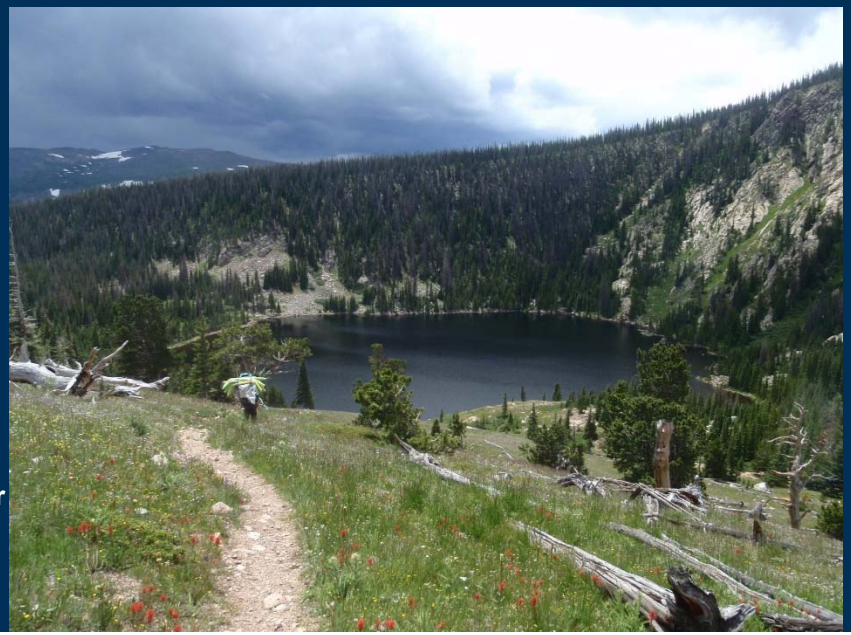
SOUTHERN ROCKIES
Landscape Conservation Cooperative

Climate Change and Cutthroat Trout Conservation in the Southern Rocky Mountains

JAMES J. ROBERTS
U.S. Geological Survey

Climate change and Cutthroat Trout conservation in the Southern Rocky Mountains (SRM)

James J. Roberts
USGS Colorado Water Science Center



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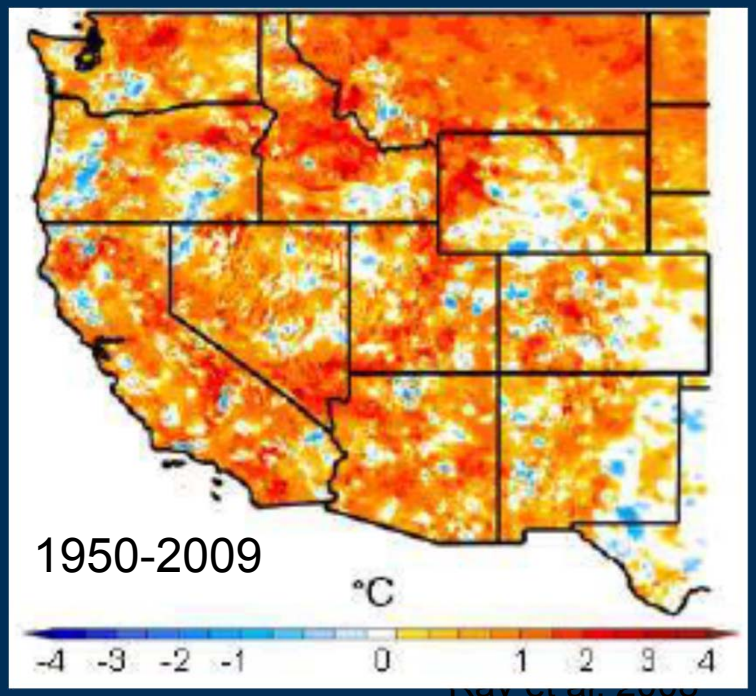
U.S. Department of the Interior
U.S. Geological Survey

Climate Change

Air temperature*

- Increase of mean annual air temperature

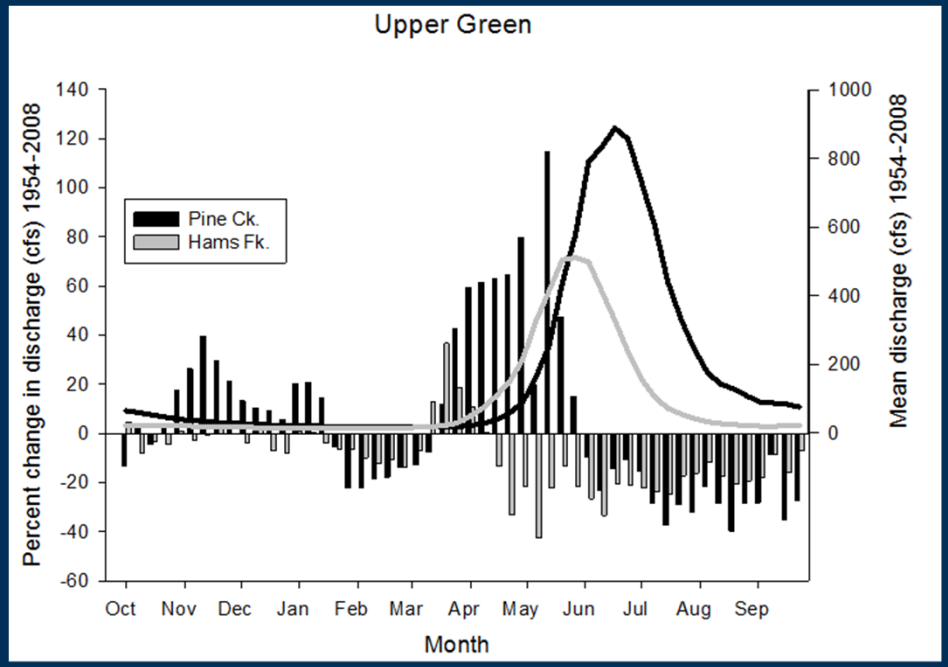


Change in temperature (°F)

Hydroclimate

- Models suggest more arid conditions
- Observed patterns*
  - Earlier snowmelt

and peak discharge



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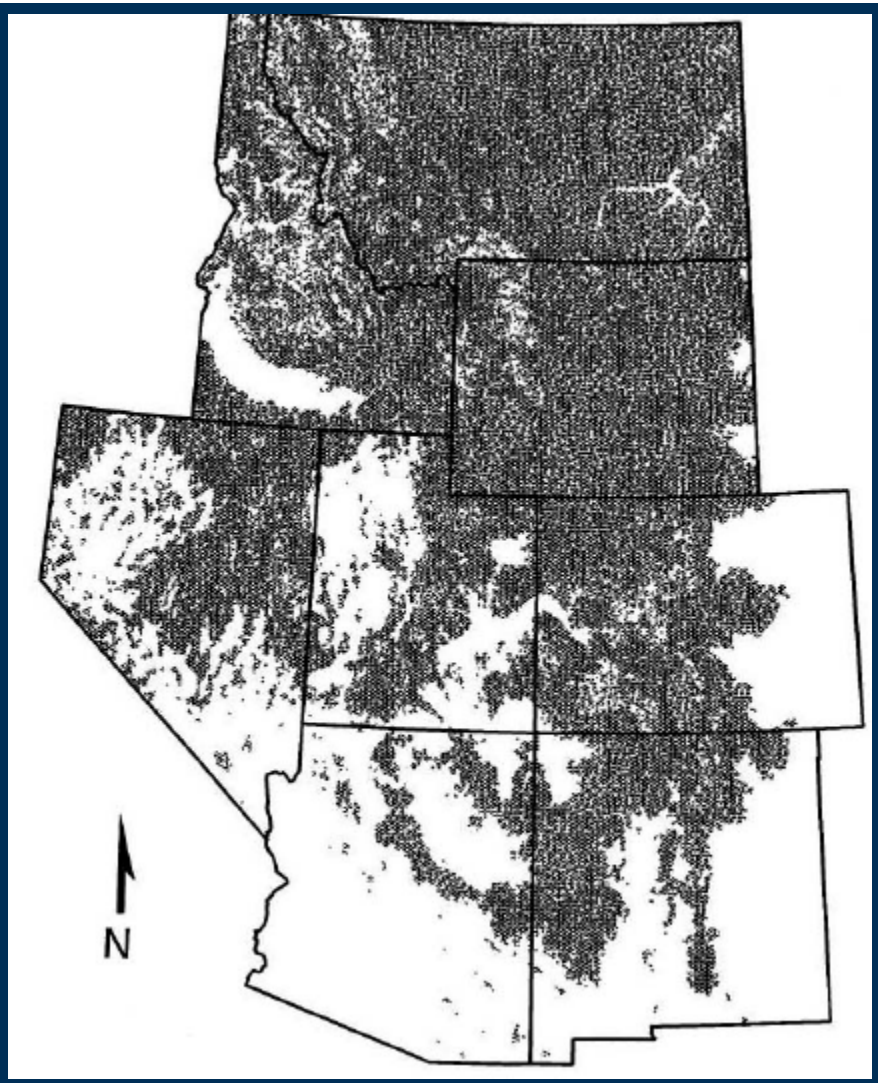
*Isaak et al. 2012, Fisheries



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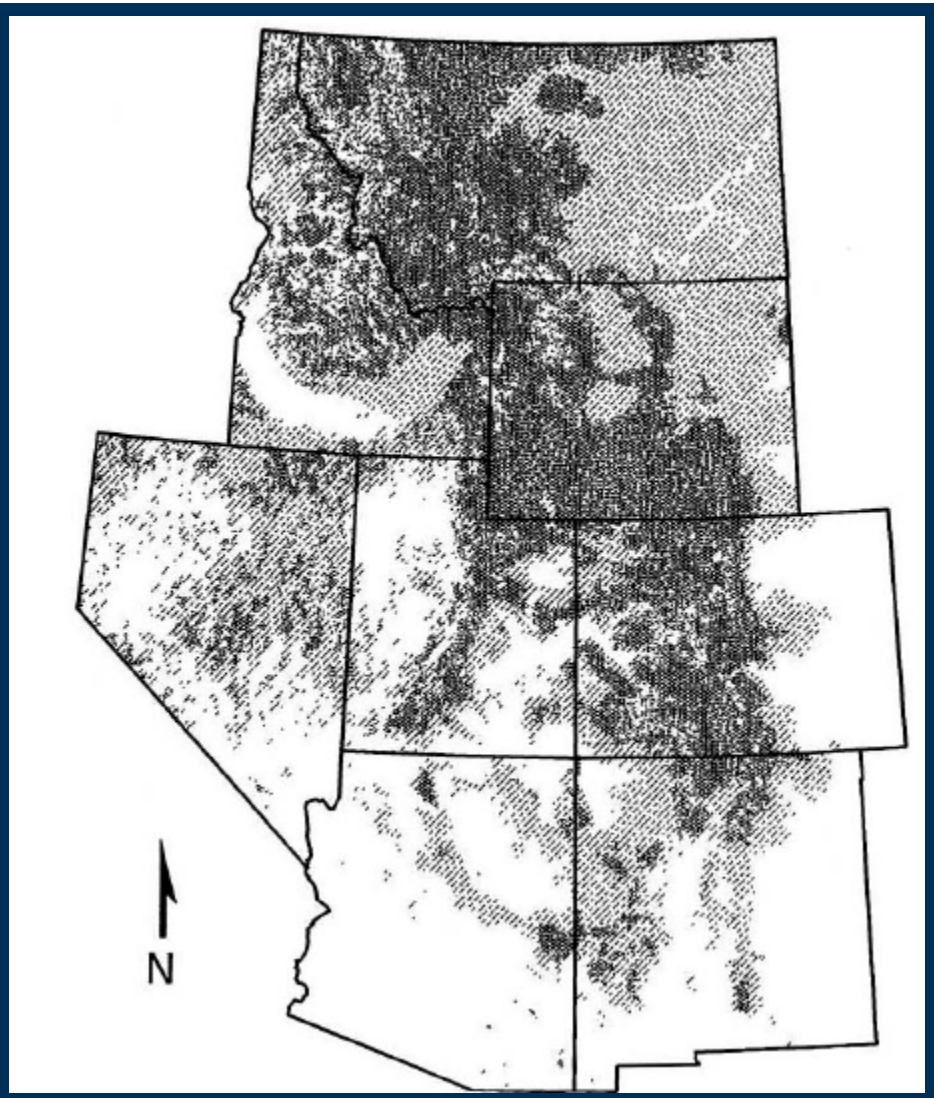

