Standard Operating Procedures for Full Year Monitoring of Temperatures in Wadeable Streams

Dan Isaak and Zack Holden
General outline:
1) Relevance of stream temperature data
2) Types of air & stream temperature sensors
3) Calibration & logging intervals
4) Protocols for full year monitoring
5) Example sensor networks
6) Temperature monitoring resources
Temperature is a Primary Control for Aquatic Ectotherms

Metabolism

Thermal Niche

In the lab...

& the field

McMahon et al. 2007

Isaak & Hubert 2004
Temperature is Important Within Regulatory Contexts

TMDL standards
Rising stream and river temperatures in the United States

Sujay S Kaushal, Gene E Likens, Norbert A Jaworski, Michael L Pace, Ashley M Sides, David Seekell, Kenneth T Belt, David H Secor, and Rebecca L Wingate

Kaushal et al. 2010. Frontiers in Ecology & the Environment
2012: HOTTEST YEAR ON RECORD
Average Annual Temperature in Contiguous U.S.
Global Trends in River Temperatures

River Loire, France (1880 – 2003)

Moatar and Gailhard 2006

Danube River, Austria (1901 – 2000)

Webb and Nobilus 2007
Temperature Sensors Models

Considerations...

- Waterproof?
- Temperature range?
- Accuracy/precision?
- Cost?
- Battery life (replaceable)?
## Temperature Sensors
### Minimum Specifications

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Water Sensor</th>
<th>Air Sensor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Submersible / waterproof</td>
<td>Yes</td>
<td>Optional</td>
</tr>
<tr>
<td>Programmable start time</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Minimum accuracy</td>
<td>± 0.2°C</td>
<td>± 0.5°C</td>
</tr>
<tr>
<td>Precision</td>
<td>&lt; 0.2°C</td>
<td>&lt; 0.5°C</td>
</tr>
<tr>
<td>Temperature range</td>
<td>-5 to 37°C</td>
<td>-20 to 50°C</td>
</tr>
<tr>
<td>Memory</td>
<td>Sufficient capacity to store records at 30-minute intervals during deployment period</td>
<td></td>
</tr>
<tr>
<td>Battery life</td>
<td>Sufficient to remain active during deployment period</td>
<td></td>
</tr>
</tbody>
</table>
Calibration Technique

Recommendation: Launch sensors & expose to temperature cycles in common environment

Any data anomalies?

Retain calibration data for future reference

Stream Temperature (°C)

Time
Data Recording Interval?

Recommendation: 30 – 60 minutes

Dunham et al. 2005
We Collect Lots of Summer Stream Temperature Data

NorWeST Stream Temp

>45,000,000 hourly records
>15,000 unique stream sites

>60 agencies
Summer is Not the Whole Story
Full year temperature data needed

Annual Temperature Cycle

Olden and Naiman 2009

Summer ~40% of degree days
Challenges With Full Year Monitoring

Big snowmelt floods each year
Cable & Rebar Protocol

Mauger 2008; Ward 2011
Underwater Epoxy Protocol

Snowmelt floods each year, but...

lots of big rocks don’t move, so...

what about glue?

Isaak et al. 2010; Isaak & Horan 2011
Underwater Epoxies are Not All Created Equal!

- AquaMend® from Polymeric Systems Inc.
- AquaStik® from DuPont
- Waterweld from J-B Weld Company
- Mr. Sticky’s® Underwater Glue from Advanced Adhesion Inc.
- HIT-RE 500 from Hilti
- Sea Goin’ Poxy Putty from Permalite Plastics Corp
- A-788 Splash Zone Underwater Epoxy Putty from Carboline Company

Clear winner: Fox Industries FX-764
Easy Application,
Cement-Like Adhesion
Field Trial Assessments:
Heat Conduction Effect? NO

Sensor

<table>
<thead>
<tr>
<th>Stream site name</th>
<th>Minimum</th>
<th>Mean</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Canyon Creek</td>
<td>0.10</td>
<td>0.00</td>
<td>-0.06</td>
</tr>
<tr>
<td>Grimes Creek, rock 1</td>
<td>-0.01</td>
<td>-0.02</td>
<td>-0.08</td>
</tr>
<tr>
<td>Grimes Creek, rock 2</td>
<td>0.06</td>
<td>0.02</td>
<td>-0.03</td>
</tr>
<tr>
<td>Little Rattlesnake Creek</td>
<td>0.07</td>
<td>0.02</td>
<td>-0.15</td>
</tr>
<tr>
<td>Mores Creek, rock 1</td>
<td>0.11</td>
<td>0.07</td>
<td>0.16</td>
</tr>
<tr>
<td>Mores Creek, rock 2</td>
<td>-0.11</td>
<td>-0.07</td>
<td>-0.02</td>
</tr>
<tr>
<td>Mores Creek, rock 3</td>
<td>-0.13</td>
<td>0.10</td>
<td>0.31</td>
</tr>
<tr>
<td>Mores Creek, rock 4</td>
<td>-0.03</td>
<td>0.01</td>
<td>0.16</td>
</tr>
<tr>
<td>No Name Creek</td>
<td>0.13</td>
<td>0.09</td>
<td>0.03</td>
</tr>
<tr>
<td>Rattlesnake Creek</td>
<td>0.02</td>
<td>0.00</td>
<td>0.08</td>
</tr>
</tbody>
</table>

