Climate Change and Cutthroat Trout Conservation in the Southern Rocky Mountains

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

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**Climate Change**

**Air temperature***
- Increase of mean annual air temperature

**Hydroclimate**
- Models suggest more arid conditions
- Observed patterns*
  - Earlier snowmelt and peak discharge

*Isaak et al. 2012, Fisheries*
Half of trout habitat in the West will be gone by 2080

Wenger et al. 2011; PNAS
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

Dave Herasimtschuk
Freshwaters Illustrated
Native Trout in SRM

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

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

Median length: 5.9 km

N = 309
Bayesian Network: Predicting CRCT persistence

- Maximum stream temperature-MWMT
- Warmest 30-day temperature-M30AT
- Population Size (genetic risks)
- Habitat potential
- Stream fragment length
- Stochastic effects

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

* Hostetler et al. 2011
Thermal Criteria for CRCT

- **Survival**
  - Upper Incipient Lethal Temperature
    - >26 °C with diel fluctuation

<table>
<thead>
<tr>
<th>State name</th>
<th>Stream temp (Maximum)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Survival</td>
<td>&lt;26 °C</td>
</tr>
<tr>
<td>Mortality</td>
<td>≥26 °C</td>
</tr>
</tbody>
</table>
Thermal Criteria for CRCT

- **Survival**
  - Upper Incipient Lethal Temperature
    - $>26 \text{ C}$ with diel fluctuation

- **Recruitment**
  - $<8 \text{ °C}$ very low recruitment

- **Growth**
  - Optimum at $9.1-18 \text{ °C}$
  - $>75\%$ of maximum growth

<table>
<thead>
<tr>
<th>State name</th>
<th>Stream temp (M30AT)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very low or no recruitment</td>
<td>$&lt;8.0\text{oC}$</td>
</tr>
<tr>
<td>Low recruitment</td>
<td>8.0-9.0°C</td>
</tr>
<tr>
<td>Optimum recruitment and growth</td>
<td>9.1-18.0°C</td>
</tr>
<tr>
<td>Declining growth</td>
<td>18.1 – 19.9°C</td>
</tr>
<tr>
<td>Little or no growth</td>
<td>$\geq20.0\text{oC}$</td>
</tr>
<tr>
<td>Mortality</td>
<td>$&gt;26.0\text{oC}$ MWMT</td>
</tr>
</tbody>
</table>
Risks from fragmentation

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

<table>
<thead>
<tr>
<th>State name (1+ CRCT)</th>
<th>Stream length (km)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Immediate neg. genetic (( N_e &lt; 50 ))</td>
<td>&lt;1.7</td>
</tr>
<tr>
<td>Short-term neg. genetic (( N_e = 51-200 ))</td>
<td>1.7-4.6</td>
</tr>
<tr>
<td>Long-term neg. genetic (( N_e = 201-500 ))</td>
<td>4.7-7.7</td>
</tr>
<tr>
<td>Robust (( N_e &gt; 500 ))</td>
<td>&gt;7.7</td>
</tr>
</tbody>
</table>
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

<table>
<thead>
<tr>
<th>Stochastic effects</th>
<th>Stream length (km)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Highly susceptible</td>
<td>&lt;3.6</td>
</tr>
<tr>
<td>Variable buffering</td>
<td>3.6-7.2</td>
</tr>
<tr>
<td>Robust buffering</td>
<td>&gt;7.2</td>
</tr>
</tbody>
</table>
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

- 0.00 - 0.50
- >0.50 - 0.75
- >0.75 - 0.90
- >0.90 - 1.00

Roberts et al. 2013; GCB
Population persistence

Probability of persistence

- 0.00 - 0.50
- >0.50 - 0.75
- >0.75 - 0.90
- >0.90 - 1.00

Current

Proportion of CRCT populations vs. Probability of CRCT persistence

2080

62% at risk

Elevation (m)

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
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
Nonnative invasion: simulation
Nonnative invasion: CRCT persistence

Current

2040

2080

Roberts et al. 2017; NAJFM
Rio Grande Cutthroat Trout

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

*2008 RGCT con. team database

RGCT population
Historical habitat

N=121

Median length 5.9 km
BN model for RGCT

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

### Avg. Daily temp. (°C)

**Inlet**

<table>
<thead>
<tr>
<th>Date</th>
<th>Fryingpan Lakes</th>
<th>Clinton Gulch</th>
</tr>
</thead>
<tbody>
<tr>
<td>6-May</td>
<td>11.5*</td>
<td>14.7*</td>
</tr>
<tr>
<td>14-Aug</td>
<td>7.7*</td>
<td>7.2*</td>
</tr>
<tr>
<td>22-Nov</td>
<td>6.4*</td>
<td>6.5*</td>
</tr>
<tr>
<td>2-Mar</td>
<td>8.9*</td>
<td>13.2*</td>
</tr>
<tr>
<td>10-Jun</td>
<td>14.7*</td>
<td>7.2*</td>
</tr>
<tr>
<td>18-Sep</td>
<td>6.5*</td>
<td>6.4*</td>
</tr>
<tr>
<td>27-Dec</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*M30AT
Ecology of Cutthroat in mountain lakes
SRM lake warming

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

\[ T_{\text{surface}} = \mu + \frac{\alpha - \mu}{1 + e^{(\beta - \text{air})}} \]

NSC=0.83 (mean)
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

*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

98 existing temp. sites
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
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
Acknowledgements

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Collaborators
- CRCT conservation team
- RGCT conservation team
Questions?

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