3° C increase
50% habitat loss

Habitat loss
Suitable

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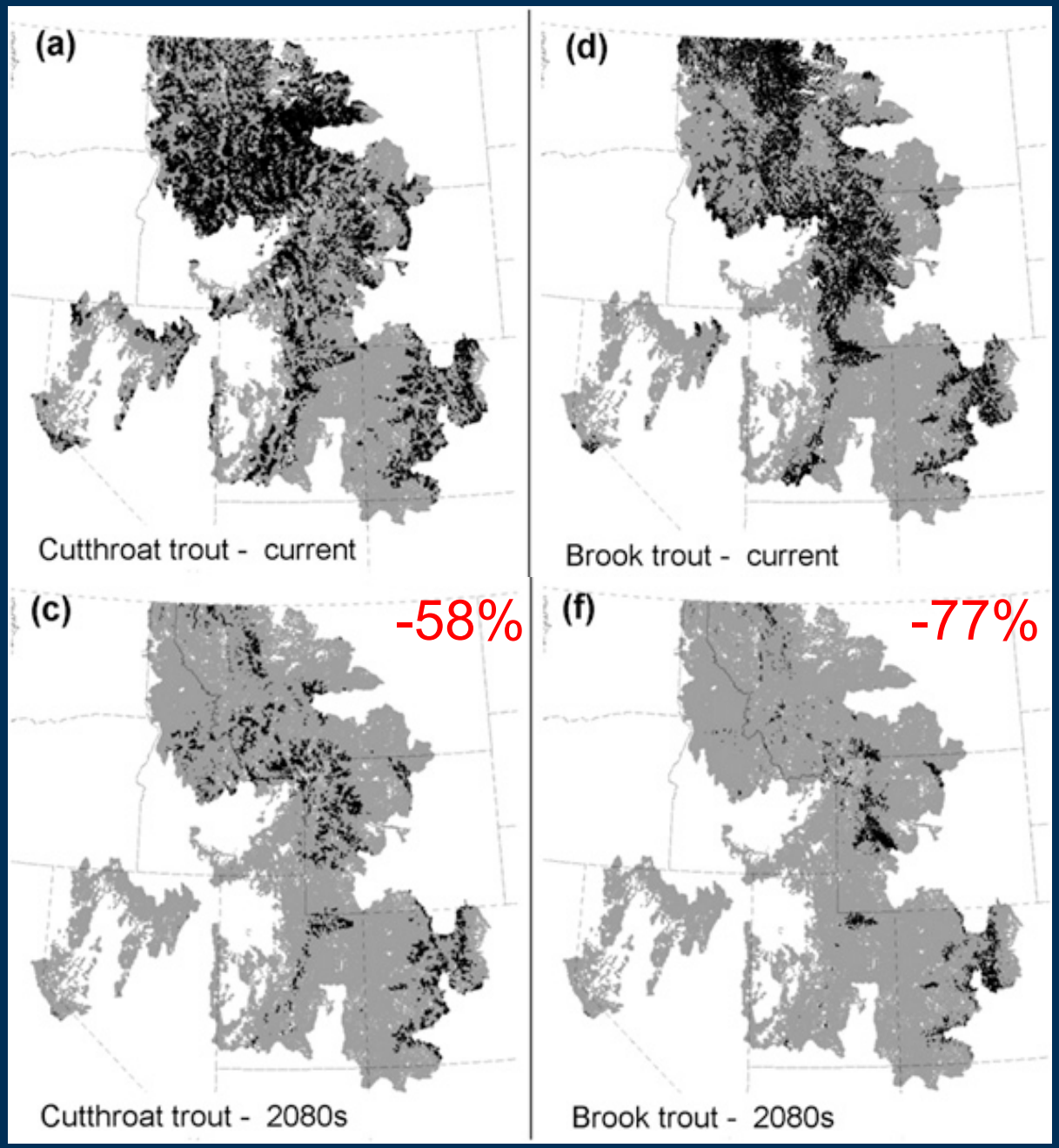
Keleher and Rahel. 1996; TAFS

Half of trout habitat in the West will be gone by 2080



Wenger et al. 2011; *PNAS*

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Climate Change: Multiple stressors

Snowmelt driven streams

- Temperature ⬆
  - Track to higher elevations
- Stream flow ⬇
  - Isolated stream pools, lower elevations
- Stochastic events ⬆
- Ecological setting
  - Connectivity
  - Nonnative species

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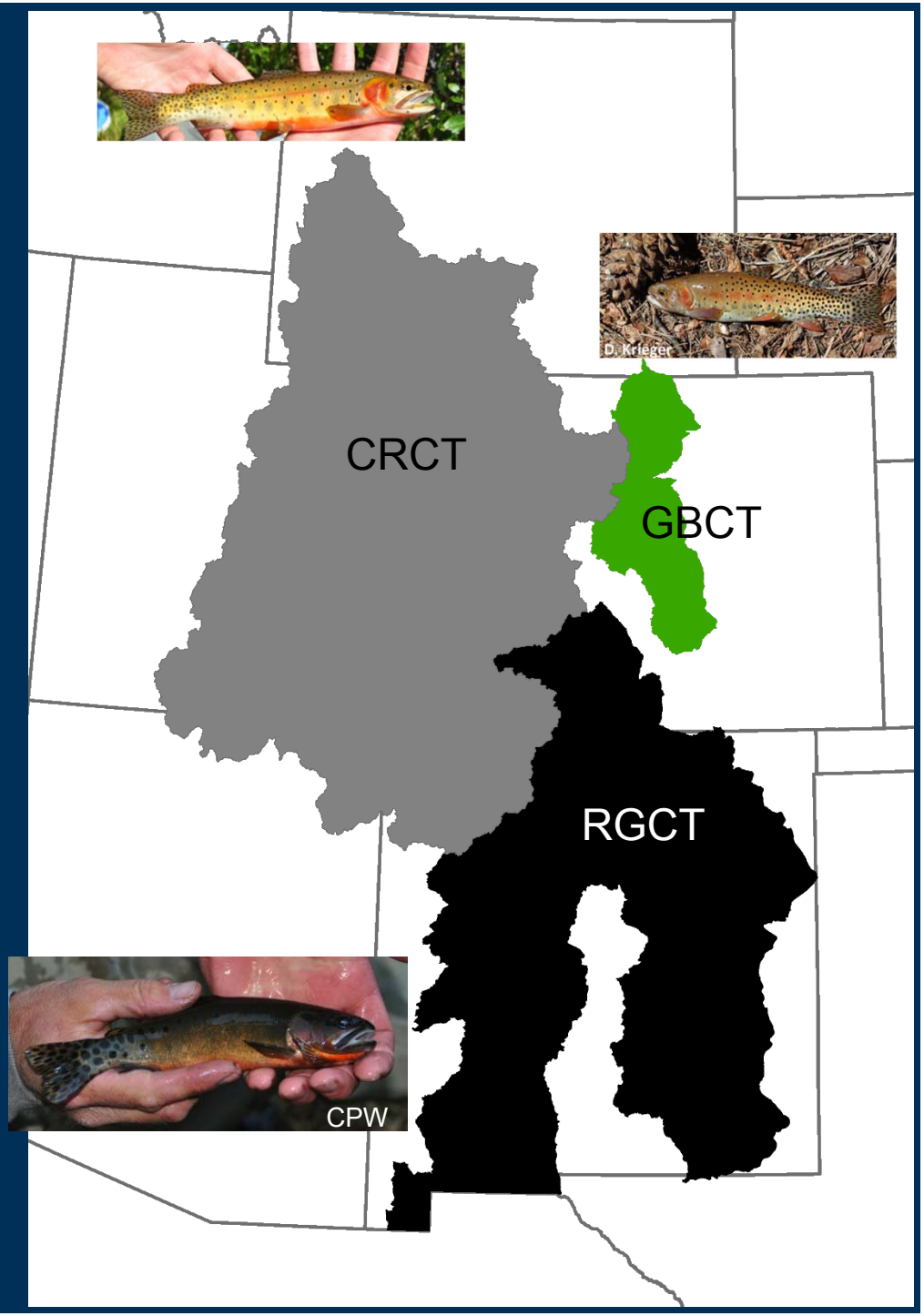
Native Trout in SRM

- Colorado River CT
  - *O. c. plueriticus;* CRCT
- Greenback CT
  - *O. c. stomias*; GBCT
- Rio Grande CT
  - *O. c. virginalis*; RGCT



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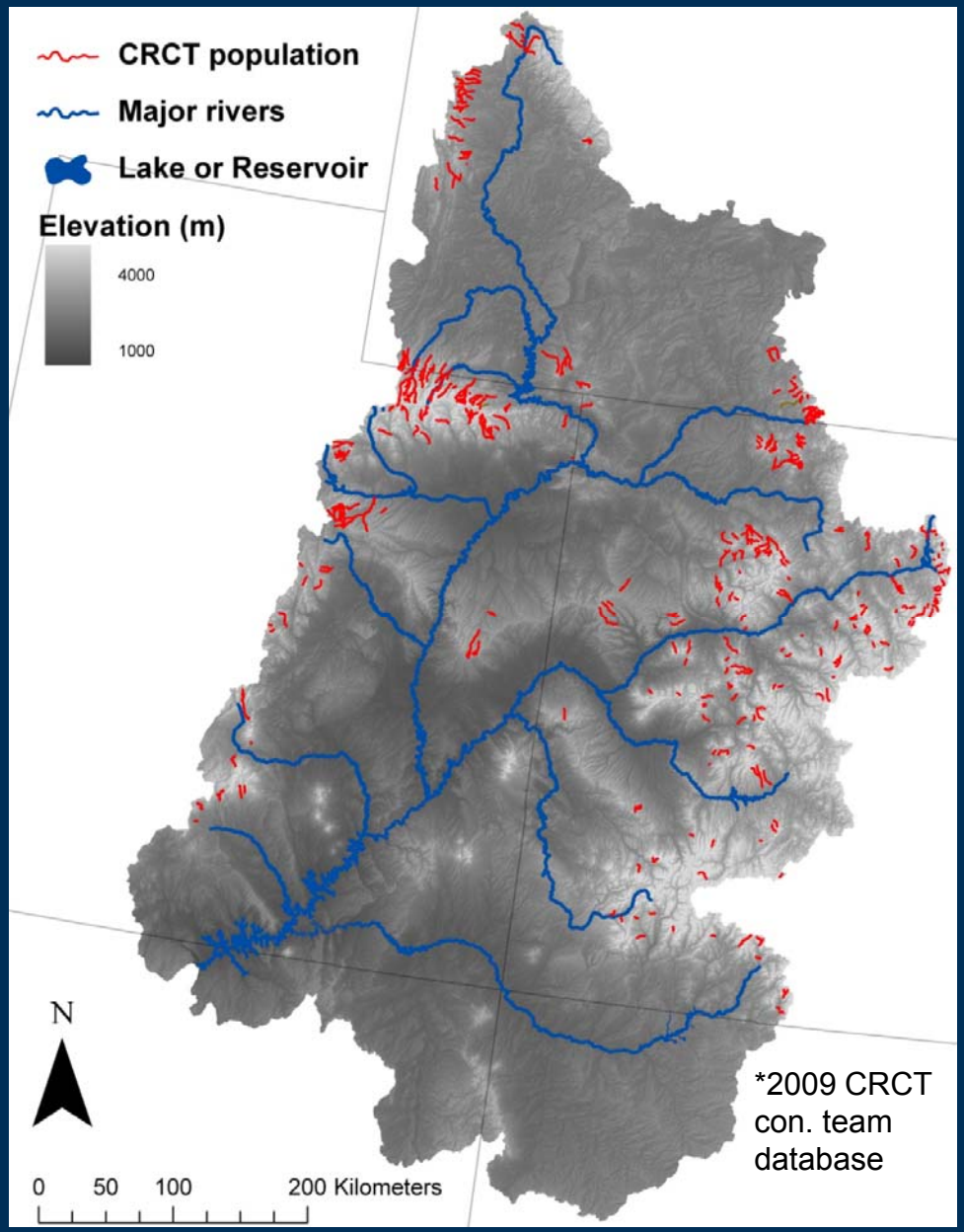
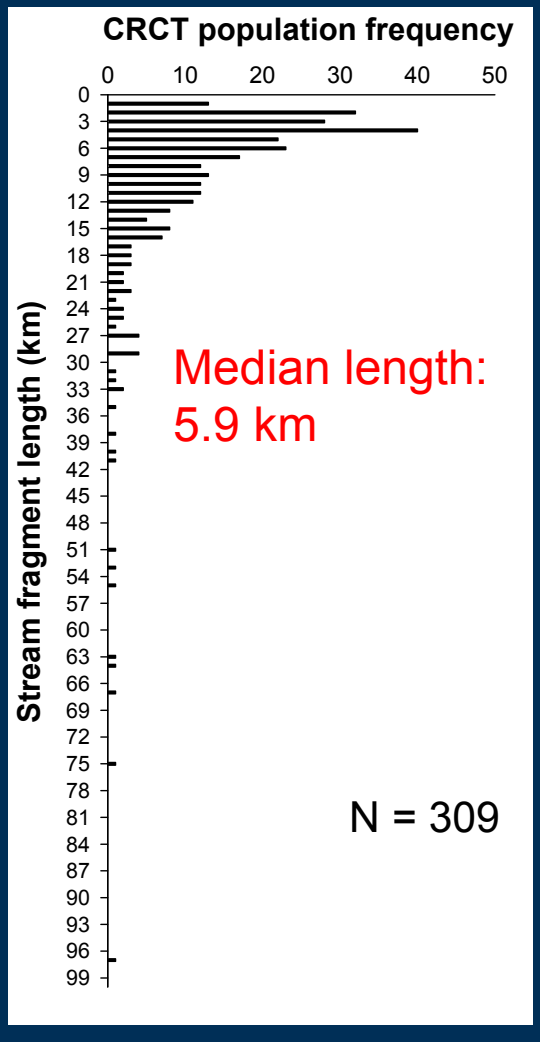
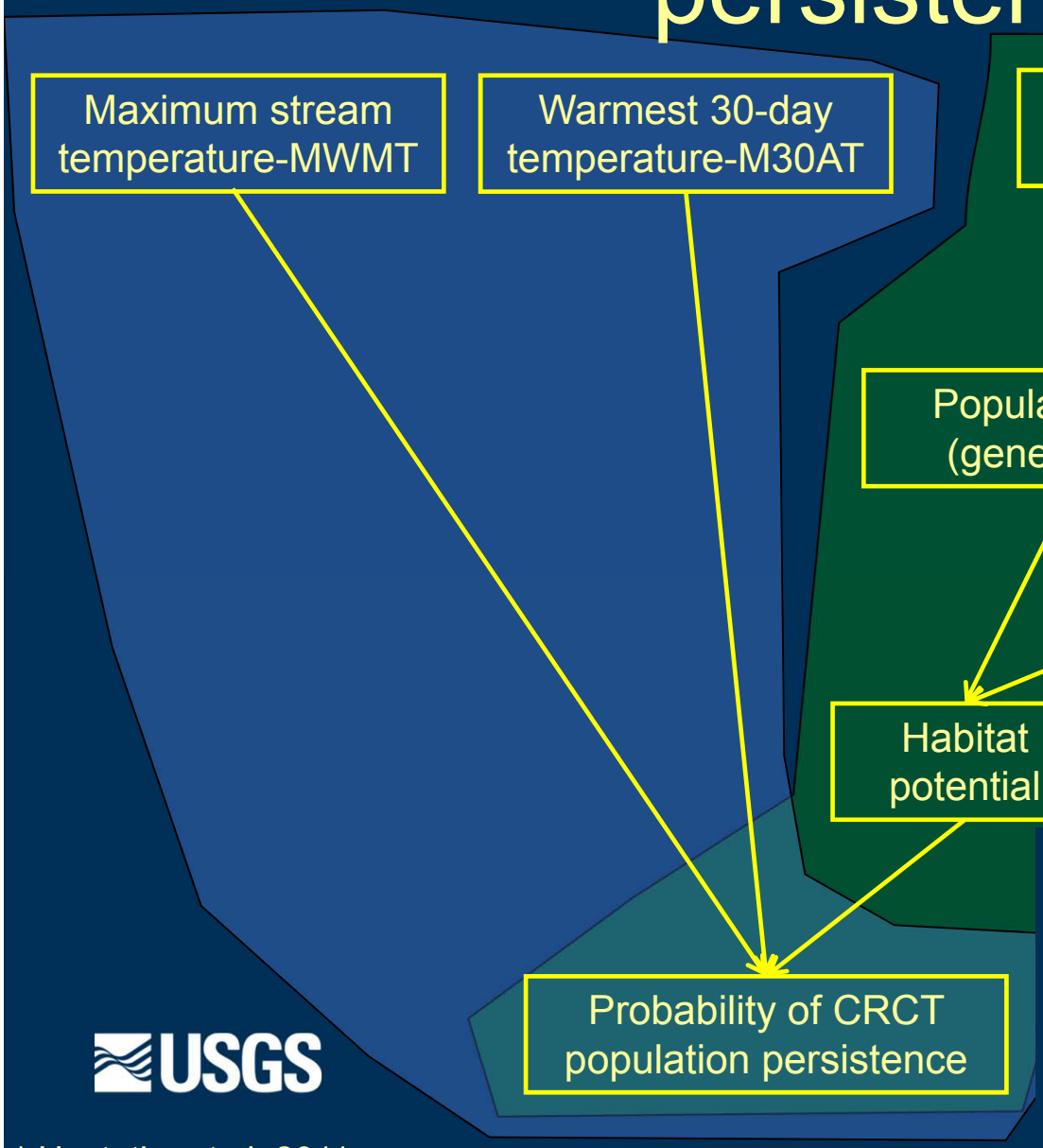
Colorado River Cutthroat Trout



