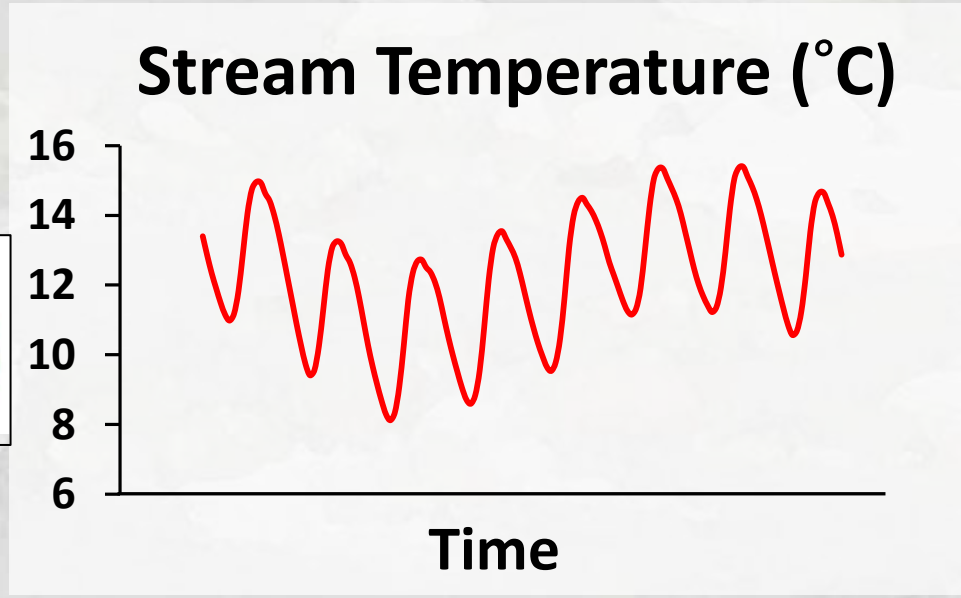
# Standard Operating Procedures for Full Year Monitoring of Temperatures in Wadeable Streams

Dan Isaak and Zack Holden

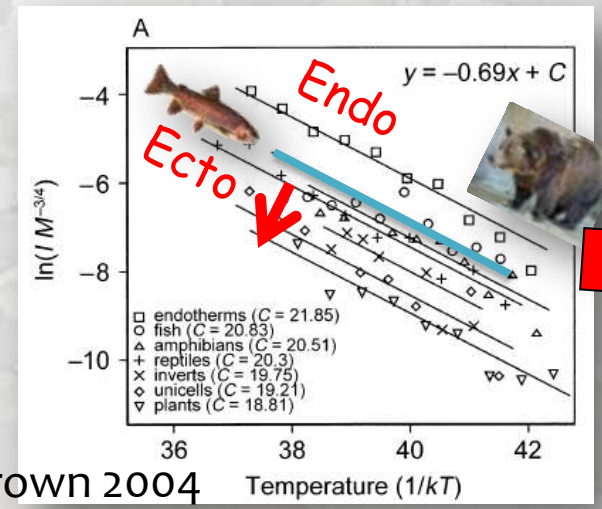



# General outline:

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

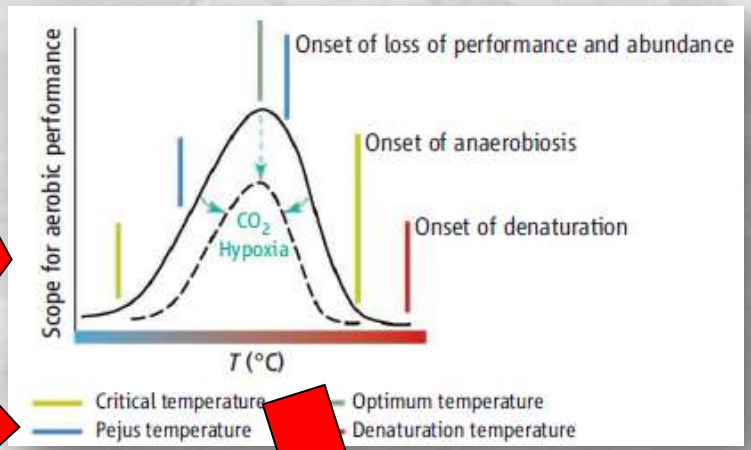
# Temperature is a Primary Control for Aquatic Ectotherms

## Metabolism

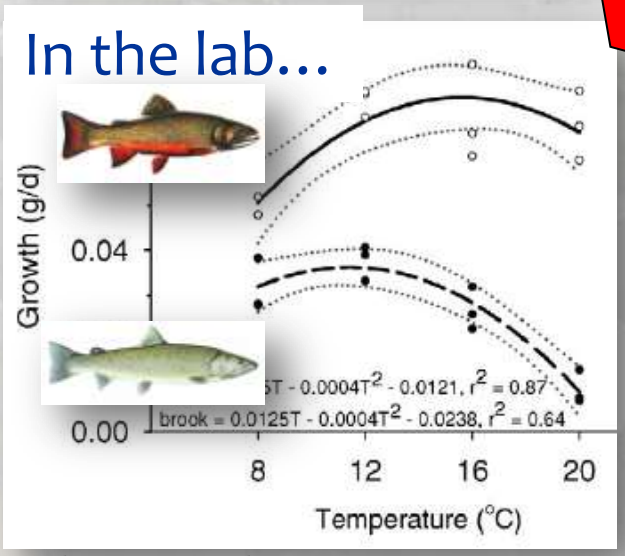



Brown 2004

## Thermal Niche

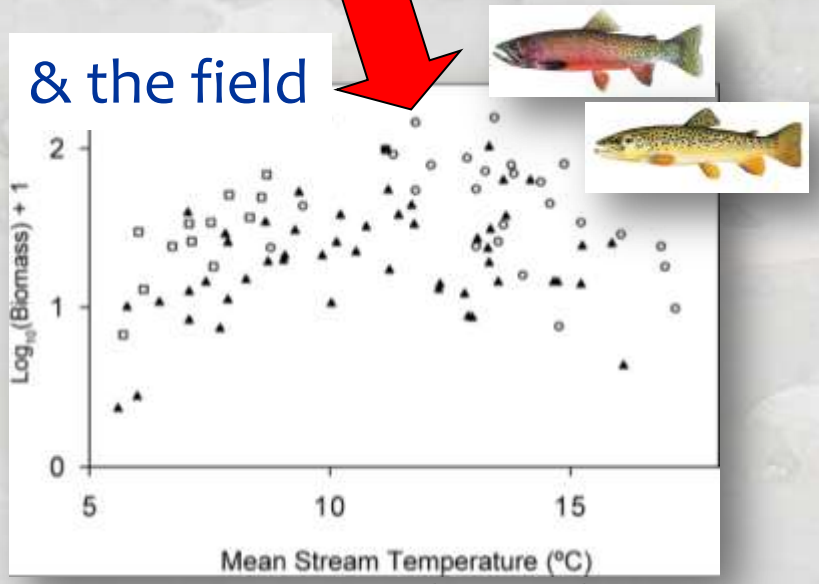



## In the lab…




McMahon et al. 2007

## & the field

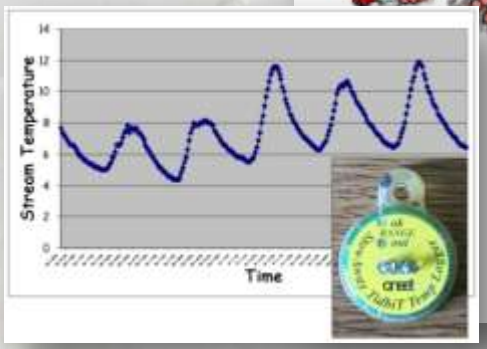



Isaak & Hubert 2004

# Temperature is Important Within Regulatory Contexts

## TMDL standards



# Rising stream and river temperatures in the United States

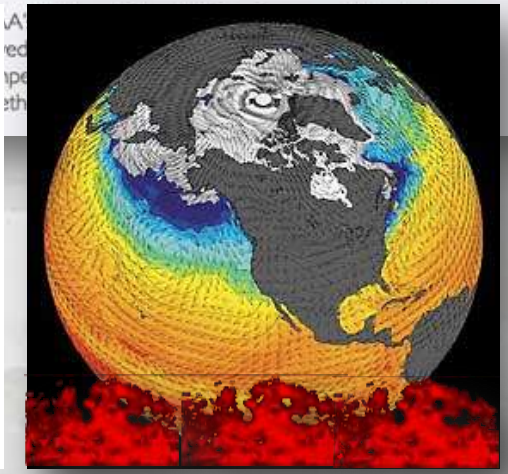
Sujay S Kaushal[1*], Gene E Likens[2], Norbert A Jaworski[3], Michael L Pace[2†], Ashley M Sides[1], David Seekell[4], Kenneth T Belt[5], David H Secor[1], and Rebecca L Wingate[1]

