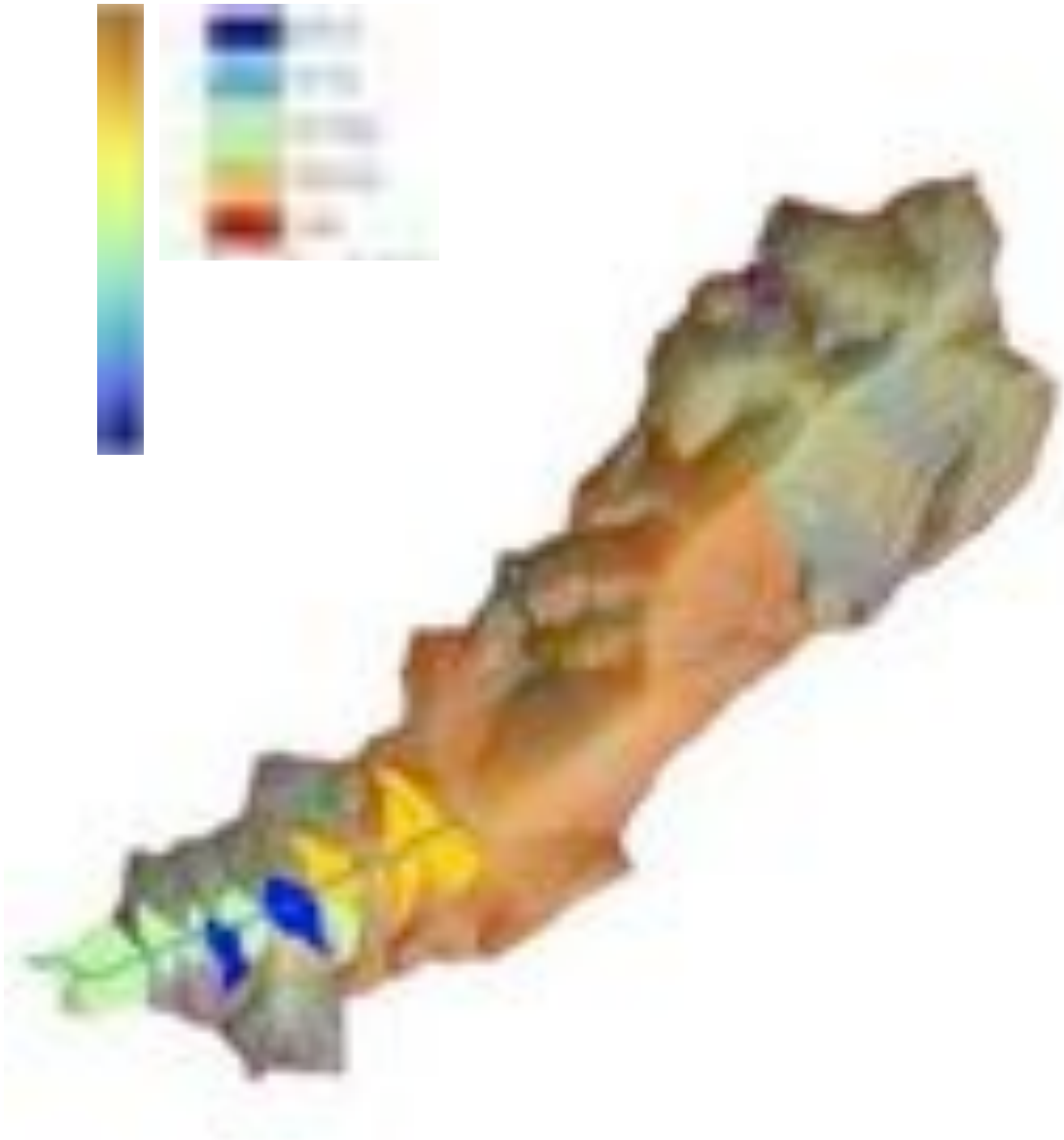
°C

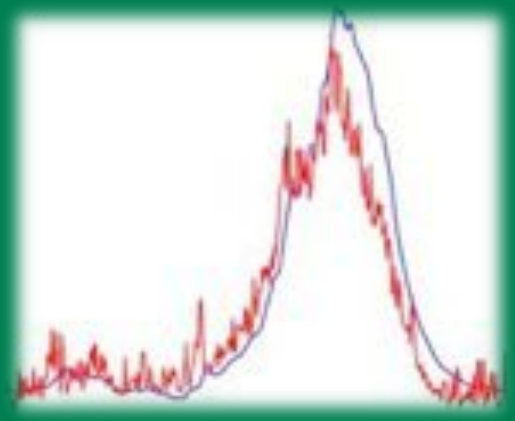
Bull Trout Habitat
Spawning/Rearing
Unspecified Occupancy
Foraging, Migrating, Overwintering
Unoccupied/Unsurveyed
1st Order Stream
Fish Barriers
Redd Counts
2006
Fire Simulation