Average difference\(^1\) = 0.02 (-0.05, 0.09) 0.02 (-0.02, 0.06) 0.03 (-0.07, 0.13)
\(^1\) = values after the average difference are 95% confidence intervals
Field Trial Assessments: Direct Solar Effect? YES

Sunlight biases measurements \(-0.2 - 0.5 \, ^\circ C\)
Solar Shield Alternatives...

Neoprene flap & directly glue sensor to rock

PVC housing protects sensor & makes data retrieval/sensor replacement easy
Field Trial Assessments: Durability of Installations?

9 of 11 weathered above average floods in spring 2010
Large Scale Field Durability Assessment

- 300 sensors deployed in 2010
- Stream slopes ranging from 0.1% - 16%

Year 1 retention:
85% (64/75) retained in stream slopes < 3%

Year 2 retention:
>90% retention
Easy Method for Full Year Monitoring

Underwater Epoxy Protocol

Annual Flooding Concerns

Underwater epoxy cement

$130 = 5 years of data

Data retrieval

PVC housings glued to boulders or bridge pilings

Big Boulders, Bridge Pilings, Roadbed Riprap...
Sensor Relocations Are Easy
Sites monumented by boulder or bridge... & metal forestry tag
“How-to” installation video...

http://www.youtube.com/watch?v=vaYaycwfmXs&feature=youtu.be
What Stream Location?

**Good**
- Near reach where biological data collected
- Well-mixed flow throughout year
- Sufficient depth to year-round submersion
- Low human activity

**Bad**
- Localized warm or cool water sources...
  - Downstream of tributary confluence
  - Impoundments/lakes (including beaver ponds)
  - Point-source discharges
  - Stream-side wetland areas
  - Hotsprings
Example Monitoring Networks

NoRRTN: Northern Rockies River Temperature Network

- Cost = $50,000;
- \( n = 210 \) sites;
- 3 replicates/river;
- 70 rivers;
- 2 technicians;
- 1 summer of work;
- 1,000 years of data
Ecological Temperature Networks

Bull Trout natal habitats

Chinook salmon natal & migratory habitats
Dense Sensor Arrays for Detailed Landscape Analysis

Boise River Basin
Air & stream sensor locations

Stream temp map

Air temp map
Pairing Air w/ Stream Sensors

Well-ventilated radiation shield needed

$50 - $150

$2
Pairing Air w/ Stream Sensors
Well-ventilated radiation shield needed

Materials:
- Corrugated plastic
- ½ inch stapler
- Aluminum HVAC tape
- Plastic Zipties
- Nails/Hammer for installation

Holden et al. In review. Hydrologic Processes
Pairing Air w/ Stream Sensors

Recommendation: <200 meters from stream sensor

Pole Mounted

Tree Mounted

In Riparian or Out?

Holden et al. In review. Hydrologic Processes
“How-to” installation video...

http://www.youtube.com/watch?v=LkVmJRsw5vs

Zack’s air temperature website:
http://www.fs.fed.us/rm/boise/AWAE/projects/air_temperature_r1.shtml
Full Year Stream Temperature Monitoring Becoming Popular...
A GoogleMap Tool for Dynamic Queries of Temperature Monitoring Sites

Regional Sensor Network

Site Information
- Stream name
- Data steward contact information
- Agency
- Site Initiation Date

Query Individual Sites

Webpage:
>3,000 sites as of January 28, 2013
>400 new deployments last year
Google Map for Northeast Stream Temperature

Contact: Jana Stewart, 608-821-3855, jsstewar@usgs.gov
Key Points for Ensuring High Quality Full Year Stream Temperature Data

1) No sunlight
2) No sediment
3) No air
4) Flowing water
5) Accurate georeferencing/photo archiving
QA/QC Checks & Database Archiving

Simple plots show a lot

Stream Temperature (°C)

Trim the tags!

Screen for air exposure

Have a plan for data archiving. Don’t fall behind...

Consistent units °F vs °C?
Check date & time stamp

Dunham et al. 2005; Sowder and Steel 2012
Literature Cited...


http://www.ecy.wa.gov/programs/eap/qa/docs/ECY_EAP_SOP_Cont_Temp_Mon_Ambient_v1_0EAP080.pdf
Resources – Stream Temperature Website

Google “Forest Service Stream Temperature”

- Stream temperature publications & project descriptions & recent talks
- Protocols for temperature data collection & demonstration videos
- Processing macro for temperature data
- Dynamic GoogleMap showing current temperature monitoring sites
The End