- 14% of historical habitat
- Isolated headwater streams
  - >1700m elevation



Bayesian Network: Predicting CRCT persistence



- Time horizon
  - 2040 and 2080
- Stream Temperature Model for UPCO
  - Dynamically Downscaled Climate Projections*

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* Hostetler et al. 2011

Thermal Criteria for CRCT

- Survival
  - Upper Incipient Lethal Temperature
    - ≥26 C with diel fluctuation

State name	Stream temp (Maximum)
Survival	<26 °C
Mortality	≥26 °C

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Thermal Criteria for CRCT

- Survival
  - Upper Incipient Lethal Temperature
    - ≥26 C with diel fluctuation
- Recruitment
  - < 8 °C very low recruitment
- Growth
  - Optimum at 9.1-18 °C
  - ≥75% of maximum growth

State name	Stream temp (M30AT)
Very low or no recruitment	<8.0°C
Low recruitment	8.0-9.0°C
Optimum recruitment and growth	9.1-18.0°C
Declining growth	18.1 – 19.9°C
Little or no growth	≥20.0°C
Mortality	≥26.0°C **MWMT**

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Risks from fragmentation

- Genetic risks - Population size (N)–
  - Predict N from fragment length (Young et al. 2005)
  - N_e:N ratio = 0.25

State name (1+ CRCT)	Stream length (km)
Immediate neg. genetic (N_e<50)	<1.7
Short-term neg. genetic (N_e=51-200)	1.7-4.6
Long-term neg. genetic (N_e=201-500)	4.7-7.7
Robust (N_e>500)	>7.7

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Risks from fragmentation

- Genetic risks - Population size –
  - Predict from length (Young et al. 2005)
  - N_e:N ratio = 0.25
- Stochastic effects
  - Patchy
  - Drying and freezing
  - Wildfire and sediment

Stochastic effects	Stream length (km)
Highly susceptible	<3.6
Variable buffering	3.6-7.2
Robust buffering	>7.2

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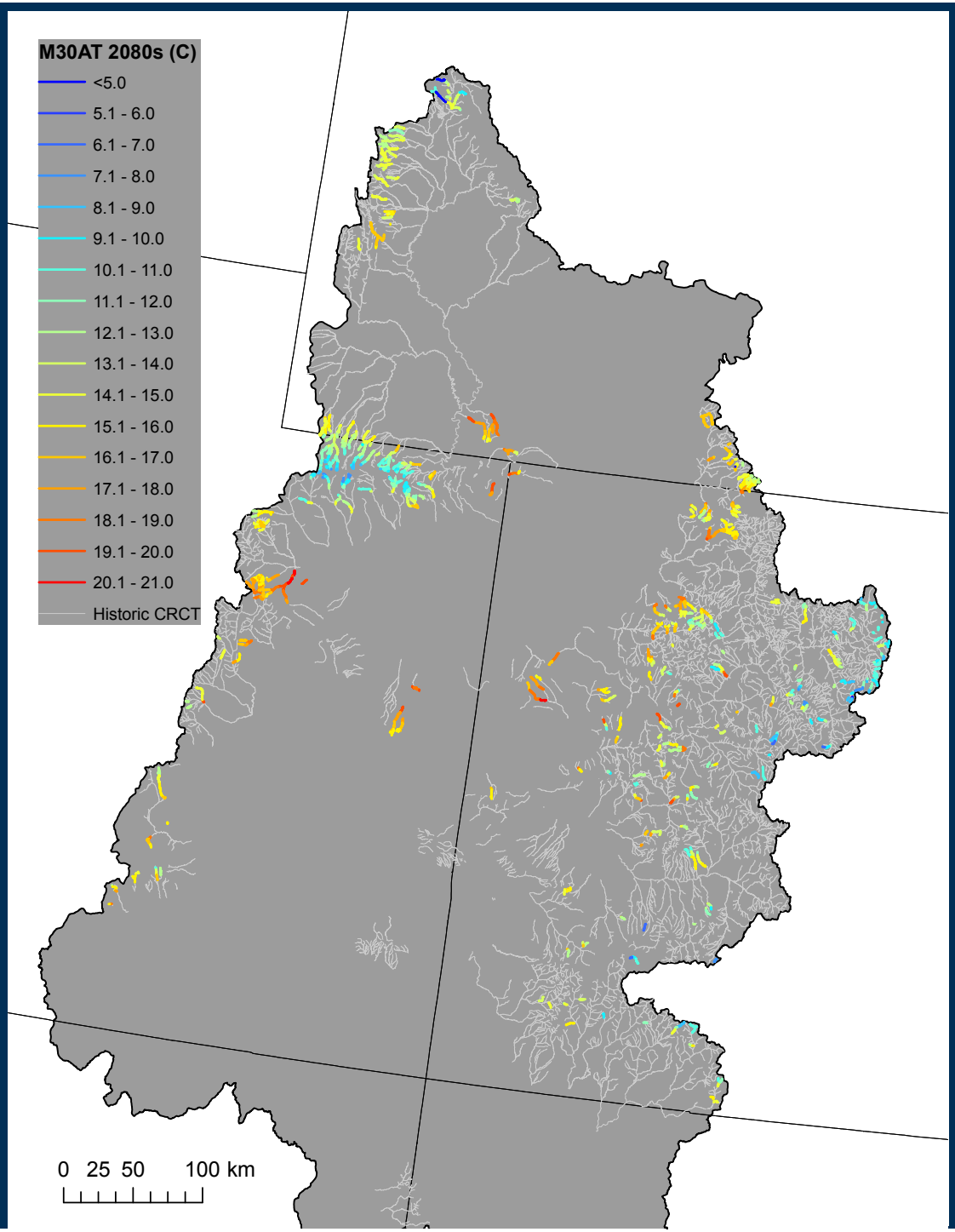
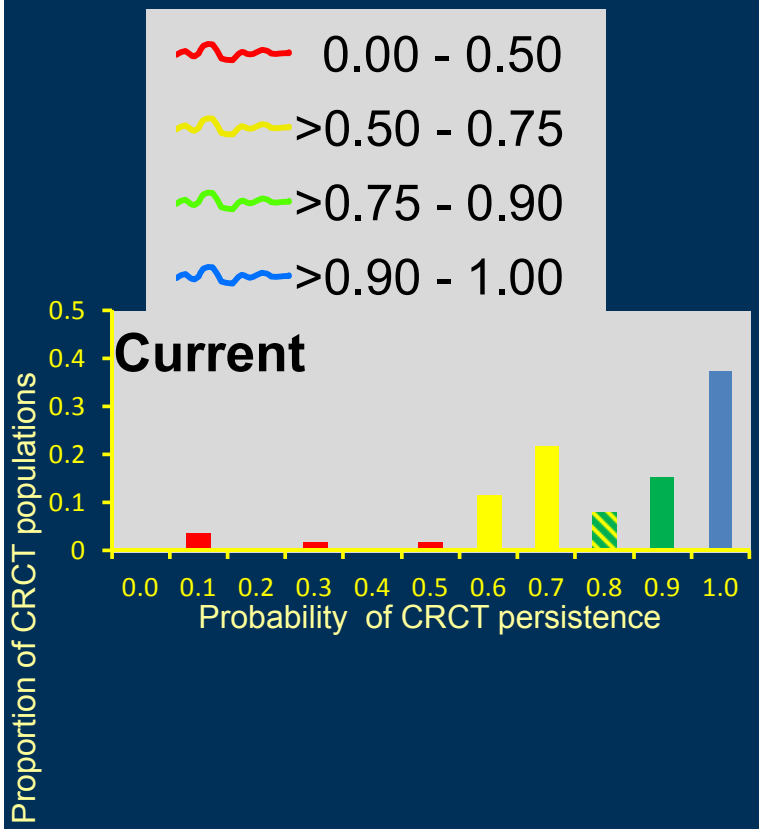
Stream Temperature

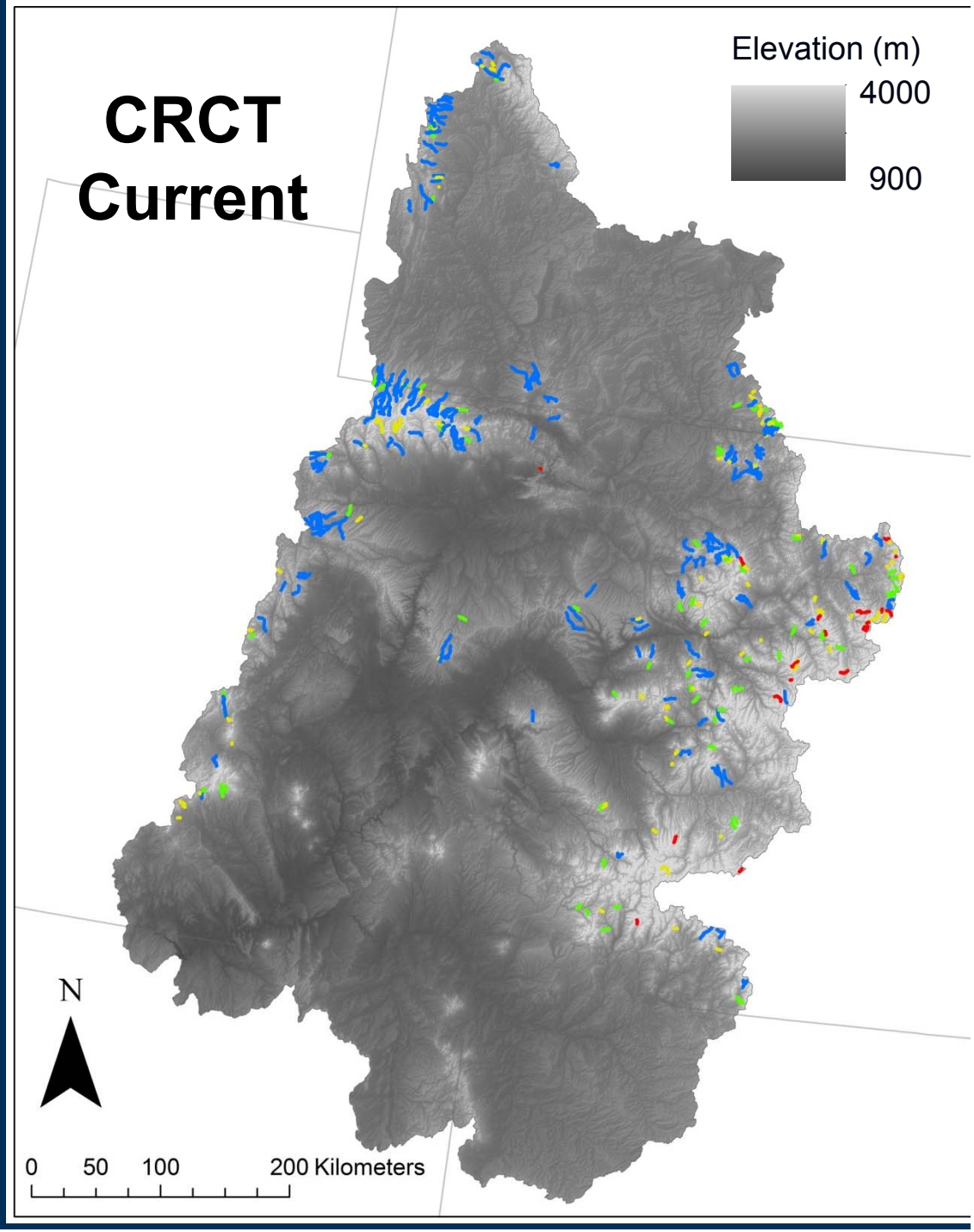
- Stream Temperature Model for UPCO
  - 483 records
  - Predictors
    - Climate
      - Air temp., Streamflow
    - Landscape
      - Elevation, aspect, drainage area, slope
  - Universal Kriging
    - 1.98 °C RMSPE
  - M30AT +1.1°C 2080
  - 86% of segments suitable (n=823)