Kaushal et al. 2010. *Frontiers in Ecology & the Environment*

# 2012: HOTTEST YEAR ON RECORD

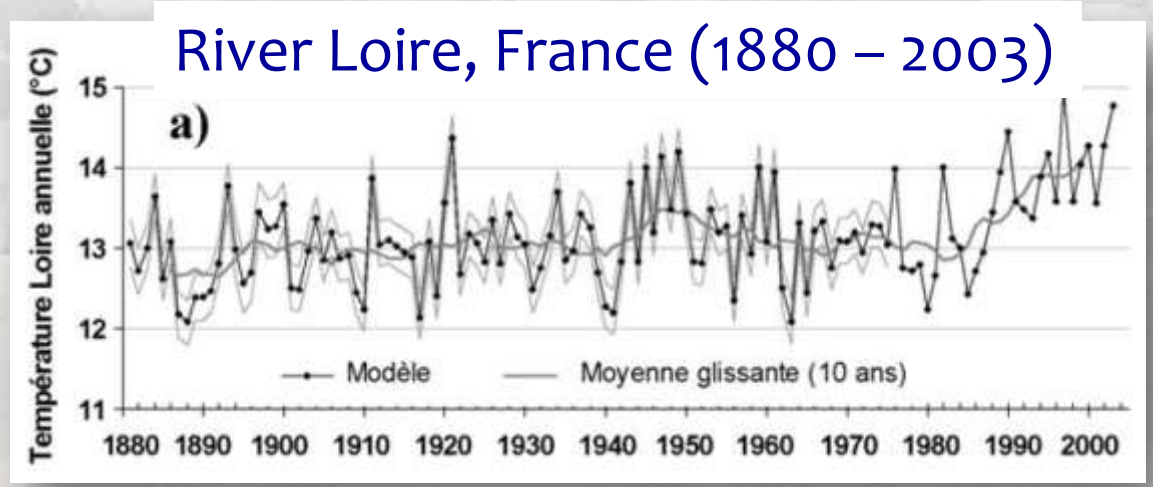
Average Annual Temperature in Contiguous U.S.


CLIMATE CENTRAL

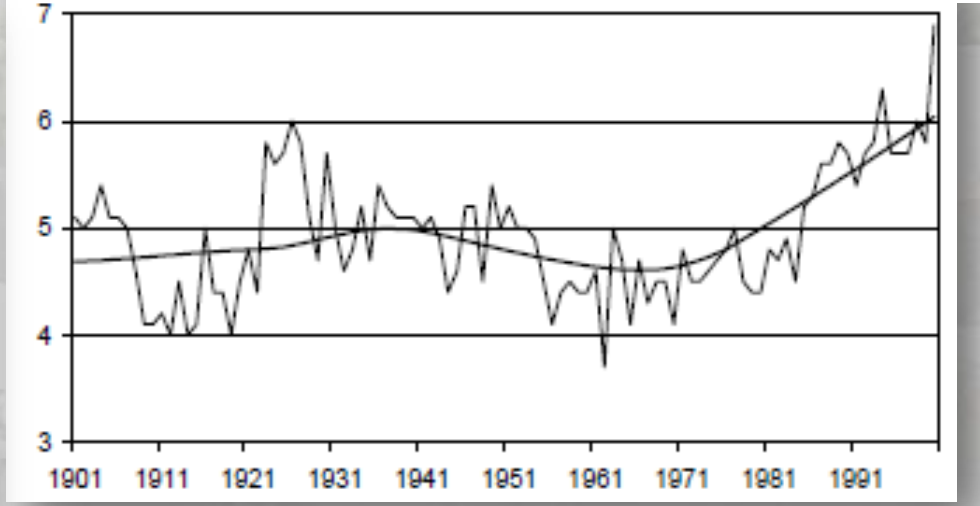
# Global Trends in River Temperatures

River Loire, France (1880 – 2003)




Moatar and Gailhard 2006

Danube River, Austria (1901 – 2000)




Webb and Nobilus 2007

# Temperature Sensors Models


**Stream**

**Air**

## Considerations…

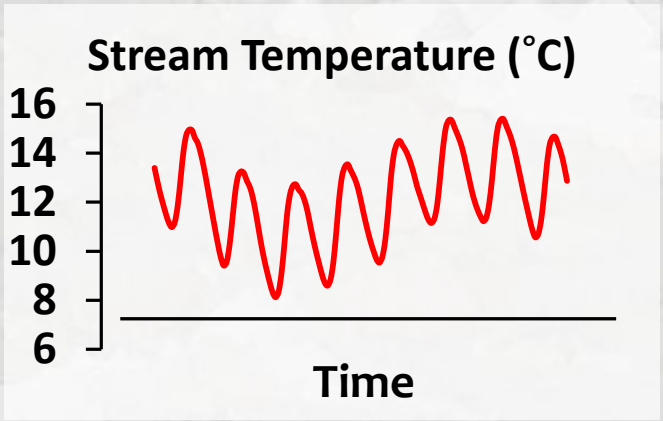
- Waterproof?
- Temperature range?
- Accuracy/precision?
- Cost?
- Battery life (replaceable)?

# Temperature Sensors Minimum Specifications

| Characteristic | Water Sensor | Air Sensor |
|---|---|---|
| Submersible / waterproof | Yes | Optional |
| Programmable start time | Yes | Yes |
| Minimum accuracy | ± 0.2°C | ± 0.5°C |
| Precision | < 0.2°C | < 0.5°C |
| Temperature range | -5 to 37˚C | -20 to 50˚C |
| Memory | Sufficient capacity to store records at 30-minute intervals during deployment period | |
| Battery life | Sufficient to remain active during deployment period | |

# Calibration Technique

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



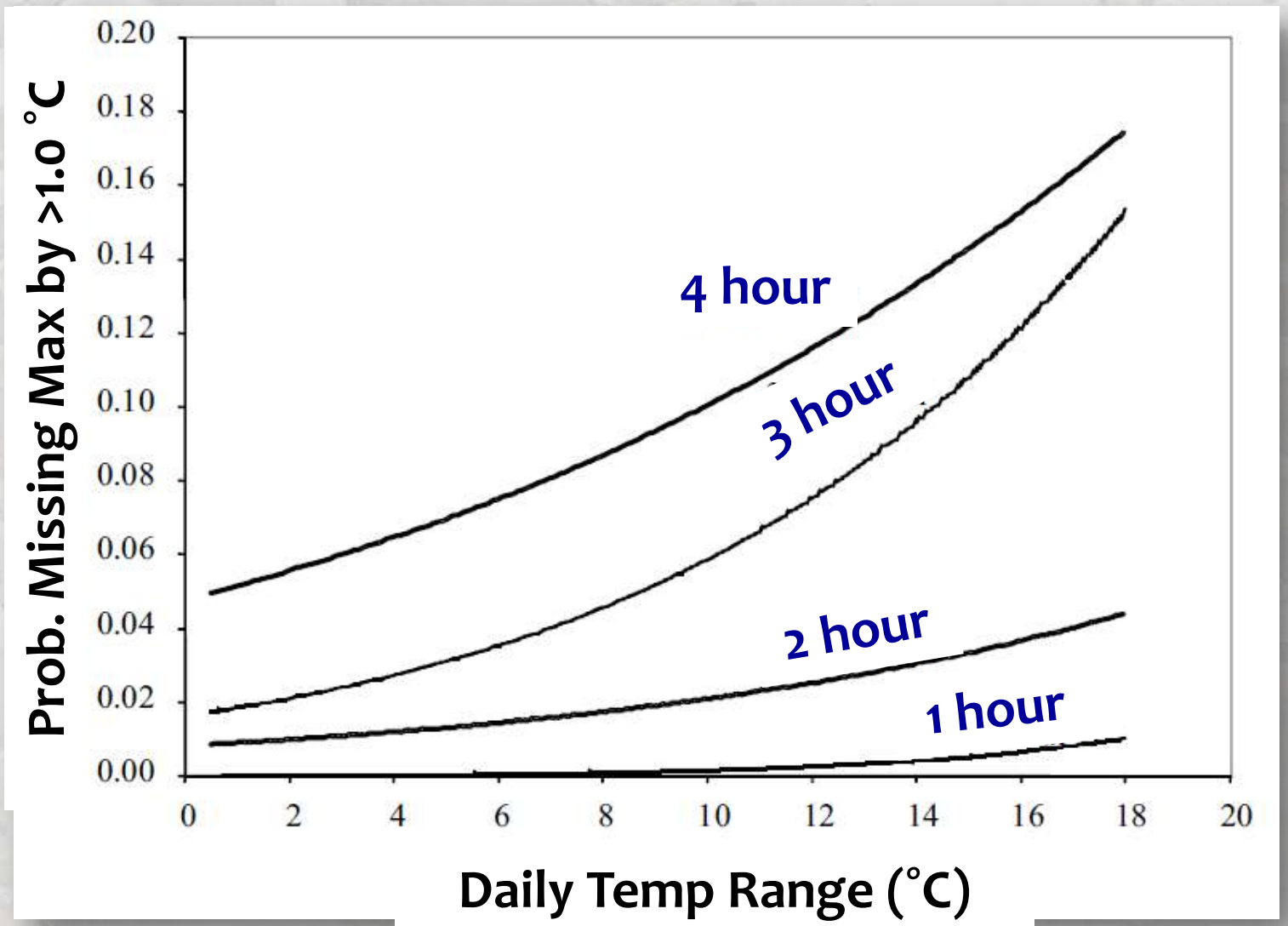

| | A | B | C |
|---|---|---|---|
| 1 | | | |
| 2 | **Stream:** | Elk Creek | |
| 3 | **Georeference:** | 610234 E, 4402546 W | |
| 4 | | | |
| 5 | **Date** | **Time** | **Temp (°C)** |
| 11 | 7/15/2005 | 23:53 | 13.55 |