°C

°C

Temperature °C





°C

Fall-Winter flooding

USGS

Climate Change Impacts on Geomorphology and Associated Bull Trout Spawning Areas

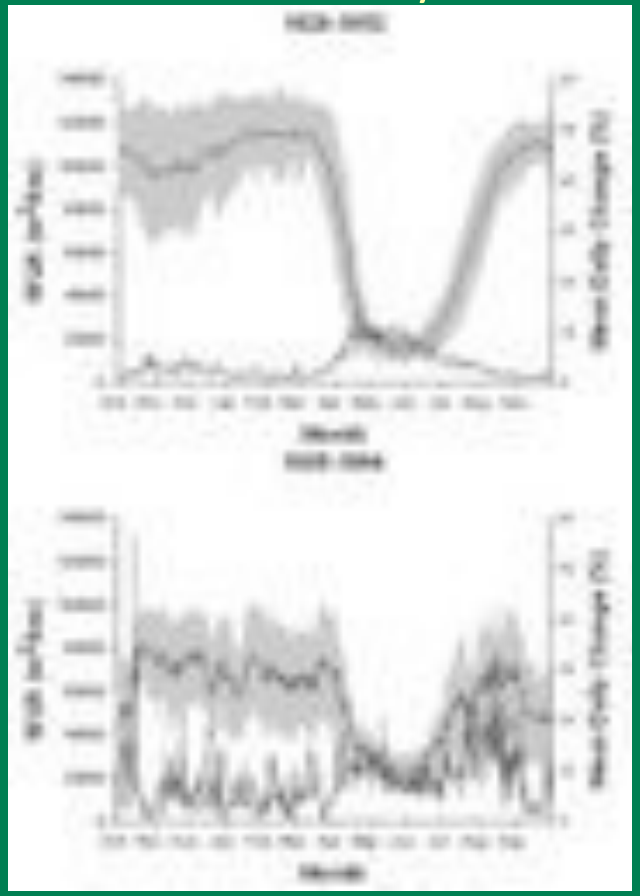
USGS

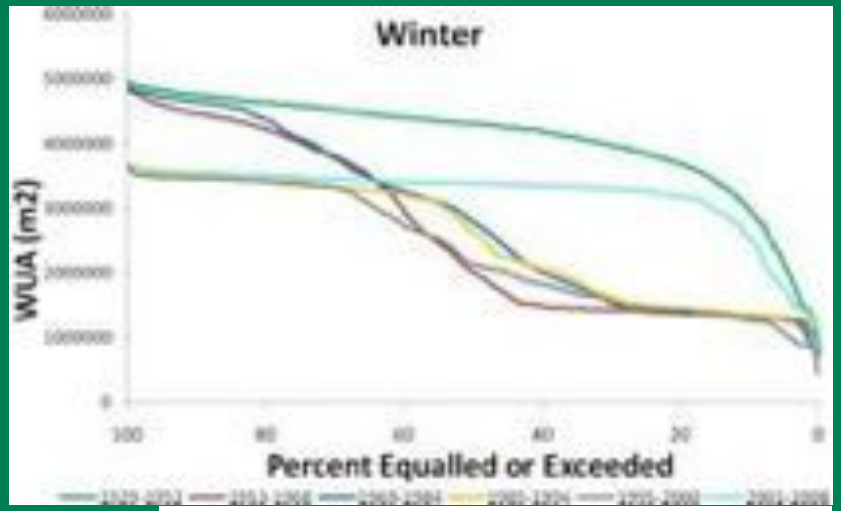
Mitigating Impacts of a Warming Climate

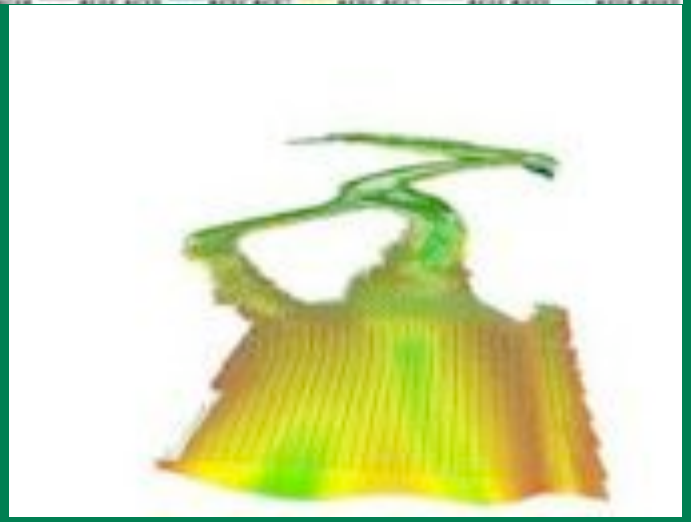
Thermal and hydrological measures :