Population persistence

Probability of persistence





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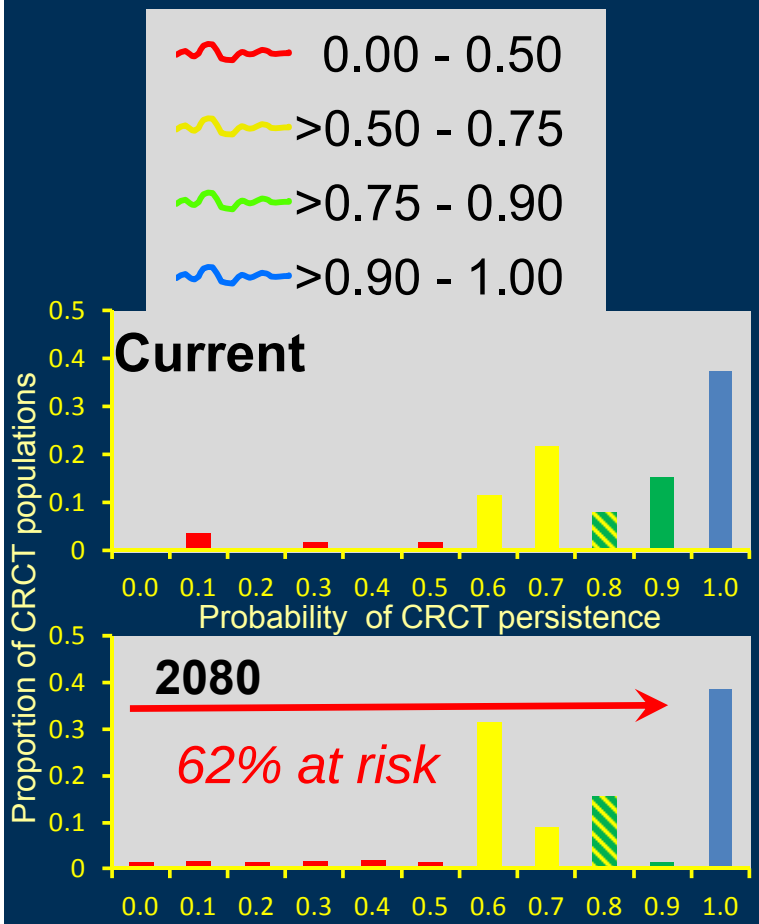
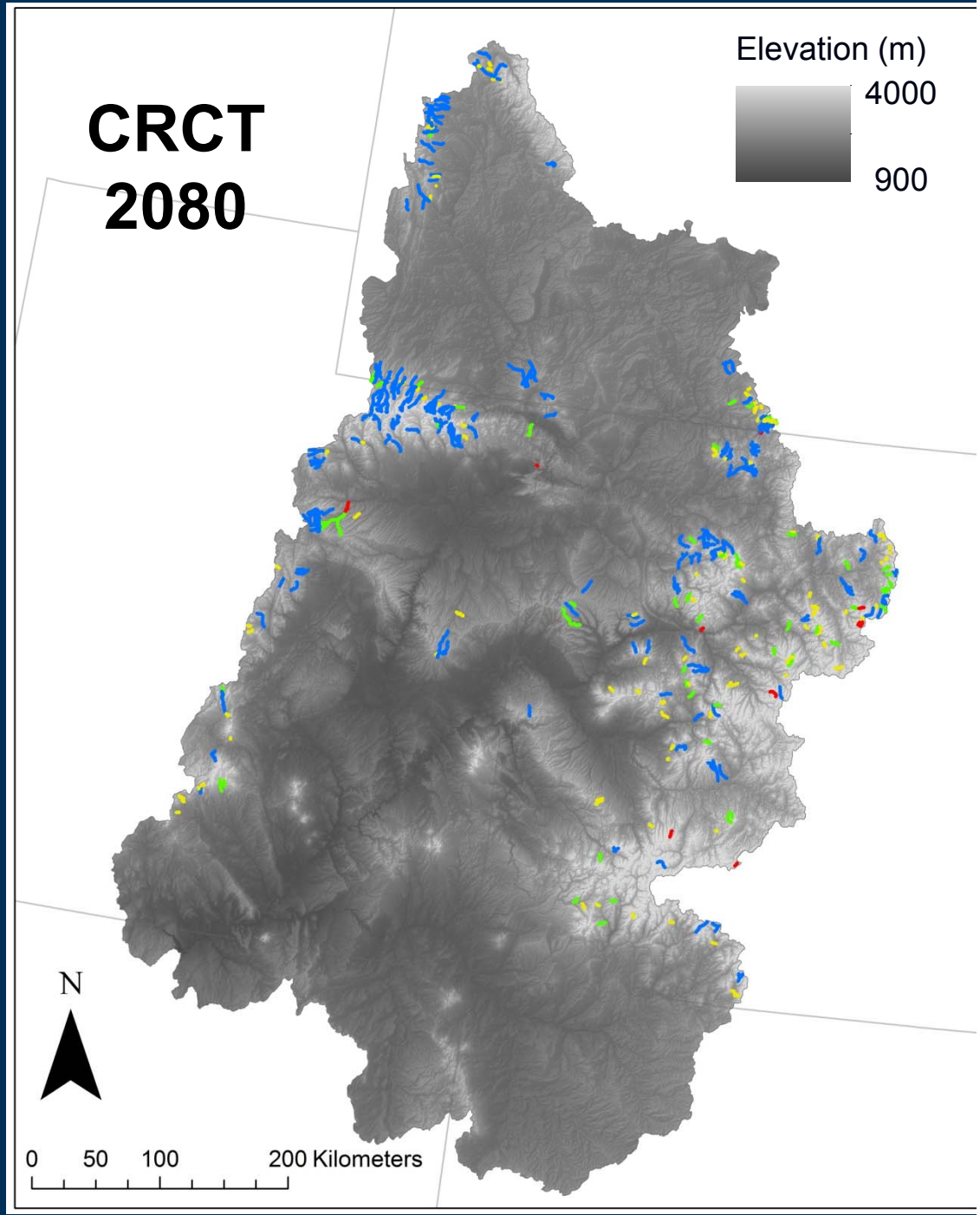
Roberts et al. 2013; GCB

Population persistence





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Roberts et al. 2013; GCB

Nonnative invasion: threat to fragment length

- Brook trout primary threat to CRCT headwater streams
  - Barrier failure or illegal introduction
  - Rapidly displace CRCT
- 8% invaded/decade (n=24)
- Reduce fragment by 1.5 km/yr
- Invade randomly on landscape


B. Zuellig-USGS


K.. Fausch

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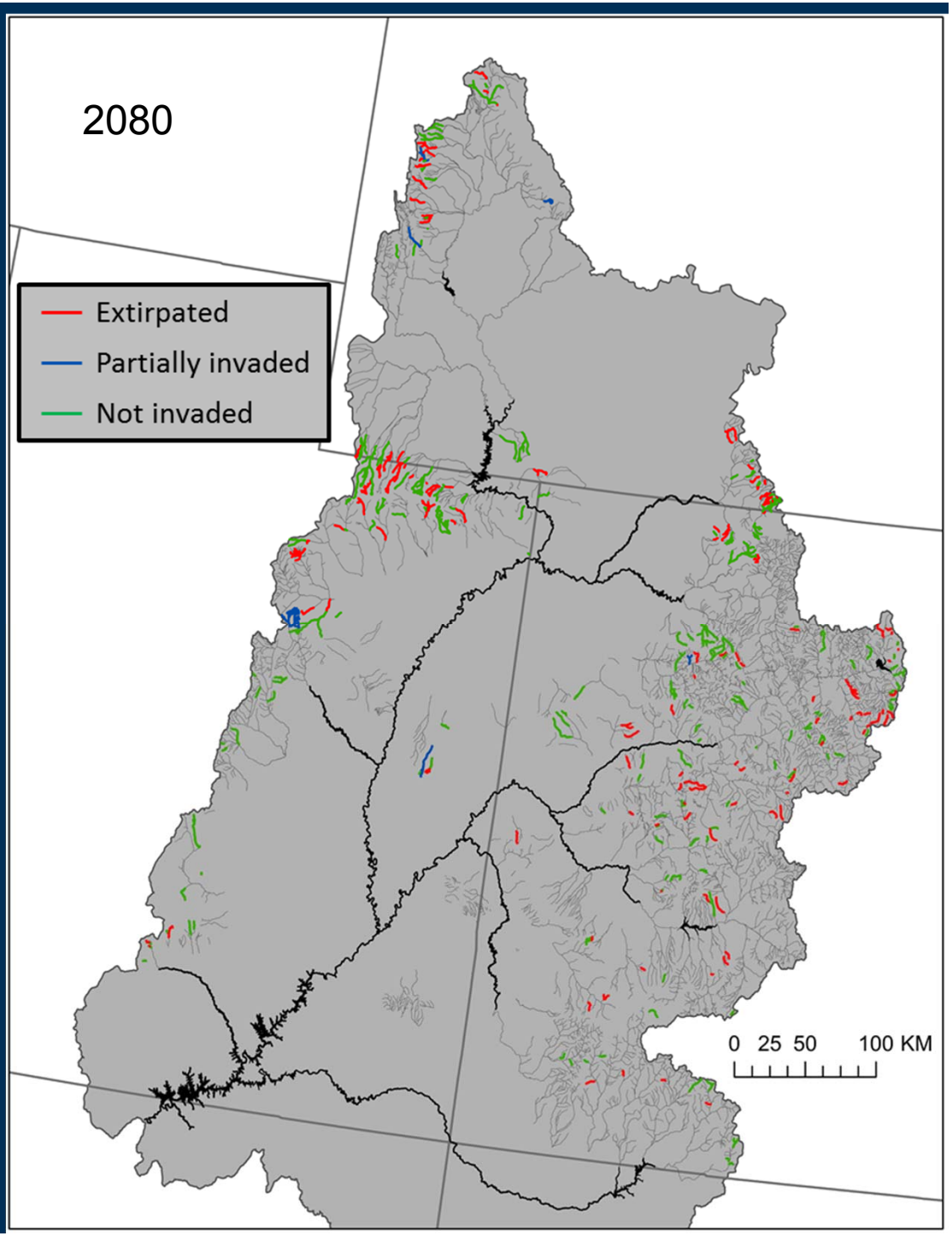
Invasion simulation

- 100 simulations
  - Yearly time-step
    - 2010-2080
- Removed invaded sections to recalculate temperature
- 122 extirpated
  - range 98-140
- 5 partially invaded
  - range 1-11
- 182 not invaded