**Retain calibration data for future reference**

**Any data anomalies?**

# Data Recording Interval?

## Recommendation: 30 – 60 minutes




Dunham et al. 2005

# We Collect Lots of Summer Stream Temperature Data

NorWeST Stream Temp



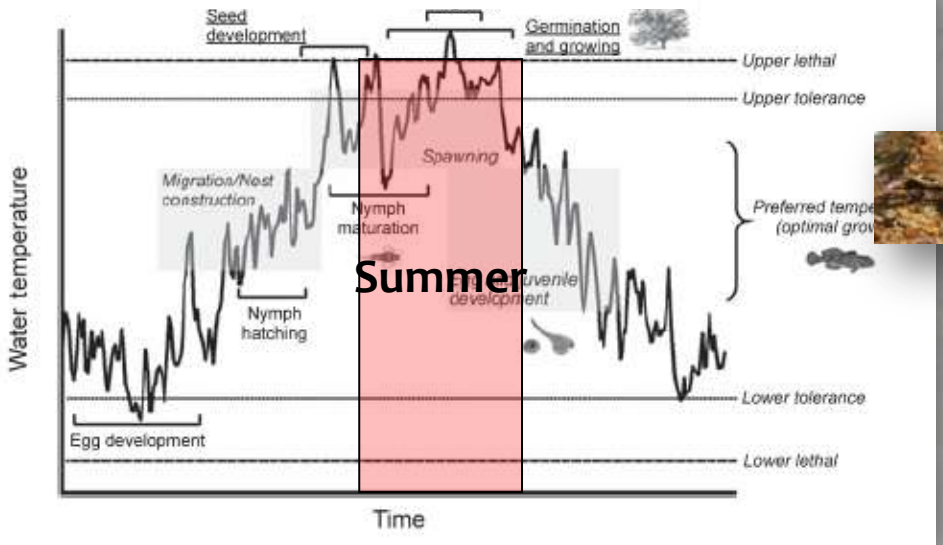

>45,000,000 hourly records
>15,000 unique stream sites

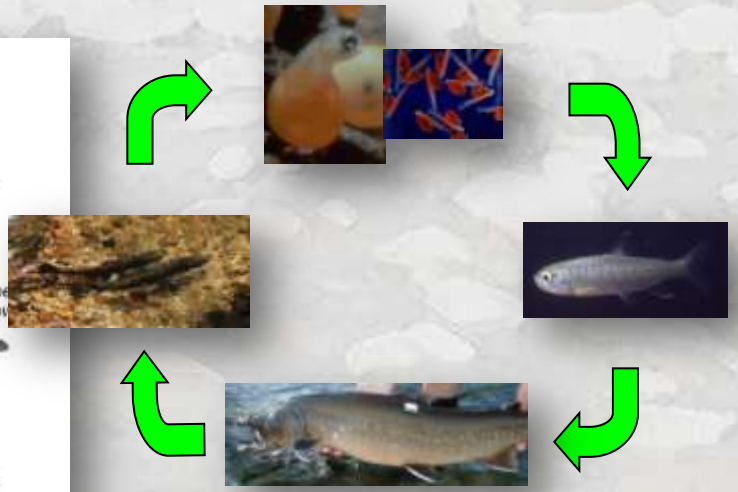
>60 agencies

# Summer is Not the Whole Story

## Full year temperature data needed

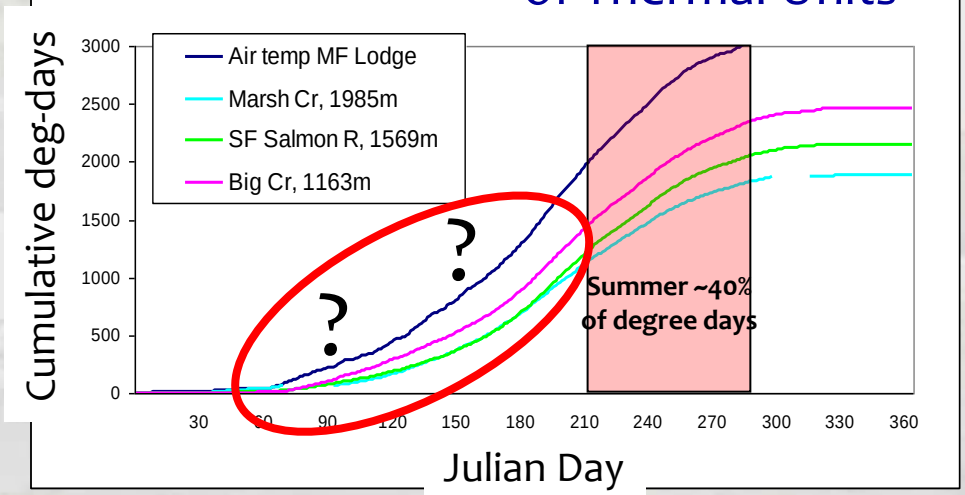
### Annual Temperature Cycle



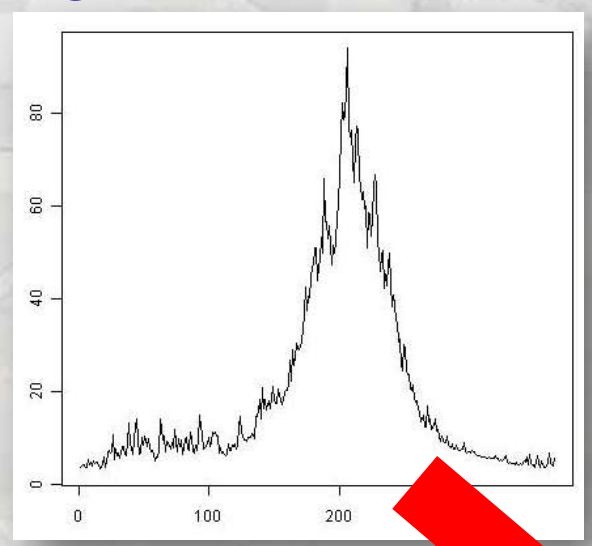
Olden and Naiman 2009

### Annual Accumulation of Thermal Units



# Challenges With Full Year Monitoring

Big snowmelt floods each year

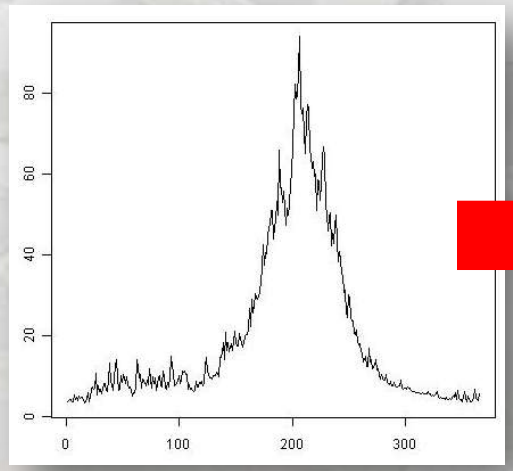



# Cable & Rebar Protocol

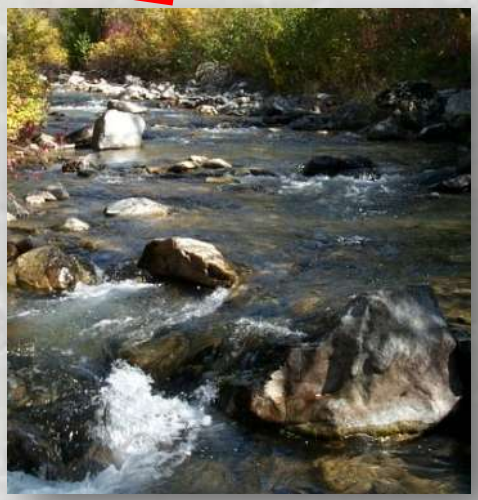
Mauger 2008; Ward 2011

# 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!

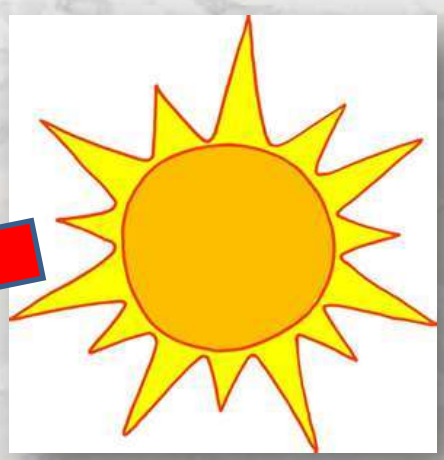
- AquaMend® from Polymeric Systems Inc.
- AquaStik® from DuPont
- Waterweld from J-B Weld Company
- Mr. Sticky's® Underwater Glue from Advanced Adhesion Inc.
- HIT-RE 500 from Hilti
- Sea Goin' Poxy Putty from Permalite Plastics Corp
- A-788 Splash Zone Underwater Epoxy Putty from Carboline Company

