Climate Change and Native Species Responses in Riverine Ecosystems of the Pacific Northwest

Jason Dunham

USGS Forest and Rangeland Ecosystem Science Center
Two topics (active and proposed research):

Prospective analysis of bull trout

Retrospective multi-species analysis
Coauthors/collaborators

Prospective analysis of bull trout

John Buffington, Christopher Cuhaciyan, Dan Isaak, Gordon Grant, Charlie Luce, USFS; Christina Tague, USCB; Jim O’Connor, USGS

Retrospective multi-species analysis

Bryan Black, OSU; Sarah Shafer, USGS
Bull trout habitat requirements

- **Thermal “riverscape”** for bull trout
- **Spawning and rearing** (suitable year-round)
- **Migratory** (seasonal use)
- **Refugium**
- **Unsuitable**
Climate change and bull trout

Bull trout sensitive to loss of cold water

Water temperature data are limited
Elevation and air temperature data are not
• Can these variables predict effects of climate change?
Juvenile Bull Trout Lower Elevation Limit ($R^2 = 0.74$)

\[ Y = 18693 - 191(\text{lat}) + 73.6(\text{long}) \]

1° lat = -191 m; 1° long = 73.6 m

Mean Annual Air Temperature ($R^2 = 0.89$)

\[ Y = 67 - 0.86(\text{lat}) + 0.12(\text{long}) - 0.0062(\text{ele}) \]

1° lat = -138 m; 1° long = 88 m

(Rieman et al. 2007; images courtesy Dan Isaak, USFS)
Projections based on bull trout – elevation elevation – air

(Rieman et al. 2007; images courtesy Dan Isaak, USFS)

Currently Suitable
Currently Suitable

Projections based on bull trout – elevation elevation – air
(Rieman et al. 2007; images courtesy Dan Isaak, USFS)

~ 1.6 °C Increase

<table>
<thead>
<tr>
<th>Habitat Reduction</th>
<th>Areal Extent</th>
<th># Patches &gt;5000 ha</th>
</tr>
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<tbody>
<tr>
<td>Rangewide</td>
<td>-40%</td>
<td>-60%</td>
</tr>
<tr>
<td>Idaho</td>
<td>-37%</td>
<td>-70%</td>
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Dunham 2008 presentation of preliminary information
Projections based on bull trout – elevation elevation – air

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~ 1.6 °C Increase

~ 5.0 °C Increase

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<th># Patches &gt;5000 ha</th>
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<tr>
<td>Rangewide</td>
<td>-92%</td>
<td>-99%</td>
</tr>
<tr>
<td>Idaho</td>
<td>-94%</td>
<td>-100%</td>
</tr>
</tbody>
</table>
Air temperatures ≠ water temperatures in the PNW

\[ b[0] = -1.92 \]
\[ b[1] = 0.81 \]
\[ r^2 = 0.23 \]
Water temperature vs elevation in Washington State

Temperature = elevation

$R^2 = 0.13$

Maximum summer temperature (C)

Elevation (feet)
Localized “stream effects” and elevation predictions

Temperature = stream + elevation + stream*elevation

$R^2 = 0.94$
Paradoxes: bull trout and climate

• **Contemporary** bull trout distributions tied to *elevation* and *air* temperature gradients at broad scales
Paradoxes: bull trout and climate

- Contemporary bull trout distributions tied to elevation and air temperature gradients at broad scales
- Bull trout also tied to water temperatures
Paradoxes: bull trout and climate

• Contemporary bull trout distributions tied to elevation and air temperature gradients at broad scales
• Bull trout also tied to water temperatures
• Water temperatures weakly related to elevation or air temperature
• What’s missing?
Paradoxes: bull trout and climate

What’s missing? –

The Future
Links to physical process

What processes actually influence water temperatures?

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Fig. 1. Factors and mechanisms influencing stream temperature.

*Modified from Johnson and Jones CJFAS 2000
What will change?

• Elevations and long-lat won’t change
What will change?

• Elevations and long-lat won’t change
• Air temps will increase
  – But air doesn’t heat water efficiently
What will change?

• Elevations and long-lat won’t change
• Air temps will increase
  – But air doesn’t heat water
• The sun (and short wave radiation) will still be here
  – But riparian zones could change
What will change?