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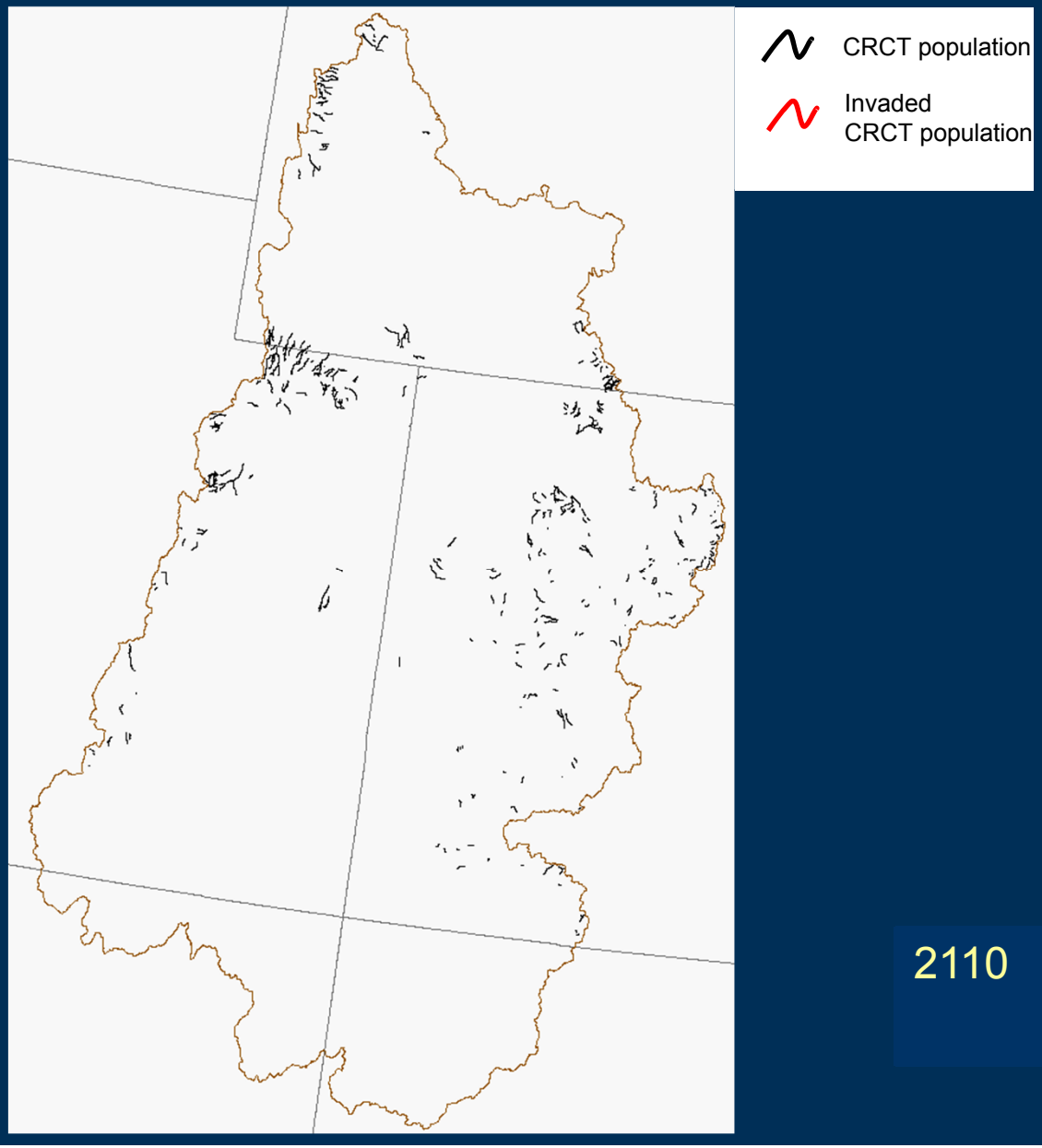
Nonnative invasion: simulation



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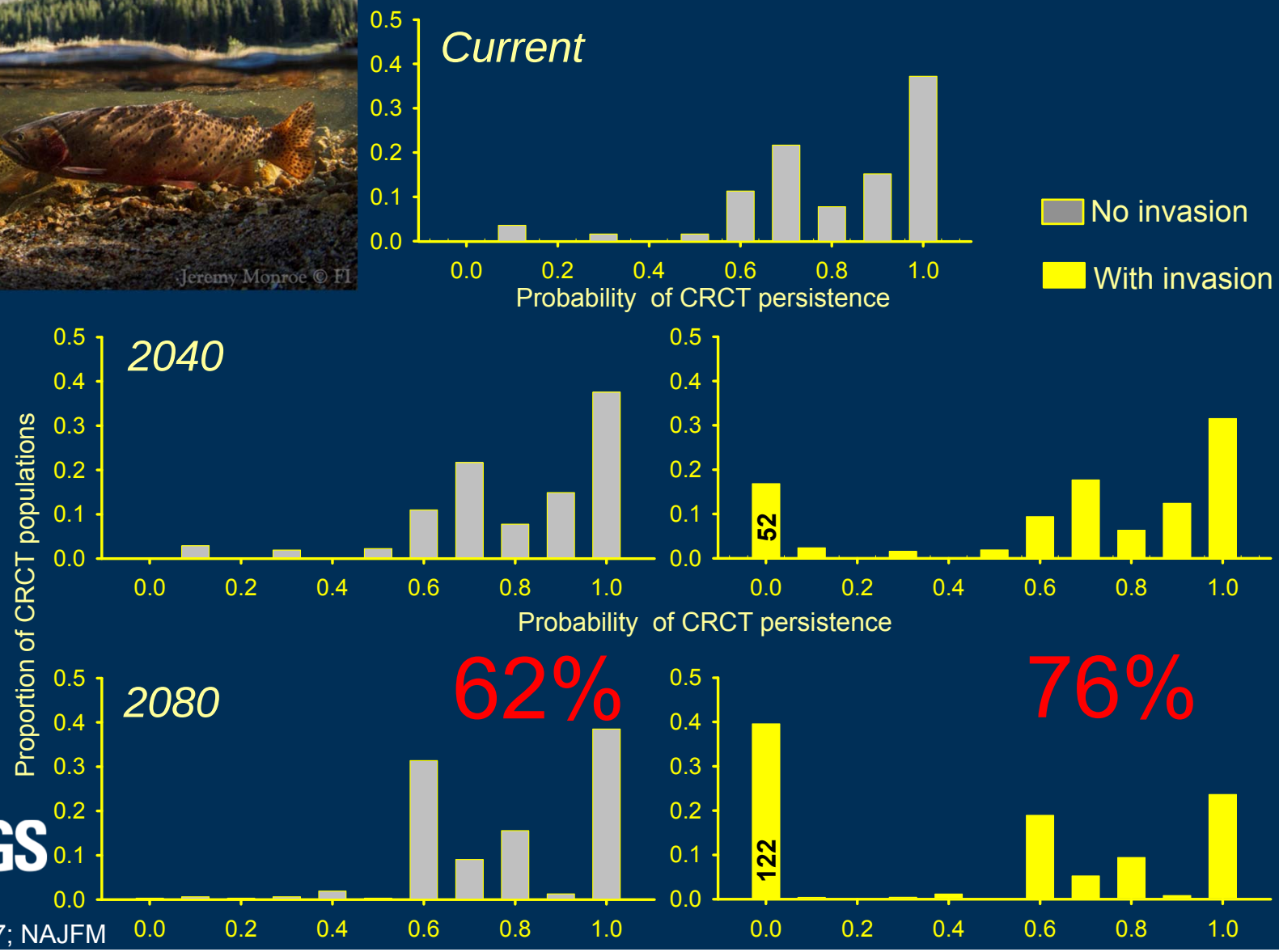
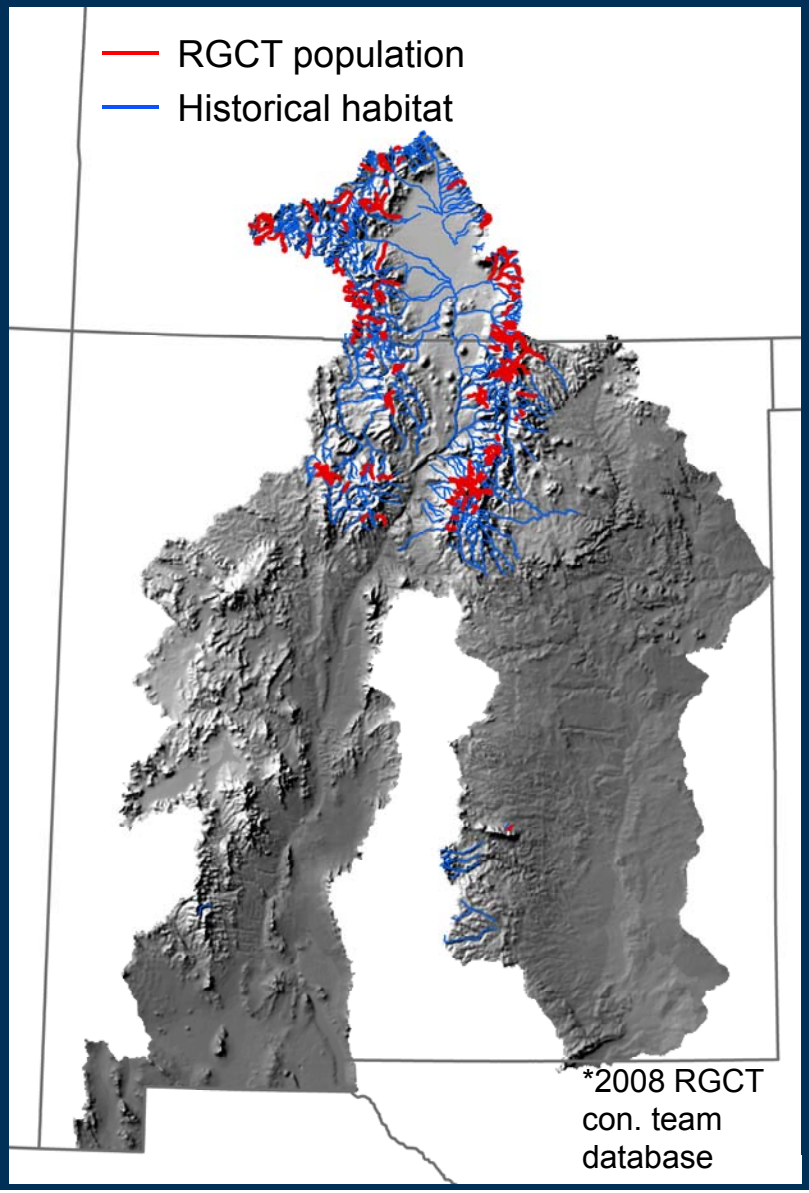
Nonnative invasion: CRCT persistence