## Clear winner: Fox Industries FX-764


# Easy Application, Cement-Like Adhesion

# Field Trial Assessments:

## Heat Conduction Effect? NO



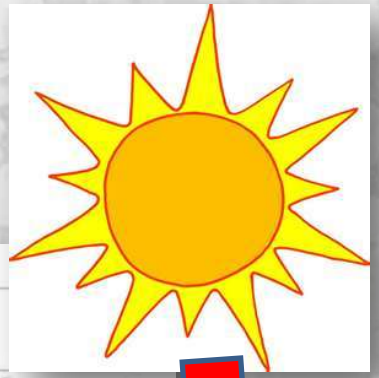
Sensor

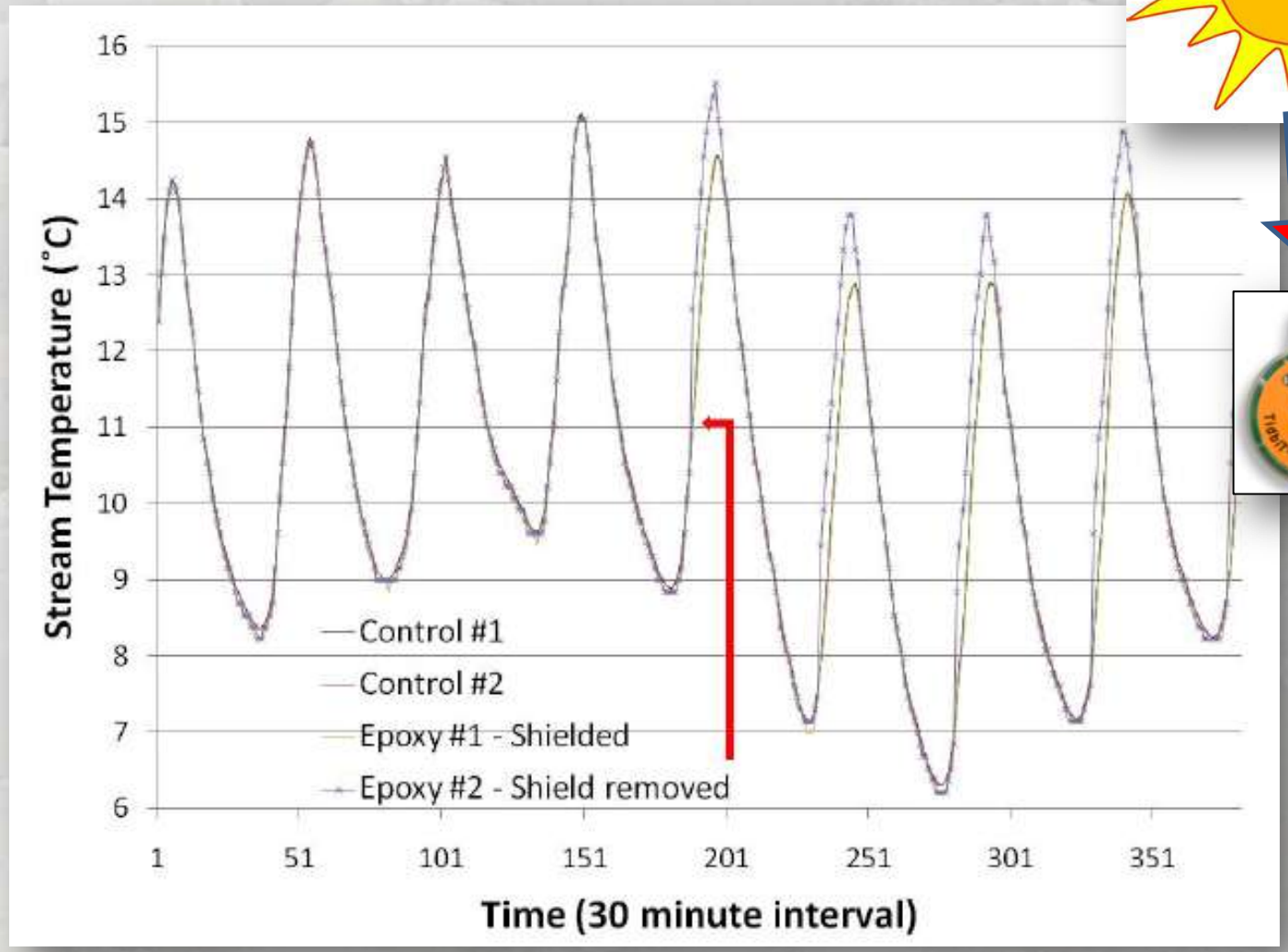
| | Temperature attribute (°C) | | |
|---|---|---|---|
| Stream site name | Minimum | Mean | Maximum |
| Canyon Creek | 0.10 | 0.00 | -0.06 |
| Grimes Creek, rock 1 | -0.01 | -0.02 | -0.08 |
| Grimes Creek, rock 2 | 0.06 | 0.02 | -0.03 |
| Little Rattlesnake Creek | 0.07 | 0.02 | -0.15 |
| Mores Creek, rock 1 | 0.11 | 0.07 | 0.16 |
| Mores Creek, rock 2 | -0.11 | -0.07 | -0.02 |
| Mores Creek, rock 3 | -0.13 | 0.10 | 0.31 |
| Mores Creek, rock 4 | -0.03 | 0.01 | 0.16 |
| No Name Creek | 0.13 | 0.09 | 0.03 |
| Rattlesnake Creek | 0.02 | 0.00 | 0.00 |
| 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 C**

# Solar Shield Alternatives…

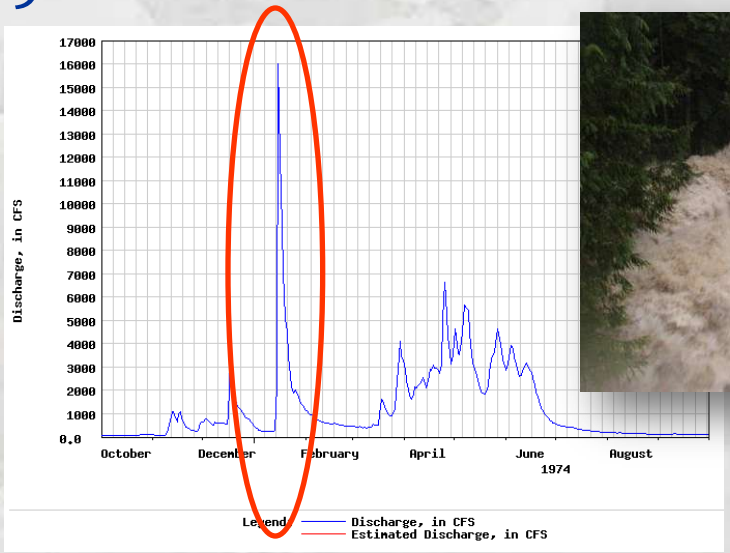
## Neoprene flap & directly glue sensor to rock

PVC housing protects sensor & makes data retrieval/sensor replacement easy

# Field Trial Assessments:

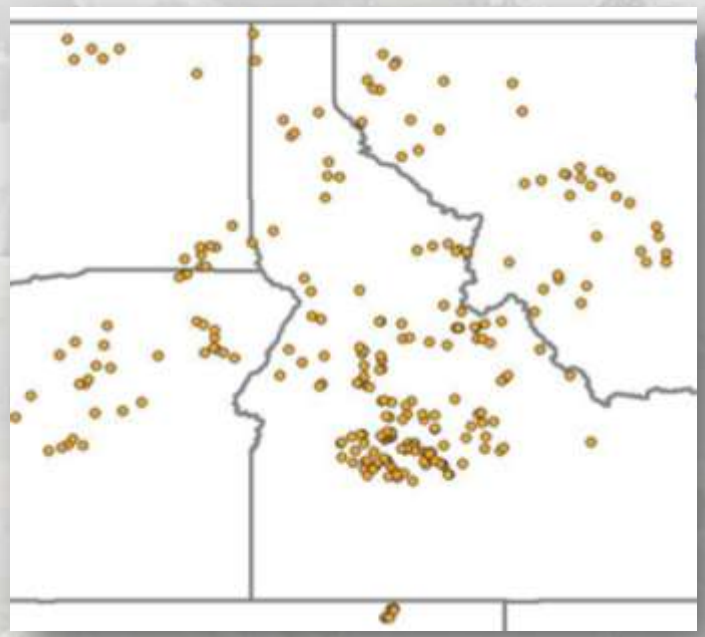
## Durability of Installations?

