Stream Temperature and Thermal Networks

A GIS and Remote Sensing Approach to Assess Aquatic Habitat

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Boise Lab Disciplines

Fisheries

Watershed
Physical Environment as a Template
Physical Environment Affects Stream Temperature

- Air temperature
- Elevation
- Shade
- Stream width

Temperature affects biology
Species of Concern

ThREATENED BULL TROUT

20 °C 68 °F

DANGER
U.S. Bull Trout Range
Basin Diversity
Typical Temperature Network

- EPA and BNF Temp. Loggers 2002
- Third Order (plus) Streams

Scale: 25 Kilometers
Potential Bull Trout Network

Typical Scenario

Number of stream reaches in potential range: 1500
Number with known temperature: 11
Challenge:
Estimate stream temperature at the drainage basin scale.....
...for all stream reaches in the basin
Goal: Relate stream temperature to physical landscape variables
Stream Temperature
Thermographs and Locations

Thermographs
780 observations
518 unique locations
14 year period
~ 40 per year
Determine the Physical Variables that Matter

We looked at:

- Basin elevation
- Radiation (shade)
- Air temperature
- Stream flow
- Contributing area (stream size)
- Glacial valley
- Stream gradient
- Valley bottom
- Drainage density
- Lakes
Physical Variables

- Elevation
- Solar radiation (shade)
- Air temperature
- Stream flow
Physical Variables Continued

Stream size

Glaciated valley

Stream gradient

Flat valley
Detour - Radiation
Estimating Radiation (Shade)

Objective: Estimate incident solar radiation at the stream surface, for the entire basin.

The amount of radiation hitting the stream surface is mostly dependent on riparian vegetation.

Thematic Mapper satellite imagery can be used to map riparian vegetation and thus, radiation.
Estimating Radiation (Shade)

We need to know how much solar radiation gets through each vegetation type:

- Trees
- Shrubs
- Open/grass
Estimate Radiation for Each Vegetation Type
Canopy Photography

- Collected 181 canopy photos
- Differential GPS
Hemispherical Canopy Photography

- Sites distributed among different vegetation types and stream sizes
- Processed photos using Hemiview software
- Total June radiation, direct and diffuse
- Radiation values range from 118 – 1038 MJ/m²·yr
- Collected horizontal photos
Canopy Photography and Horizontals

Radiation (MJ/m² yr)

1038

118
Cover Classes

- Open
- Shrub
- Conifer

Radiation
## Mean Radiation Per Cover Class

<table>
<thead>
<tr>
<th>Cover Class</th>
<th>Radiation (MJ/m²yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Open/Grass</td>
<td>786</td>
</tr>
<tr>
<td>Broadleaf Shrub</td>
<td>687</td>
</tr>
<tr>
<td>Conifer</td>
<td>476</td>
</tr>
</tbody>
</table>

- **Open**
- **Shrub**
- **Conifer**
Imagery to Vegetation

Imagery

Vegetation
Vegetation to Radiation

Vegetation

Radiation*  

*Radiation adjusted for stream width
End of Detour
Accumulate Physical Variables

Each variable is accumulated along the stream channel.

A distance decay function is used.

Decay tested between 1 km – 16 km.

Average upstream influence is computed for each variable.
Finally – Correlate Temperature Data With Physical Variables
Elevation vs. Stream Temperature

Temperature (MWAT) vs. Elevation (m)

$r = -0.71$
Radiation vs. Stream Temperature

\[ r = 0.47 \]
Air Temperature

Air Temperature vs. Stream Temperature

$r = 0.23$
Flow vs. Stream Temperature

$r = -0.18$
Regression Results

Response variable: Highest average 7-day stream temperature

Multiple regression, R-squared: 0.85

Meaningful predictors:

1) Basin elevation
2) Radiation (shade)
3) Air temperature
4) Stream flow
5) Contributing area (stream size)
6) Glacial valley
7) Stream gradient
8) Valley bottom

Drainage density and lakes (not significant)
Relative Importance of Each Significant Variable

- Valley Bottom
- Stream Gradient
- Glacial Valley
- Contributing Area
- Stream Flow
- Air Temperature
- Radiation
- Elevation

T-Statistic
Temperature Prediction Points

1 km spacing in fish bearing streams

- Prediction Points

Make predictions using FLoWS software

http://www.nrel.colostate.edu/projects/starmap/flows_index.htm
Mean Weekly Maximum Temperature °C - 1993
Mean Weekly Maximum Temperature °C - 2006

- 9.09 - 12.00
- 12.01 - 15.00
- 15.01 - 18.00
- 18.01 - 21.00
- 21.01 - 27.00
Thermally Suitable Habitat -- Cool Year

1993 mean weekly max air = 79°F

Bull Trout Patches 1993
Thermally Suitable Habitat and Fire

23% burned

Bull Trout Patches 2006
Bull Trout Patches 1993
Thermally Suitable Habitat - Fire vs. Climate Affects
1993 - 2006

- Blue: Habitat lost to climate effects
- Yellow: Habitat lost to fire effects
- Red: Suitable habitat in 2006
Summary

- GIS and remote sensing data (along with air temperature and flow) can be used to explain about 85% of the variance in stream temperature.
- TM satellite imagery provides a reasonable estimate of radiation for stream networks.
- Stream temperature can be mapped at the drainage basin scale.
- Thermally suitable habitat can be estimated from these data.
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