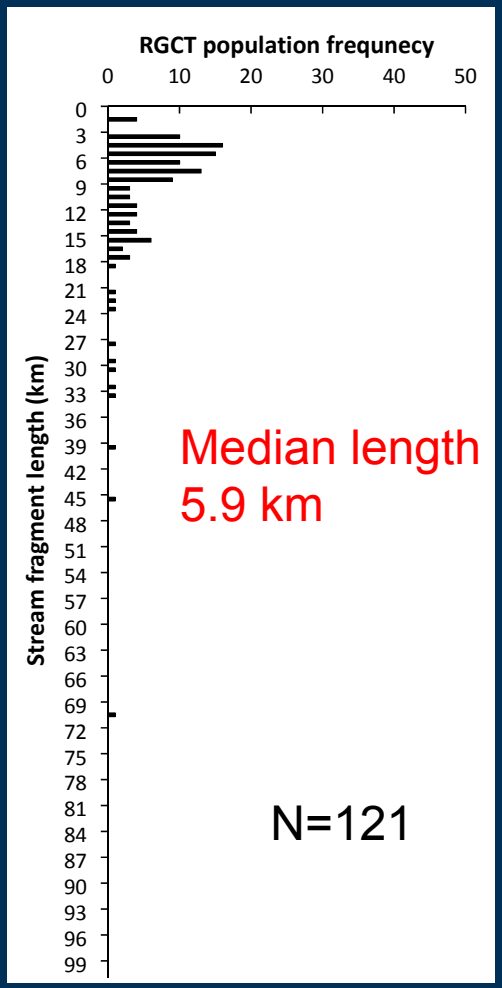


Roberts et al. 2017; NAJFM

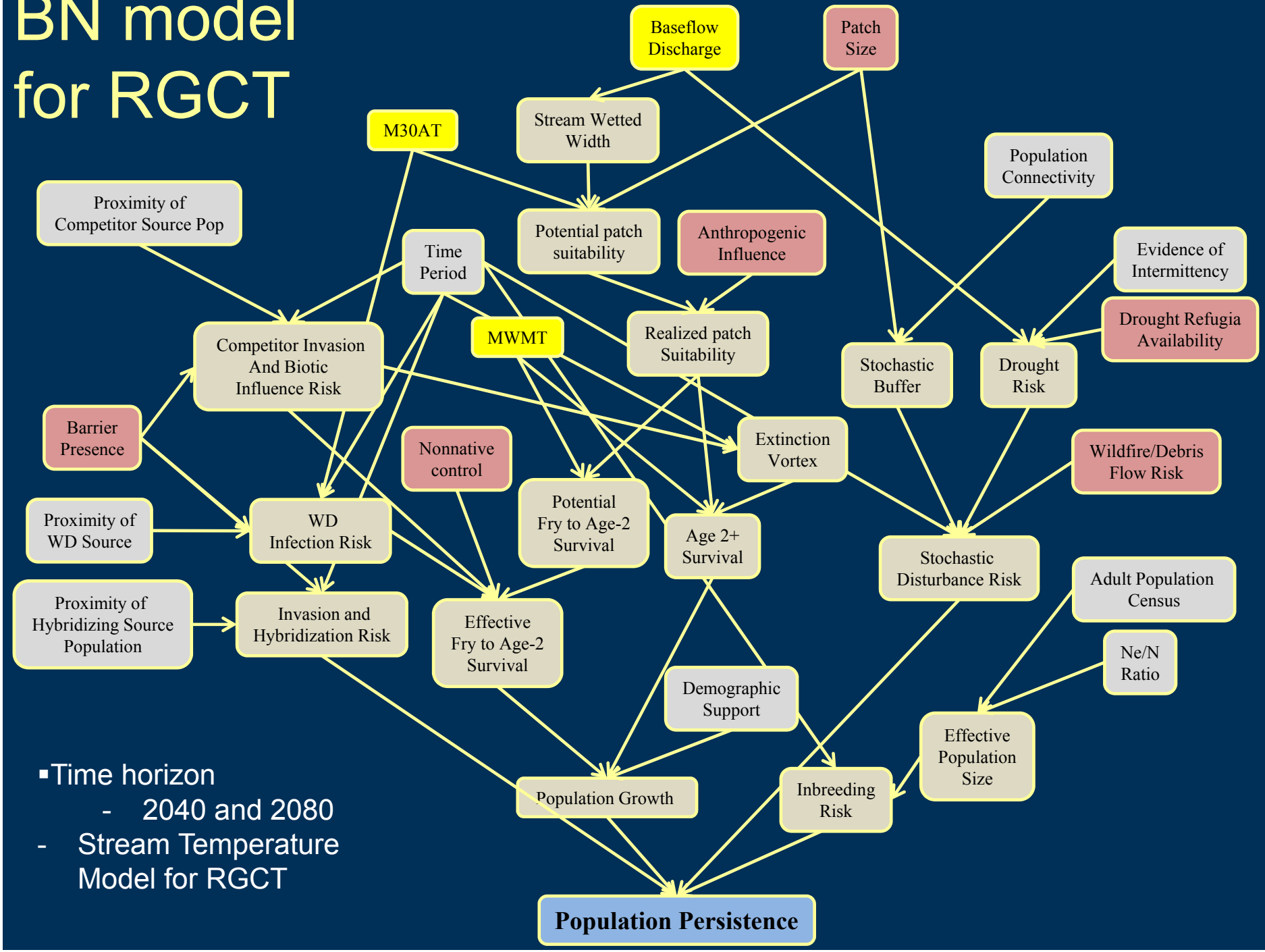
Rio Grande Cutthroat Trout

- 11% of historical habitat
- Southern most sub-species
  - Isolated headwaters



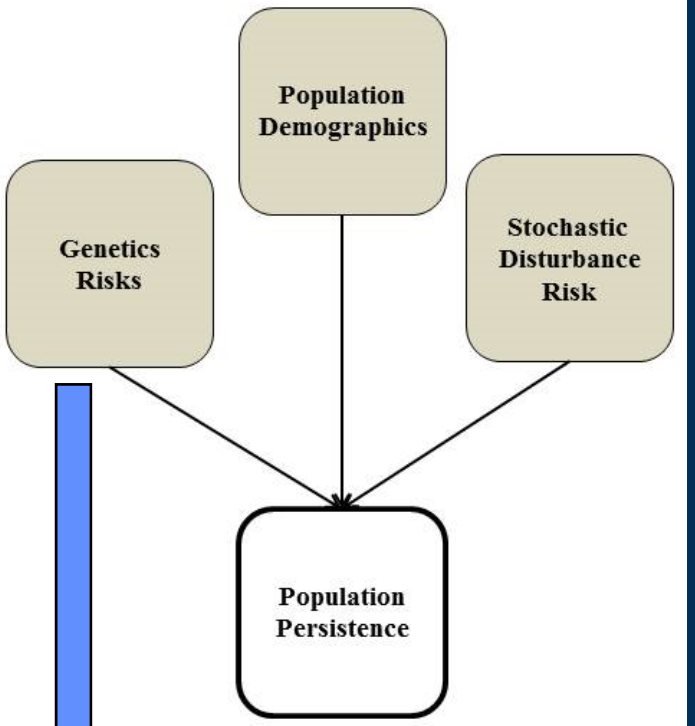


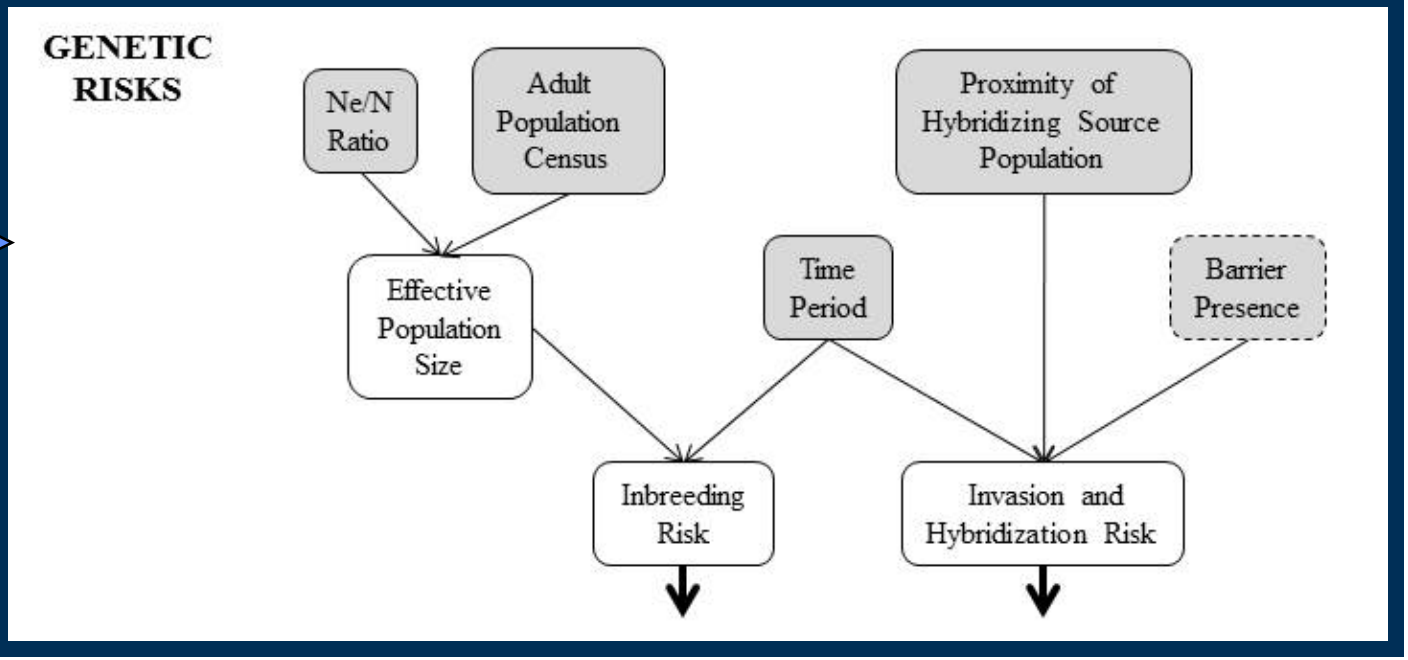
BN model for RGCT



- Time horizon
  - 2040 and 2080
- Stream Temperature Model for RGCT

RGCT BN


Population Demographics
Genetics Risks
Stochastic Disturbance Risk
Population Persistence


GENETIC RISKS
Ne/N Ratio
Adult Population Census
Proximity of Hybridizing Source Population
Effective Population Size
Time Period
Barrier Presence
Inbreeding Risk
Invasion and Hybridization Risk

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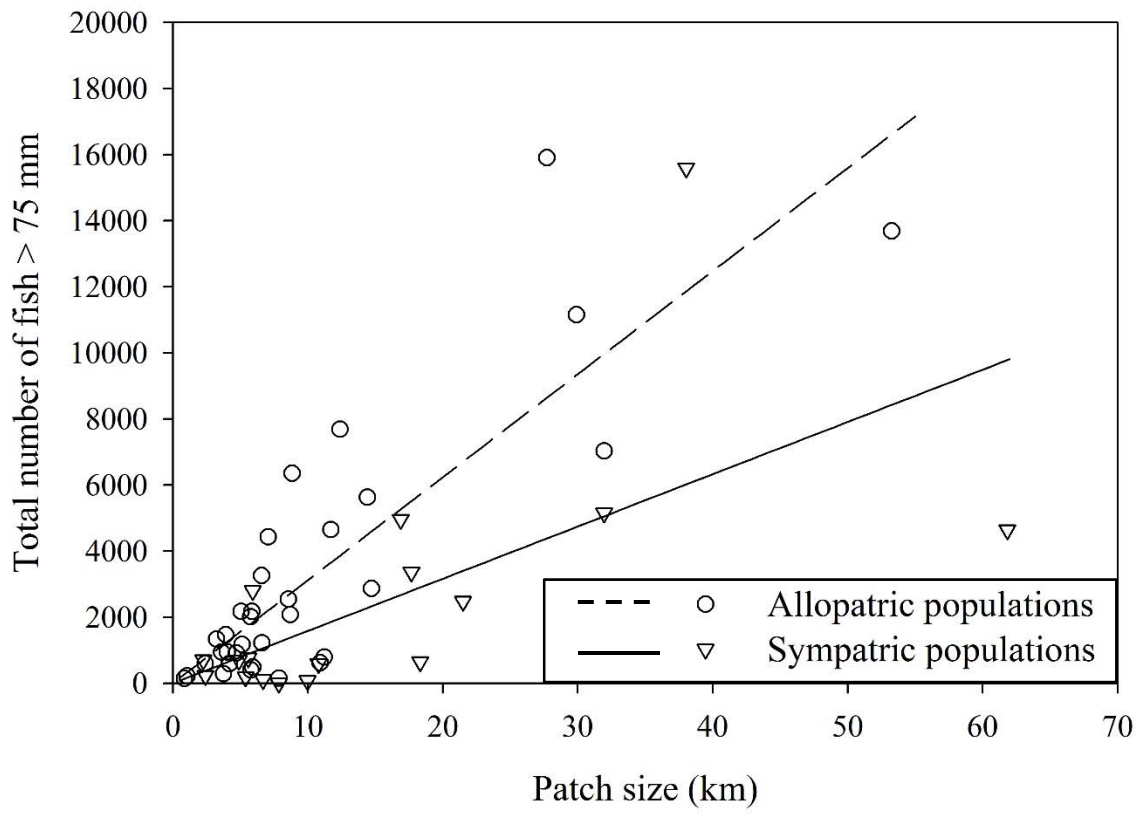
Site-specific details: nonnative influence and population size

-197 pop estimates
    -61 3+ pass
-Two equations for N
    -allopatric
    -sympatric
-More RGCT/km with no nonnative (allopatry)



Ziegler et al. *in revision*: NAJFM

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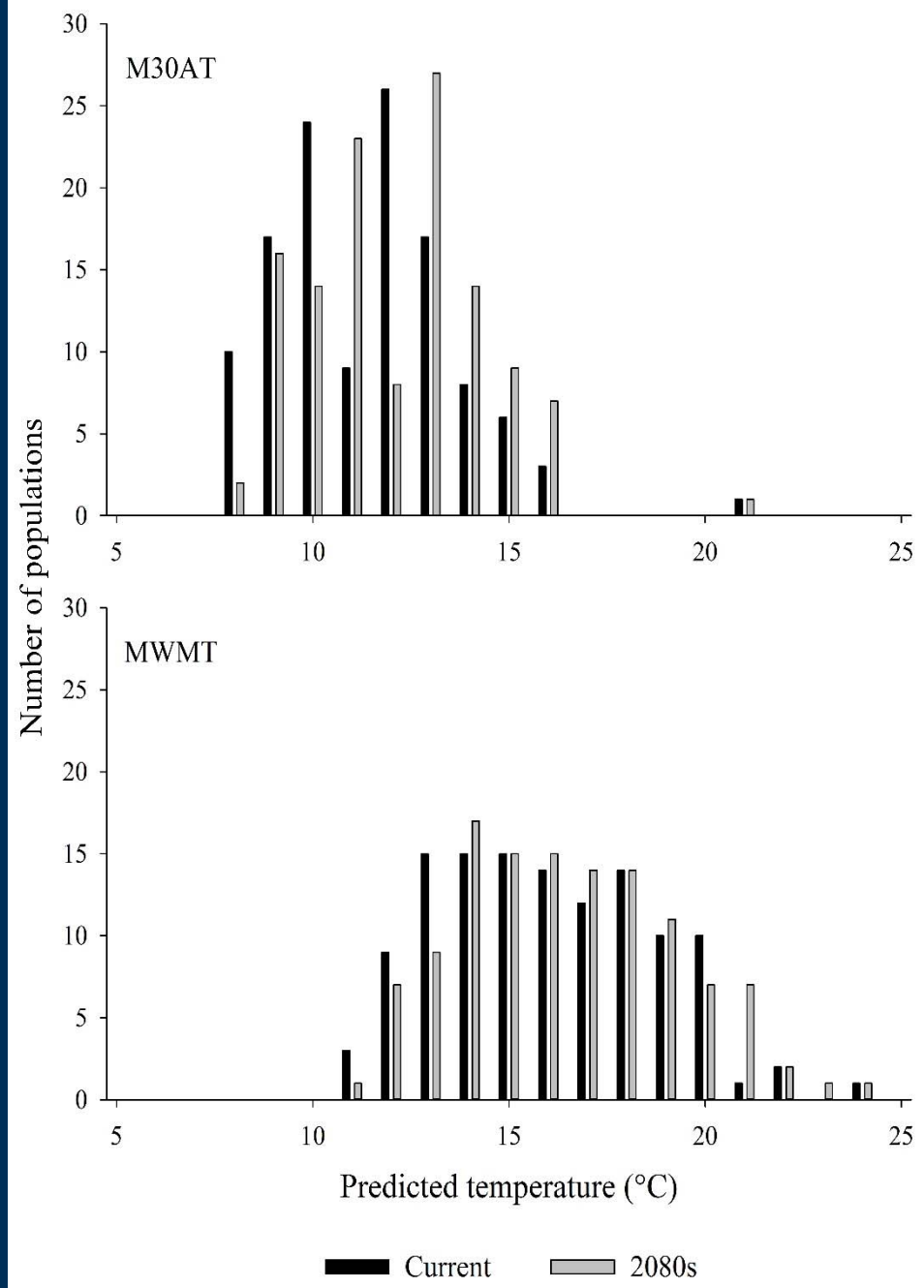
Stream temperature model: RGCT