9 of 11 weathered above average floods in spring 2010




Same location

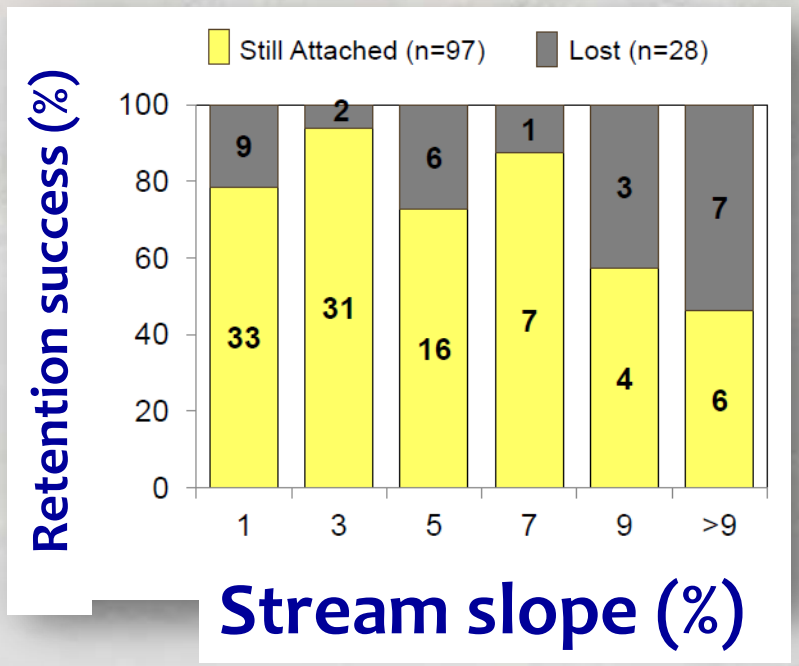
# Large Scale Field Durability Assessment



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

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

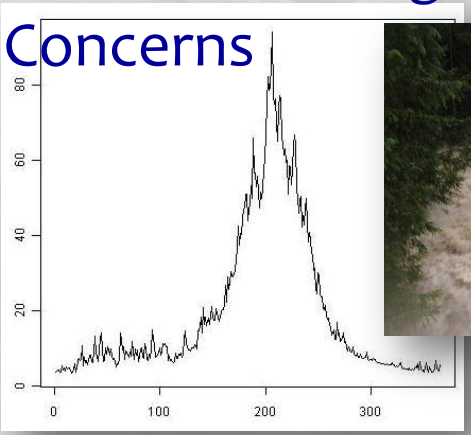
**Year 2 retention:**
>90% retention



# Easy Method for Full Year Monitoring

## Underwater Epoxy Protocol

Annual Flooding Concerns




Underwater epoxy

**$130 = 5 years of data**

Data retrieval


PVC housings glued to boulders or bridge pilings

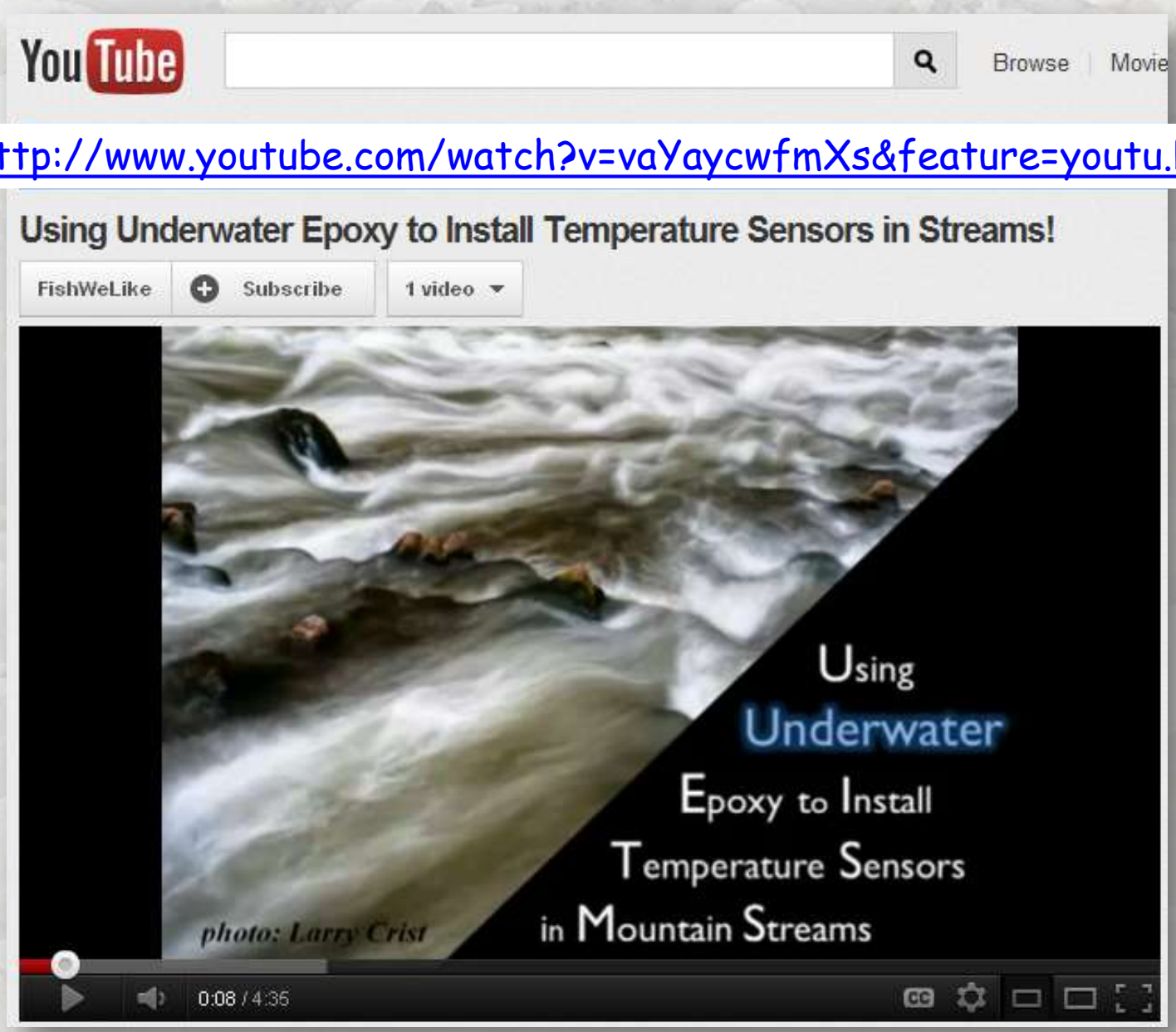
Isaak & Horan 2011. ***NAJFM*** 31:134-137

# Big Boulders, Bridge Pilings, Roadbed Riprap…


# Sensor Relocations Are Easy

Sites monumented by boulder or bridge…

# “How-to” installation video…



# What Stream Location?

## Good

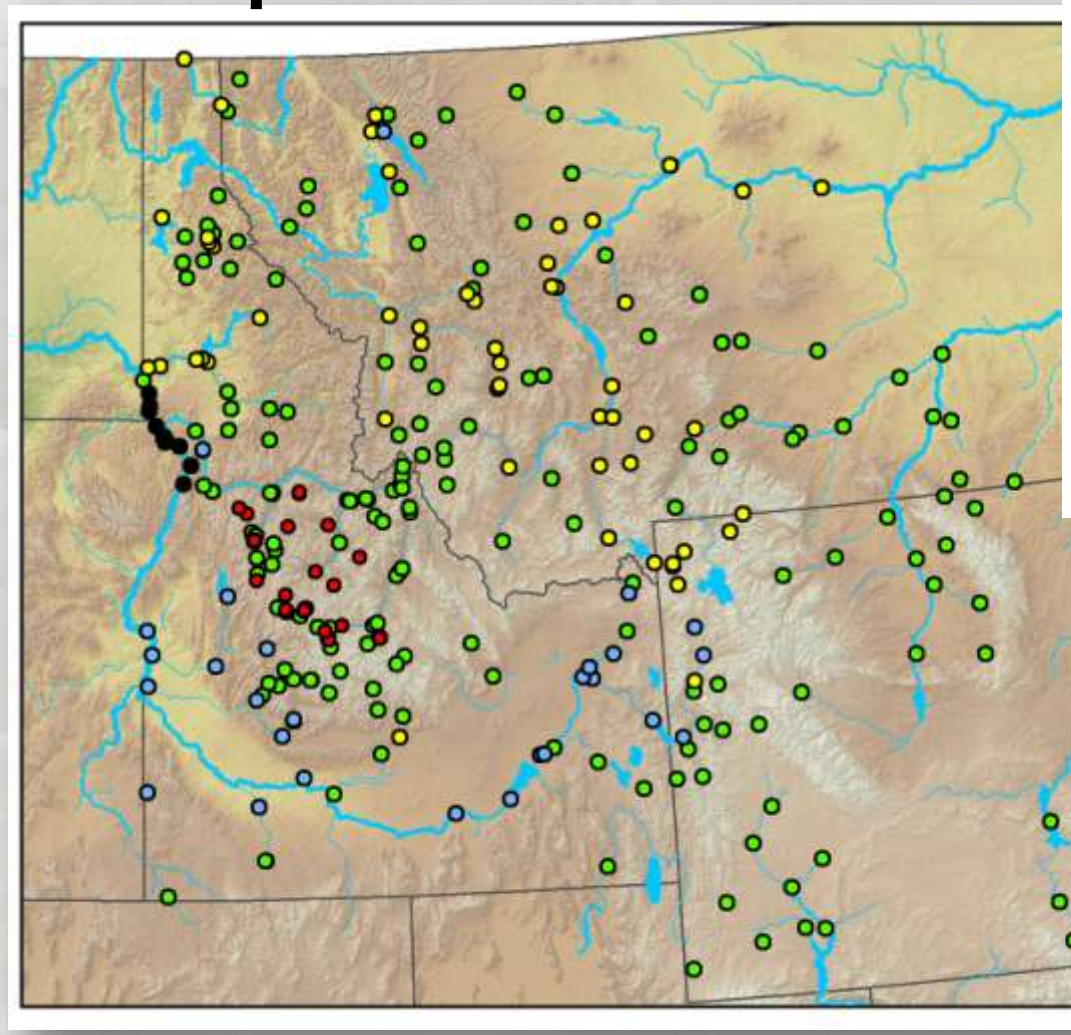
- Near reach where biological data collected
- Well-mixed flow throughout year
- Sufficient depth to year-round submersion
- Low human activity