• Elevations and long-lat won’t change
• Air temps will increase
  – But air doesn’t heat water
• The sun will still be here
  – But riparian zones could change
• **Stream hydrology** will change
  – indirect influences of timing, amount, type of precipitation and routing of water
Bull trout and climate

Climate-driven changes in flow regimes

Downstream truncation warming water temperatures

Persistence of bull trout

Other constraints
Bull trout and climate

Persistence of bull trout

Other constraints

Climate-driven changes in flow regimes

Downstream truncation warming water temperatures

Upstream truncation of low-flow network
Bull trout and climate

Persistence of bull trout
Downstream truncation warming water temperatures
Upstream truncation of low-flow network
Stream bed scour Catastrophic disturbance

Other constraints

Climate-driven changes in flow regimes
Bottom lines for bull trout

- **Temperature is critical**
  - But the future is highly uncertain
- **Other influences may be critical**
  - Stream bed scour, disturbance
- **Surprises likely from interacting factors**
  - Invasive species
  - Climate impacts on other factors (e.g., wildfire)
  - Other changing human influences

- For more details, see AFS special session website: [www.fs.fed.us/rm/boise](http://www.fs.fed.us/rm/boise)
Larger lessons: how we do science

• Biologists are good at biology
• Physical scientists are good at what they do

• "Interdisciplinarity" complex problem ≠ simple solution
  • Collaboration
  • Integration
  • Scale
  • Relevance
Retrospective multi-species analysis

• Bryan Black, Oregon State University
• Sarah Shafer, USGS

How have species responded to climate change in marine, terrestrial, and riverine ecosystems?
Tools for reconstructing the past

**Geochronology**
- Sediment cores
- Debris fans

**Dendrochronology**
- Tree rings
Dendrochronology applied to animals

Many animals live a long time - e.g., bivalves, fish

Can we apply dendro methods to learn about how different species and ecosystems respond to climate change?
Rockfish otolith increments

- opaque zone: fast growth, low protein
- translucent zone: slow growth, high protein

1933: year of birth
1989: year of capture
Splitnose chronology: 48 otoliths

Negative exponential detrending

valid: 36 to 40 degrees latitude
February SST

[Map showing SST temperatures with various color shades indicating different temperature ranges.]
Pacific Geoduck

150 yrs old
Rockfish and geoduck chronologies

Bryan Black, preliminary information 2008
Rockfish and geoduck chronologies

Principal components
PC1: 53% variance
Leading principal component

- strong growth in the north
- strong growth in the south

Feb and Mar MEI
marine chronology PC1
Geoduck and tree-rings
SST reconstruction – back to the 19th century

SST PC1 reconstruction

Tree rings alone: 49.9% variance
Geoduck alone: 49.5% variance
**Geoduck and trees: 63.9% variance**
Western Pearshell Mussel *Margaritifera falcata*

Sessile and long-lived
• 50-100 years

Widely distributed
Master chronologies *Margaritifera falcata*

Middle Fork Willamette River (blue)
Bryant Park (pink)

Standardized increment

Bryan Black, preliminary information 2008
Ring increments and local discharge

MF Willamette $r = -0.57$
Bryant Park $r = -0.57$
Combined $r = -0.68$
Ring increments and seasonal climate
Mussels vs. trees

Middle Fork Willamette

correlation coefficient

- 0.50 - 0.39
- 0.39 - 0.16
- 0.16 - 0.0
- 0.0 - 0.15
- 0.15 - 0.30

Bryan Black, preliminary information 2008
Analyze patterns of spatial and temporal synchrony
Climate vs. local drivers of response to change in rivers

Brett Blundon, MS, OSU
Bio-chronologies and climate change

- **tree rings**
  - forests

- **mussel rings**
  - rivers

- **clam rings**
  - nearshore

- **fish rings**
  - continental shelf
Opening a new toolbox

• How do species in different ecosystems actually respond to climate change?
Opening a new toolbox

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• What influences appear to be the most important in driving responses?
  – Local, regional, seasonal?
Opening a new toolbox

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• Can we use biological chronologies to reconstruct environmental histories?
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• What influences appear to be the most important in driving responses?
• Can we use biological chronologies to reconstruct environmental histories?
• Can we use bio-chronologies to look even deeper into history???
  – Middens, museum collections
Climate Change and Native Species Responses in Riverine Ecosystems of the Pacific Northwest

Main themes

• Prospective and retrospective views
• Biology + physical process “interdisciplinarity”
• Cross-ecosystem responses
• Local and regional variability – space + time
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• Climate change has changed science
• \( \Delta \) science \( \alpha \) science support