- 544 records
- Spatial Stream Network Model
  - Similar predictors
  - Network distance
  - M30AT 0.9 °C RMSPE
- Southern most sub-species
  - warming M30AT +0.7°C in 2080
  - 2.2km unsuitable in 2080
  - 11 pops with ↓ survival



Ziegler et al. *in revision*: NAJFM

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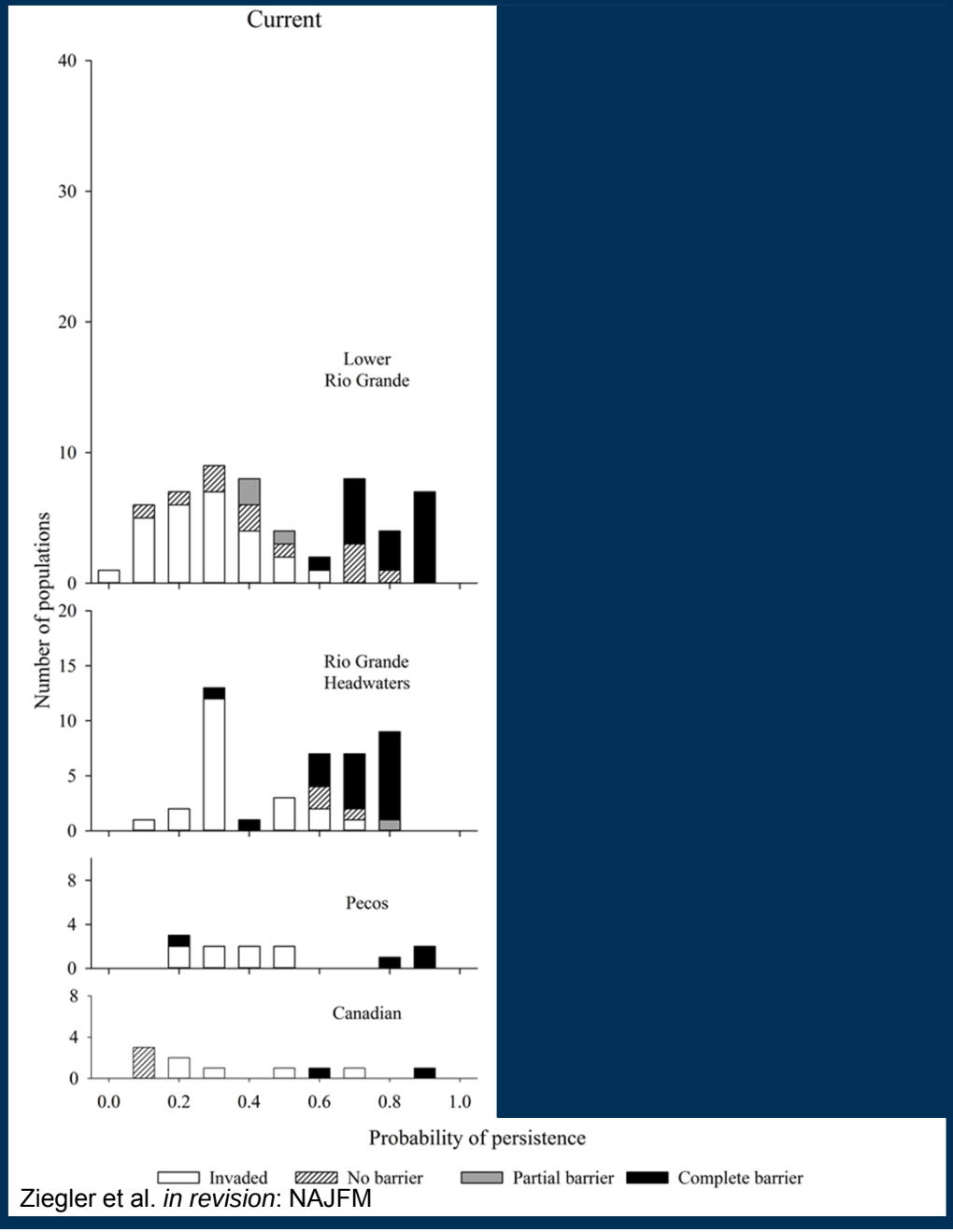
Rio Grande Cutthroat persistence

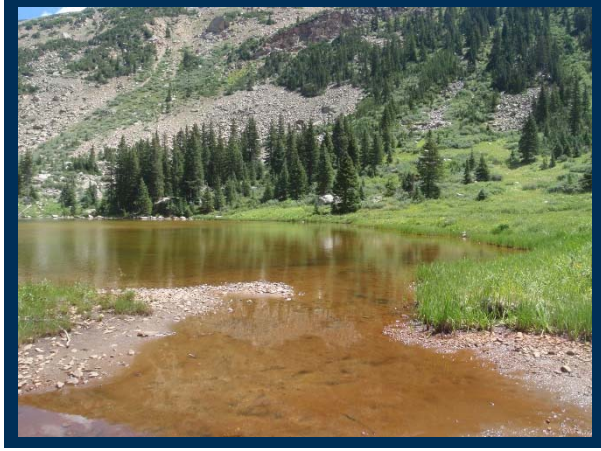
- 99% at risk
- 45 extirpated
- Intentional fragmentation crucial to persistence
  - 2080
    - 0.66 with barrier
    - 0.08 with no barrier

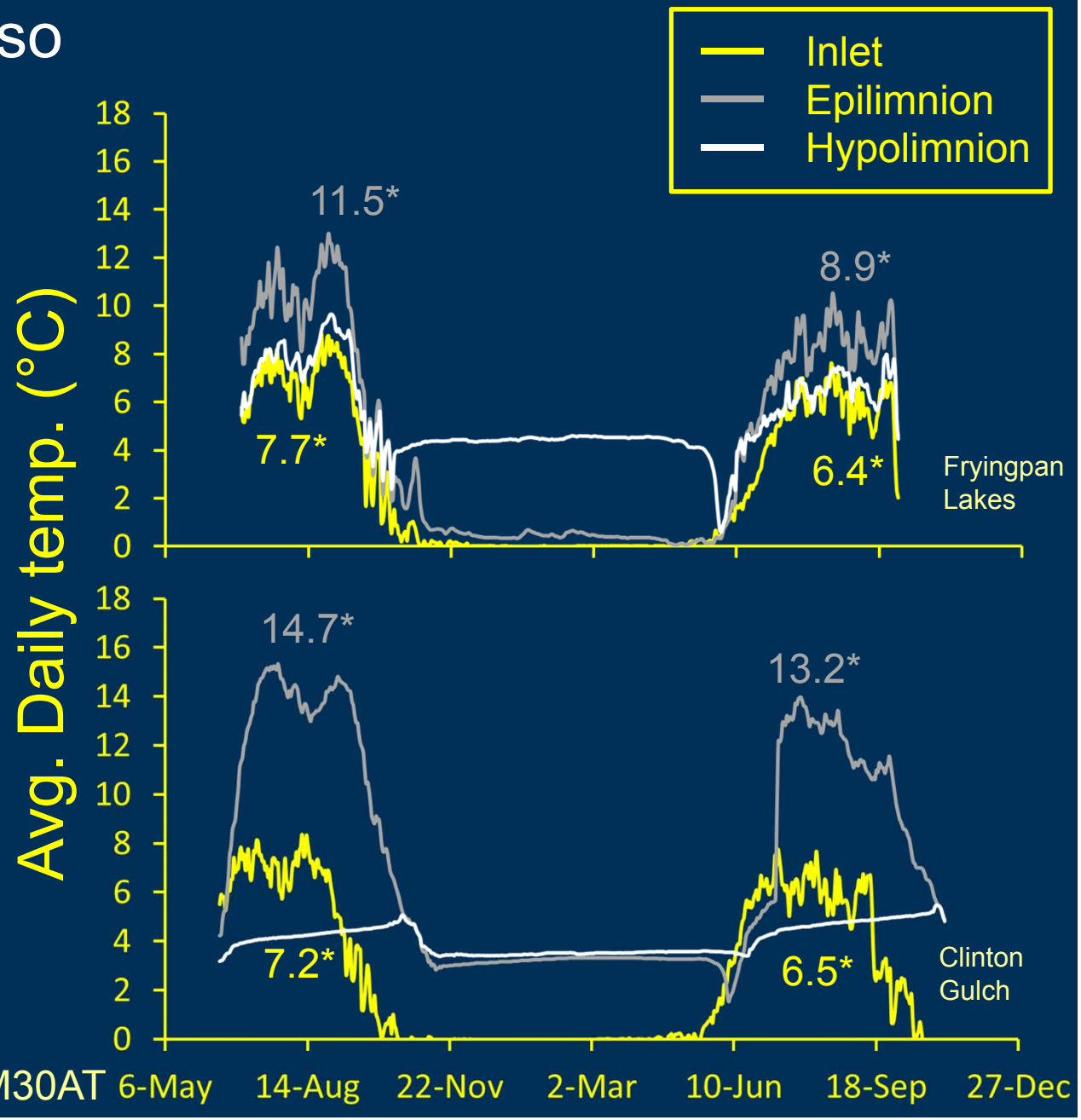


Ziegler et al. *in revision*: NAJFM

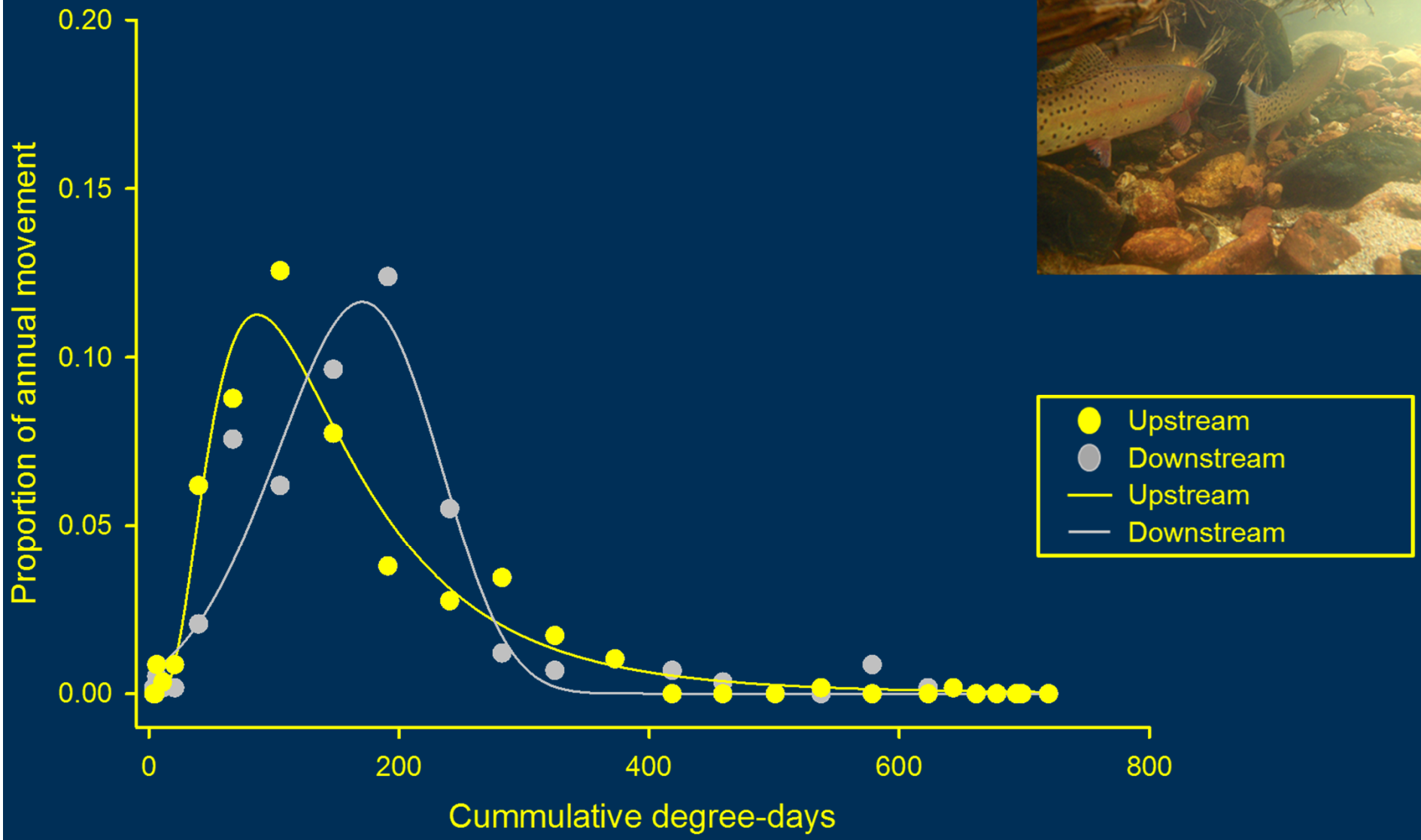
Lakes are important and unique

- SRM Cutthroat also in lakes
  - 50 (19) CRCT
  - 56 (10) RGCT
  - 36 (25) GBCT
- Unique habitat
  - Temperature
  - Complexity
  - Remote