## Bad

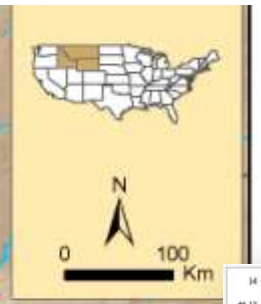
- Localized warm or cool water sources…
  - Downstream of tributary confluence
  - Impoundments/lakes (including beaver ponds)
  - Point-source discharges
  - Stream-side wetland areas
  - Hotsprings

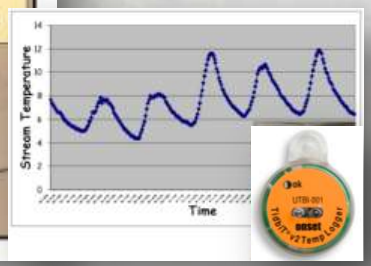
# Example Monitoring Networks

## 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

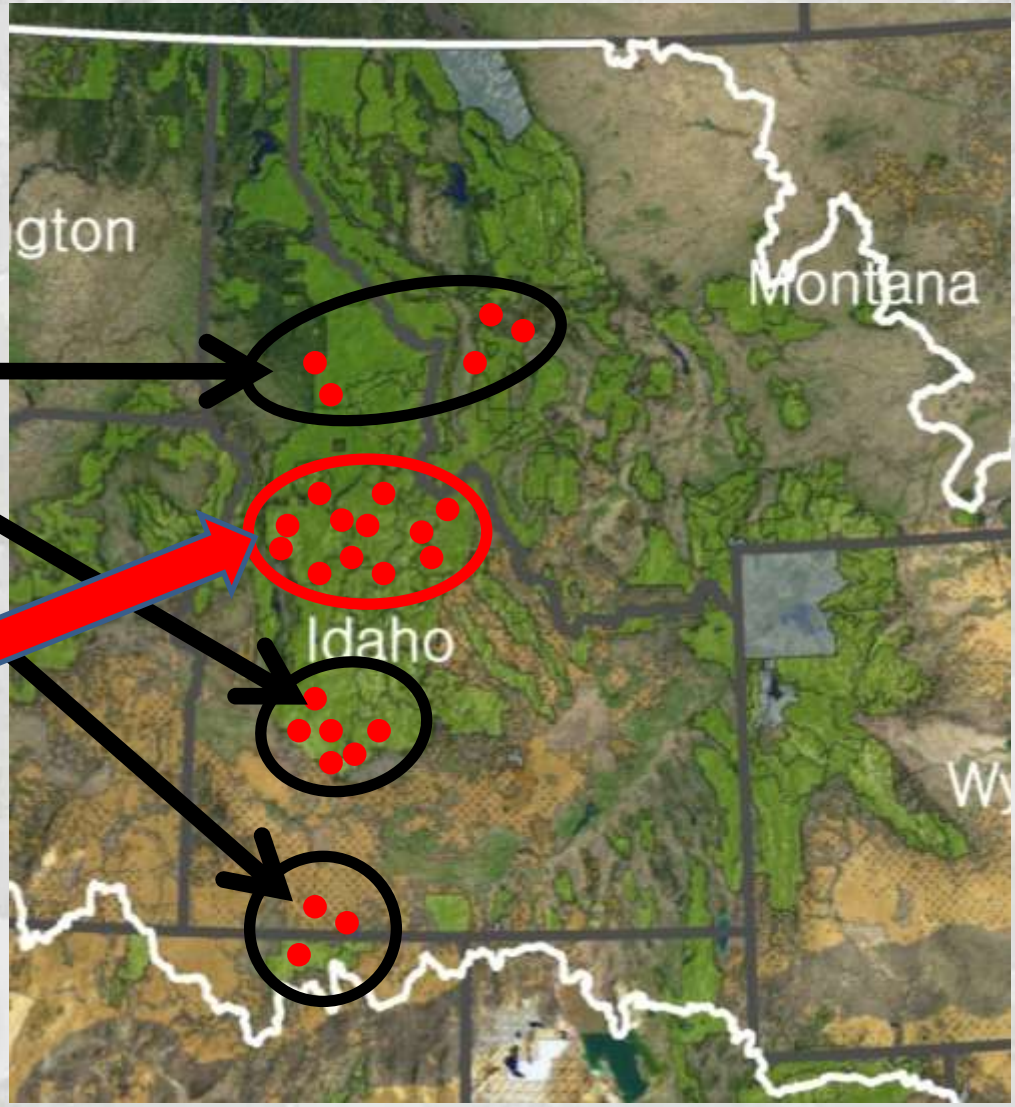


# Ecological Temperature Networks

**Bull Trout natal habitats**

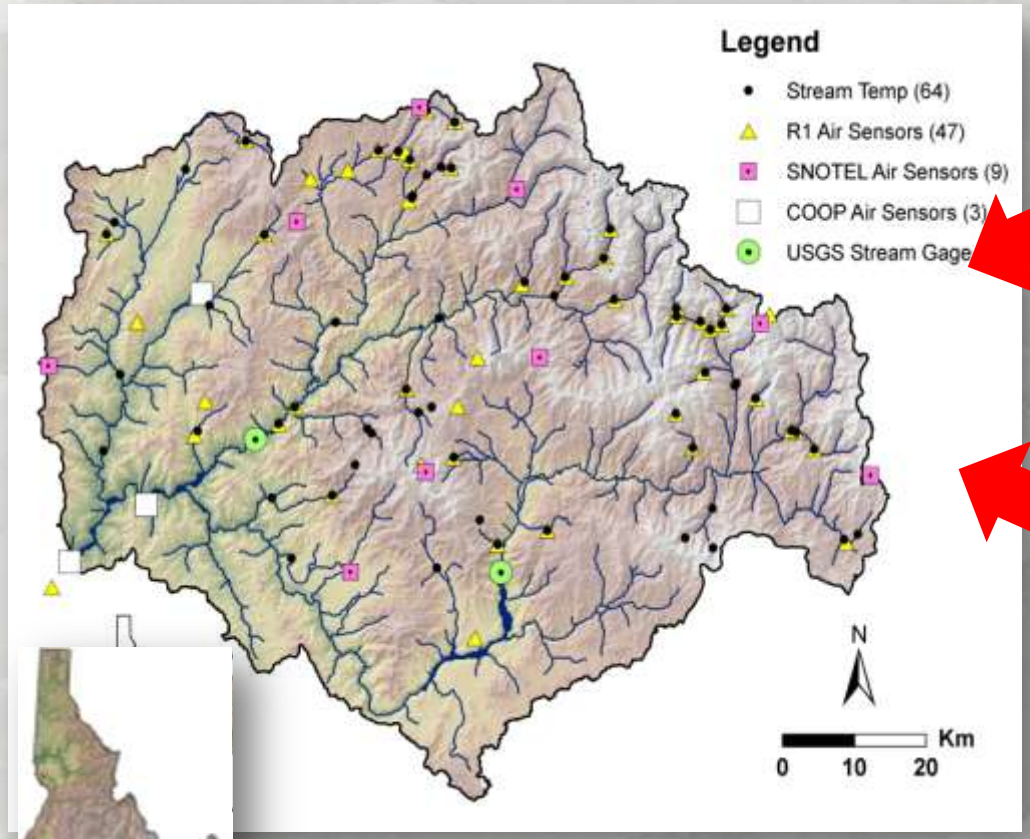
**Chinook salmon natal & migratory habitats**



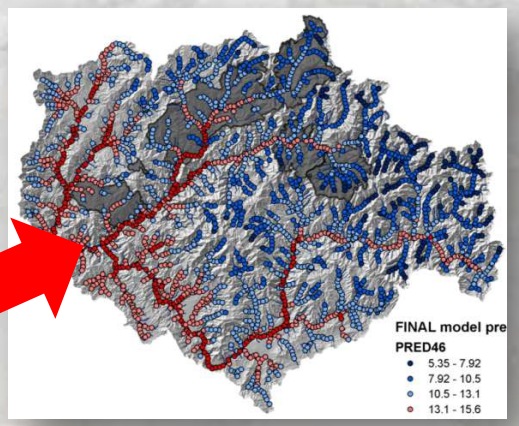
# Dense Sensor Arrays for Detailed Landscape Analysis