•Maintain/restore riparian integrity, **instream flows**, & manage distribution/ intensity of human induced wildfires

Flathead River IFIM Study :





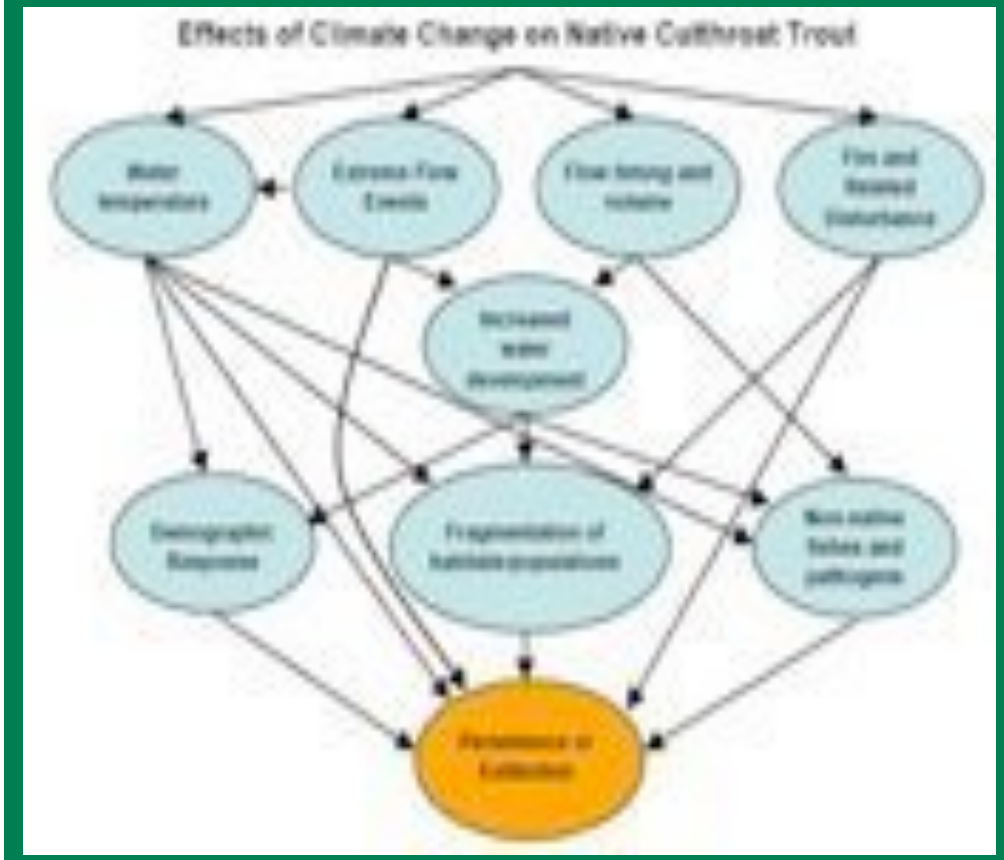


Mitigating Impacts of a Warming Climate

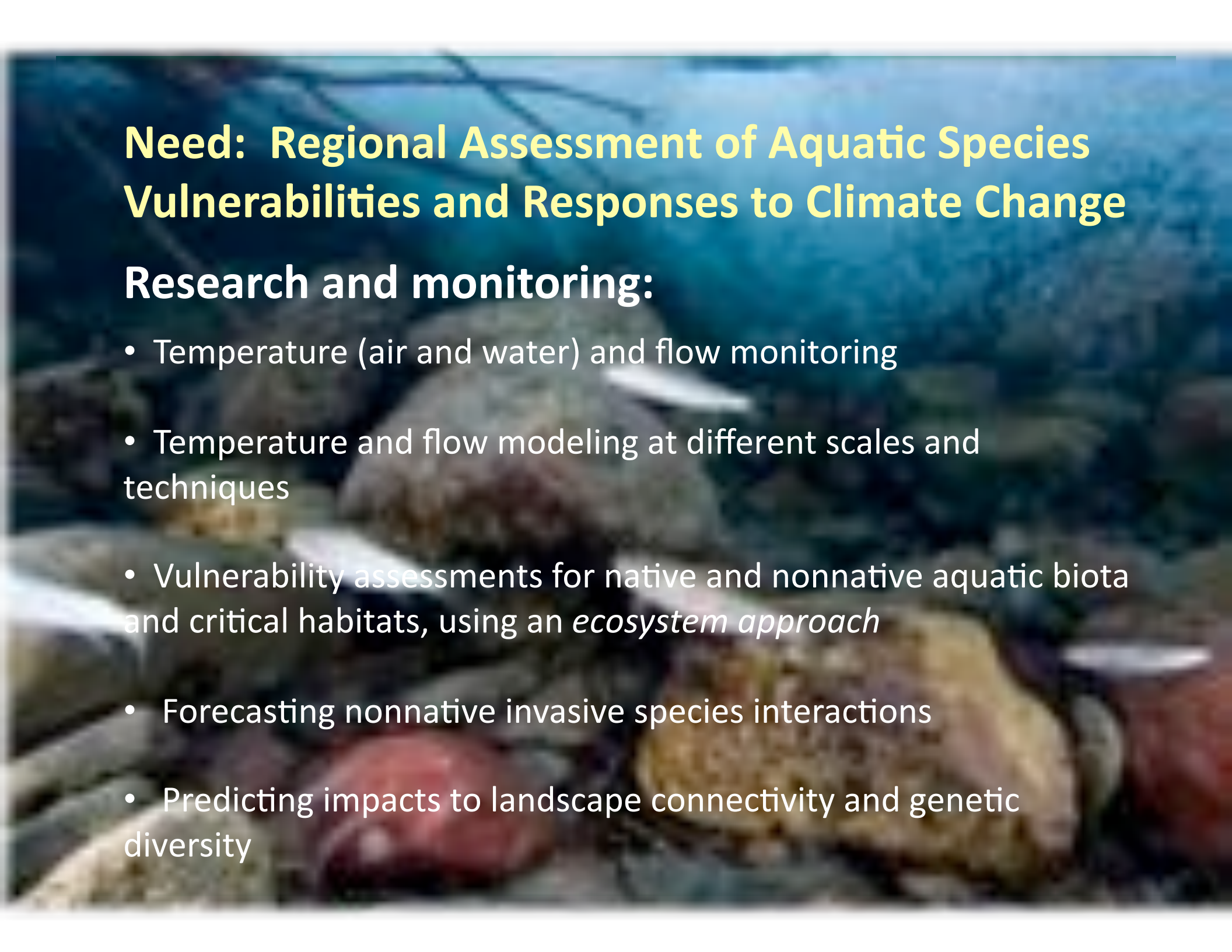
Biological measures:

- Barriers, assisted migrations/translocations
- Maintain diverse, productive habitats & populations
- Nonnative species control

Decision Support Tools for Managers

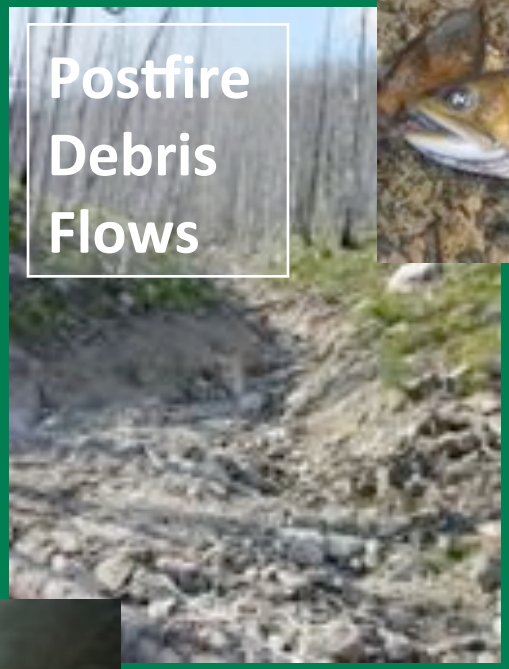


USGS



Need: Regional Assessment of Aquatic Species Vulnerabilities and Responses to Climate Change

Research and monitoring:

- Temperature (air and water) and flow monitoring
- Temperature and flow modeling at different scales and techniques
- Vulnerability assessments for native and nonnative aquatic biota and critical habitats, using an *ecosystem approach*
- Forecasting nonnative invasive species interactions
- Predicting impacts to landscape connectivity and genetic diversity

Are We Too Optimistic?