Ecology of Cutthroat in mountain lakes



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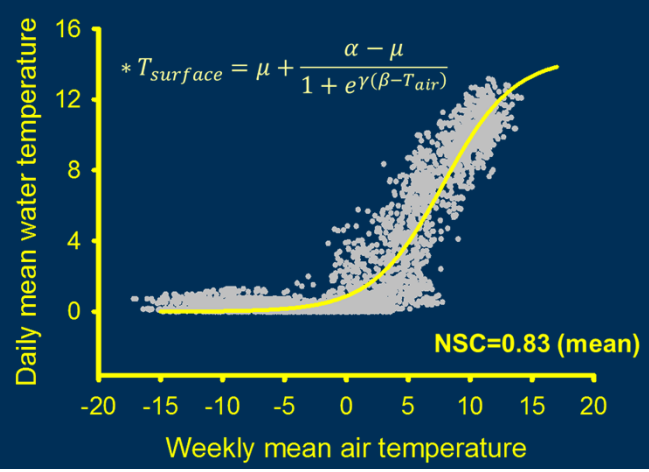
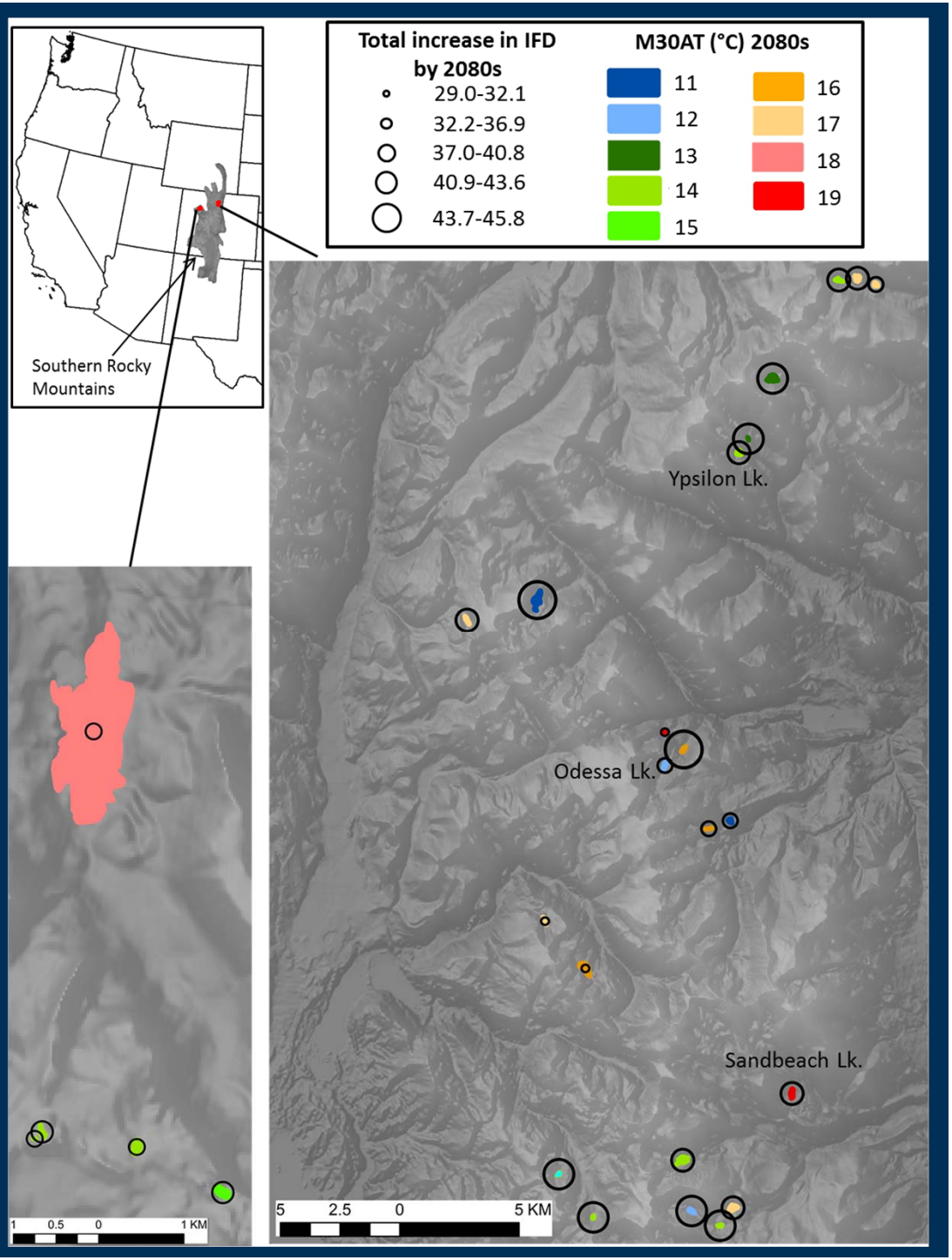
SRM lake warming

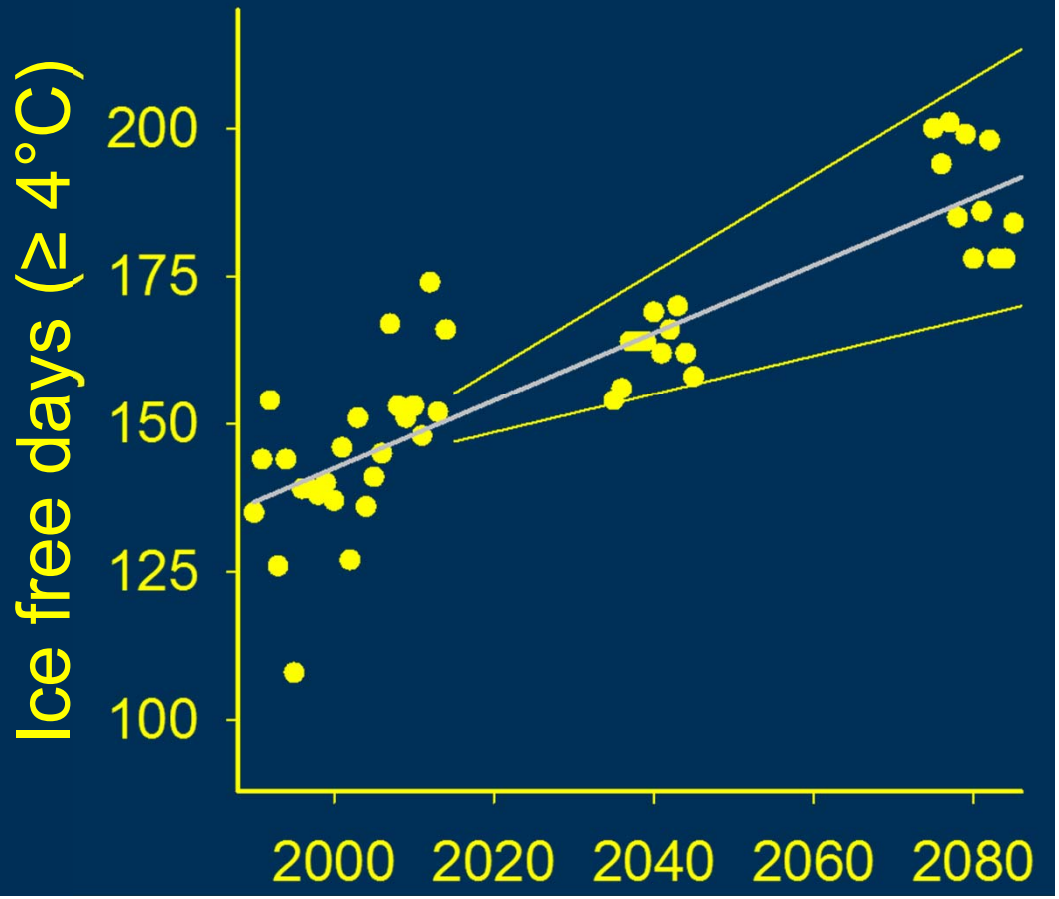
- 27 lakes
- Model of surface temp
  - SNOTEL
  - Nonlinear logistic
  - 4 metrics
  - Downscaled RCM





Lakes are warming

- Rates across 27 lakes*
  - 0.25°C•10yr^{-1} annual mean
  - 0.47°C•10yr^{-1} summer mean
  - 5.9 days•10yr^{-1} ice-free
- M30AT +2.9°C in 2080
  - Two lakes too warm in 2080
  - Greater than SRM stream increase
    - UPCO +1.1°C
    - RGB +0.7°C



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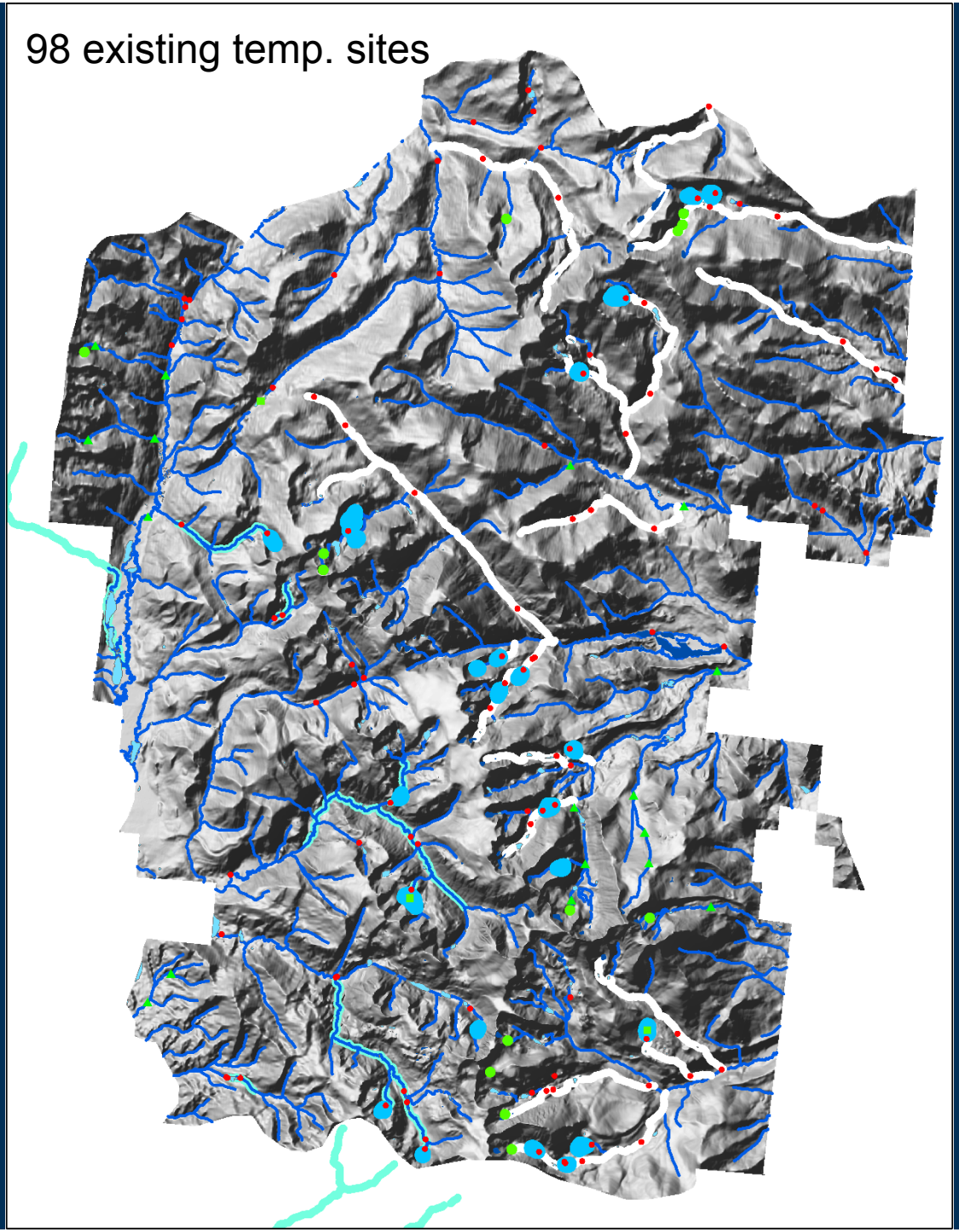
*Roberts et al. 2017; PLOS One

GBCT research: Rocky Mtn. N.P.

- 27 populations
  - 10 stream
  - 17 lake
- New temperature
  - Streams (20)
  - Lakes (13)
- Influence of lakes
  - Two too warm in 2080 (Spuce and Sandbeach Lks.)
- BN Model of persistence



Summary

- Water temperature changing at different rates
  - Among sub-species
  - Among habitat types
- Multiple stressors
  - Water temperature
  - Nonnative species
  - Streamflow
  - Stochastic disturbances
- Refuge habitats
  - Free of nonnative species
    - Barriers
  - Large fragment size
  - Habitat complexity

Future research needs

- Detailed population demographic studies
  - More life stages
  - Influence of streamflow
- Site-specific streamflow changes
  - Habitat volume
- Habitat quality
  - Secondary production (i.e., fish food)
- Importance of specific landscape features
  - Lakes

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Conclusions

- Climate change is not the only threat for SRM CT
- Type of connectivity matters!
  - Nonnative invasions
  - Lake-stream networks
- Local population data allows more detailed analyses
- Conservation embracing complexity examples
  - Current and future thermal regimes
  - Nonnative and barrier distribution important
  - Efforts to increase habitat heterogeneity

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Acknowledgements

Funding and administration

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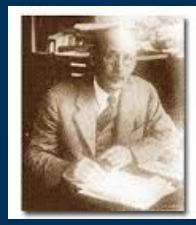

USGS Mendenhall Research Fellowship Program

Colorado State University

WYOMING GAME & FISH DEPARTMENT

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FOREST SERVICE U S DEPARTMENT OF AGRICULTURE

Collaborators

- CRCT conservation team
- RGCT conservation team

Questions?

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