## Boise River Basin

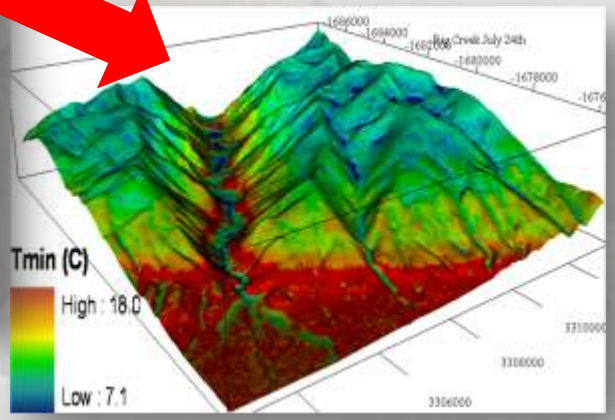
## Air & stream sensor locations




## Stream temp map




## Air temp map



# Pairing Air w/ Stream Sensors

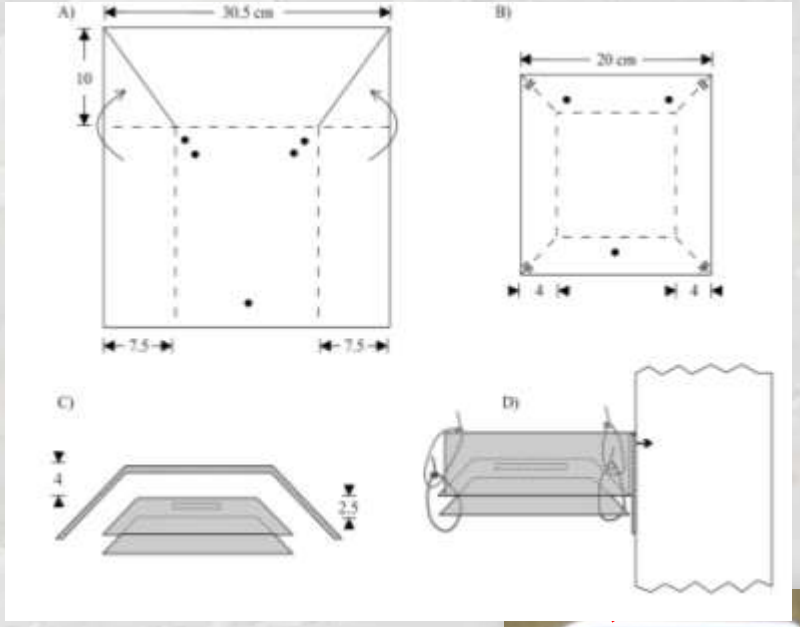
## Well-ventilated radiation shield needed

$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

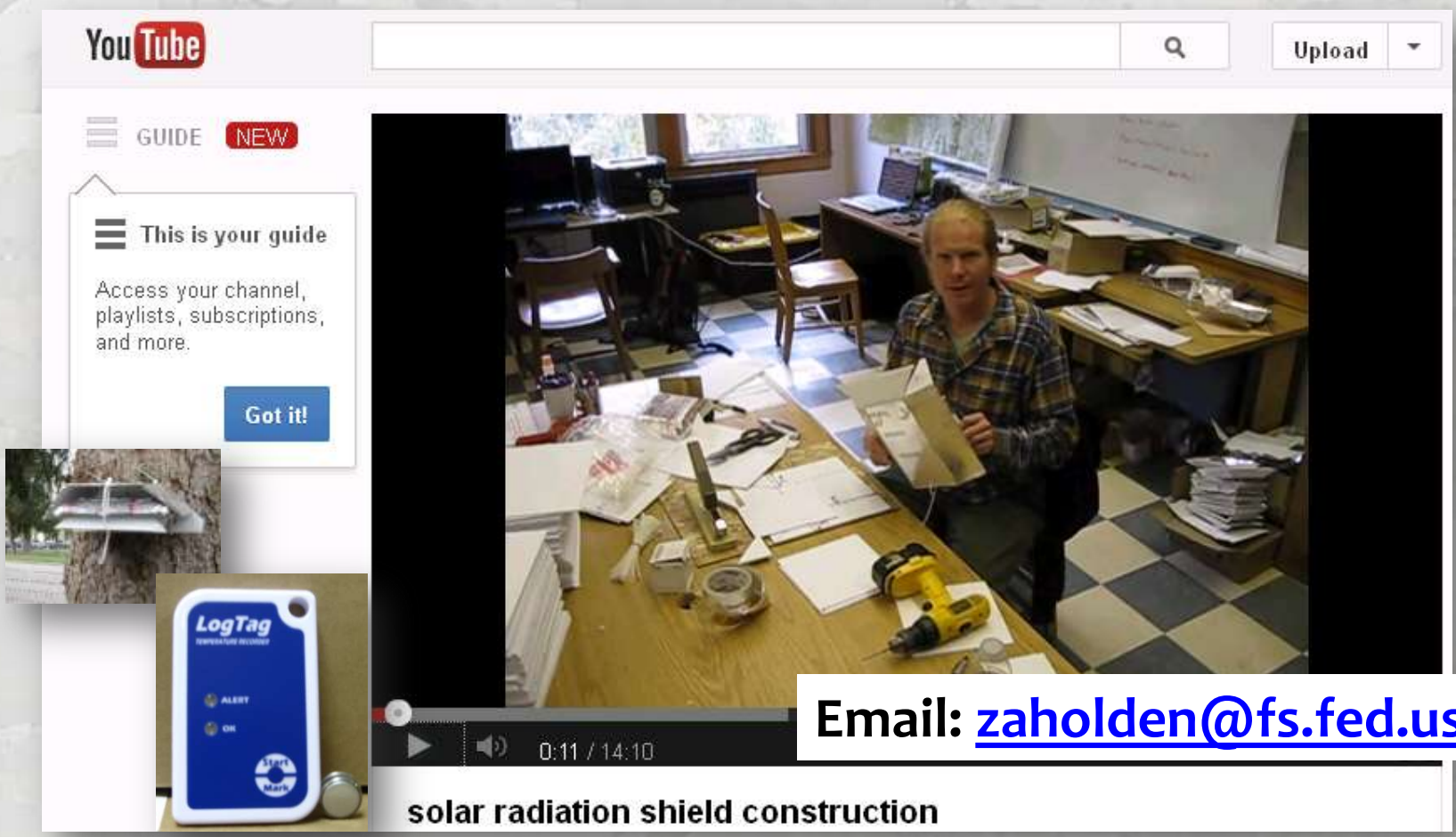
### Tree Mounted

## In Riparian or Out?

Holden et al. In review. *Hydrologic Processes*

# “How-to” installation video…

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

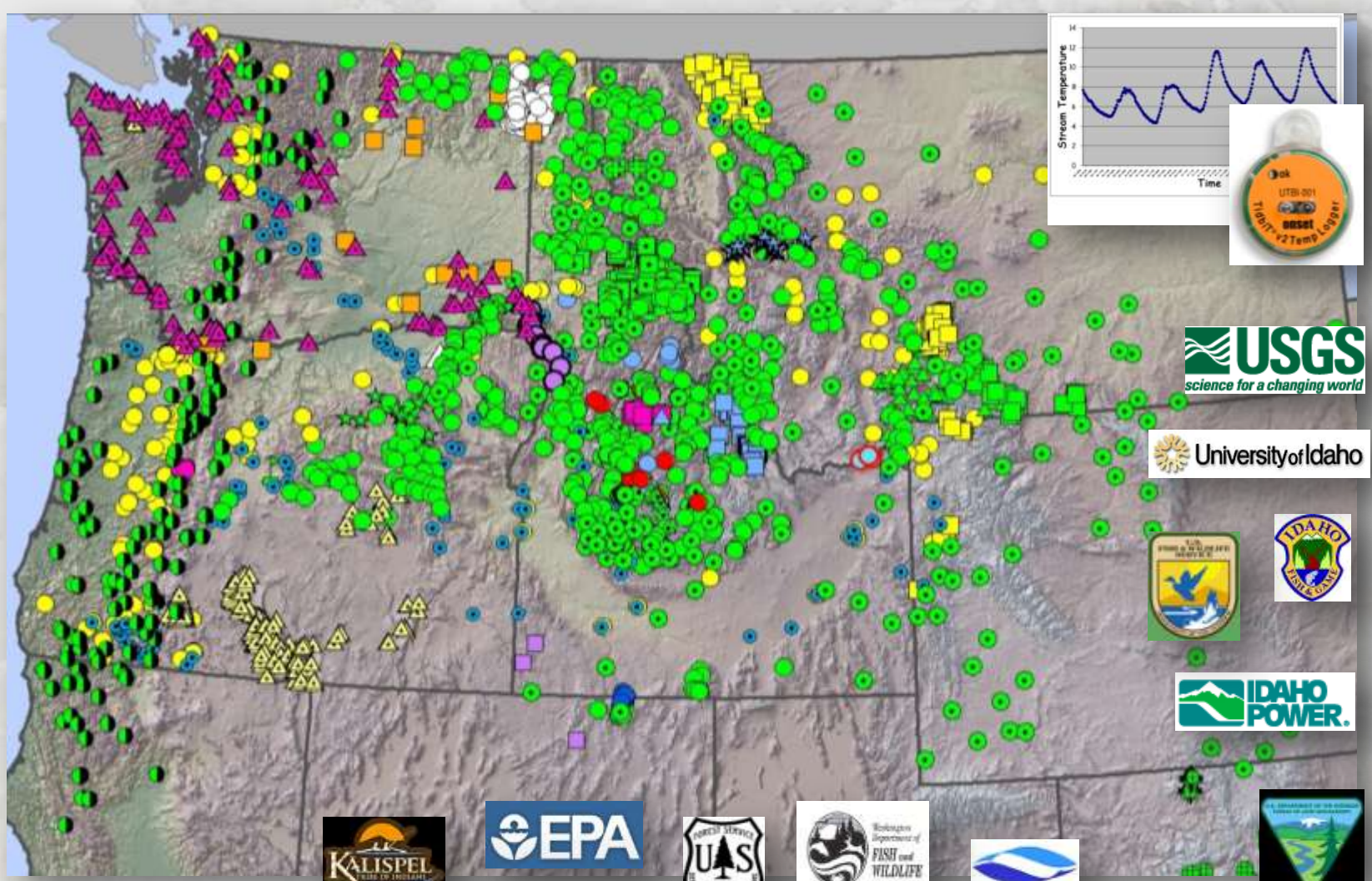



Email: zaholden@fs.fed.us

**Zack’s air temperature website:**

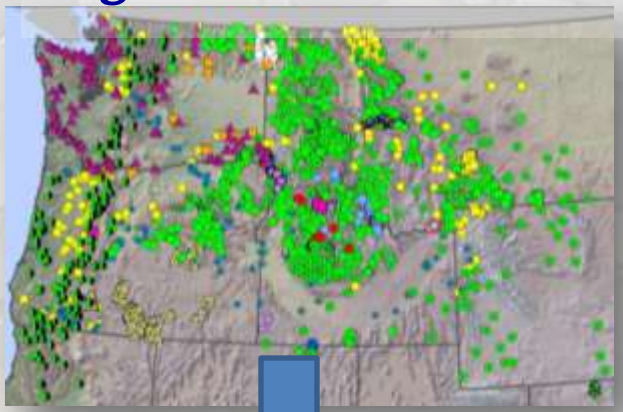
http://www.fs.fed.us/rm/boise/AWAE/projects/air_temperature_r1.shtml

# Full Year Stream Temperature Monitoring Becoming Popular…



# A GoogleMap Tool for Dynamic Queries of Temperature Monitoring Sites

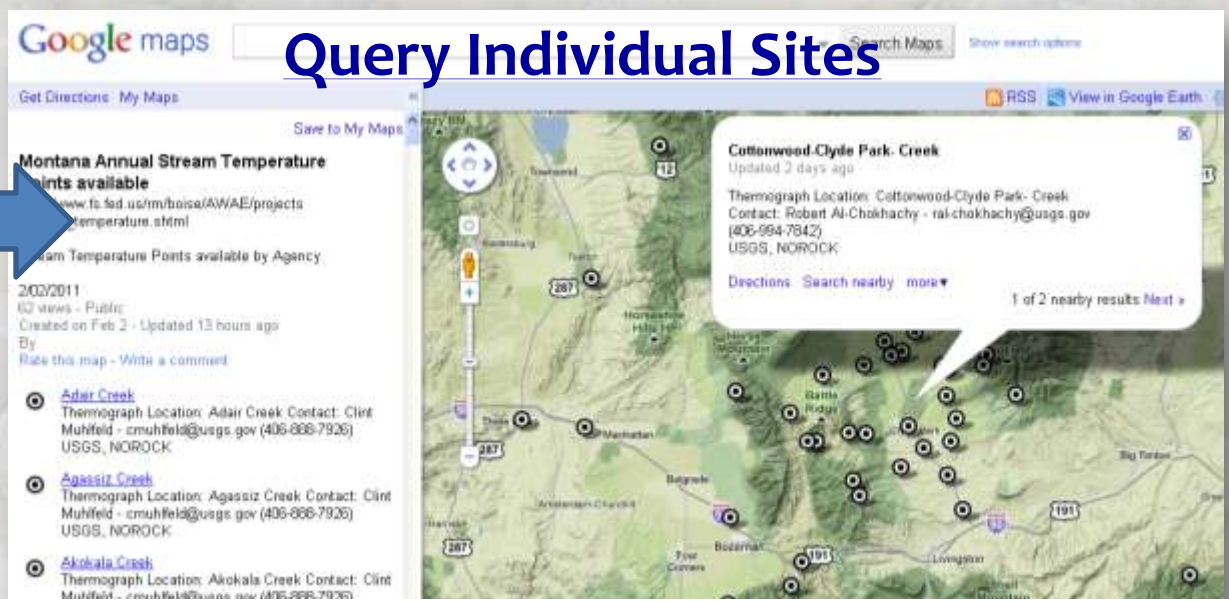
## Regional Sensor Network



## Site Information

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


## Query Individual Sites

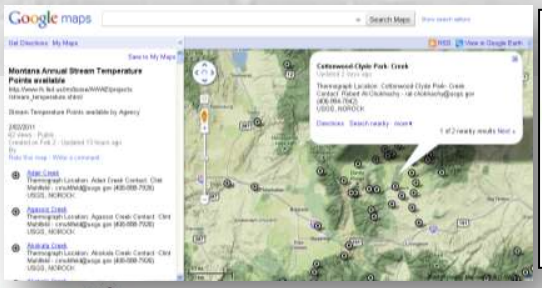



## Webpage:

https://www.google.com/fusiontables/DataSource?snapid=S3753137OpY

# >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

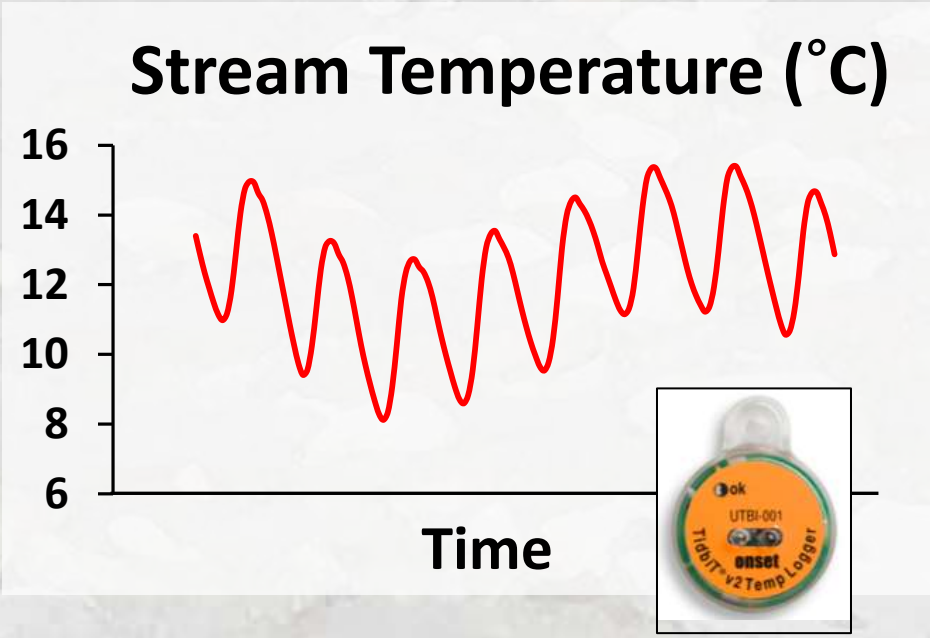
# Key Points for Ensuring High Quality Full Year Stream Temperature Data

1) No sunlight

2) No sediment

3) No air

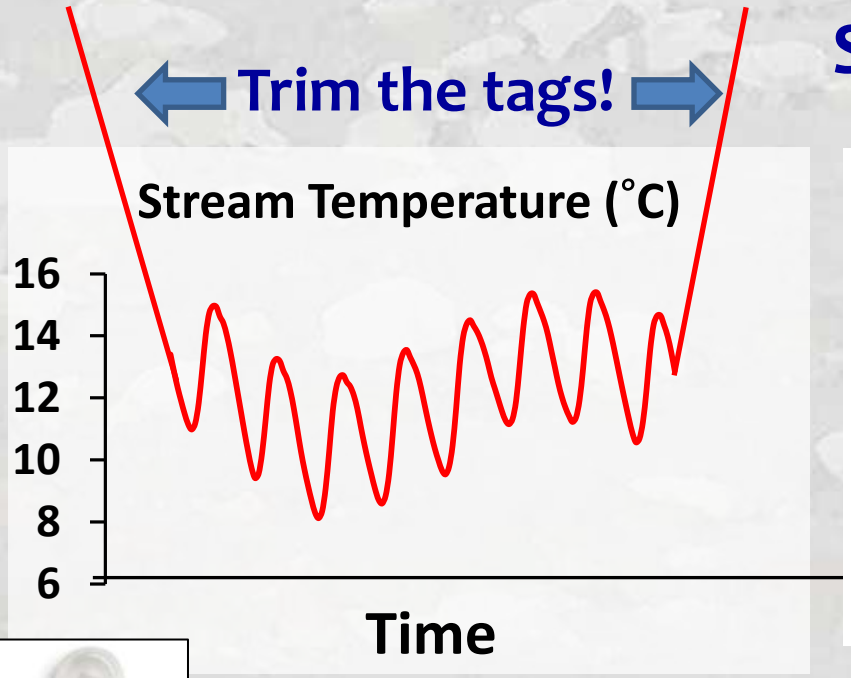
4) Flowing water

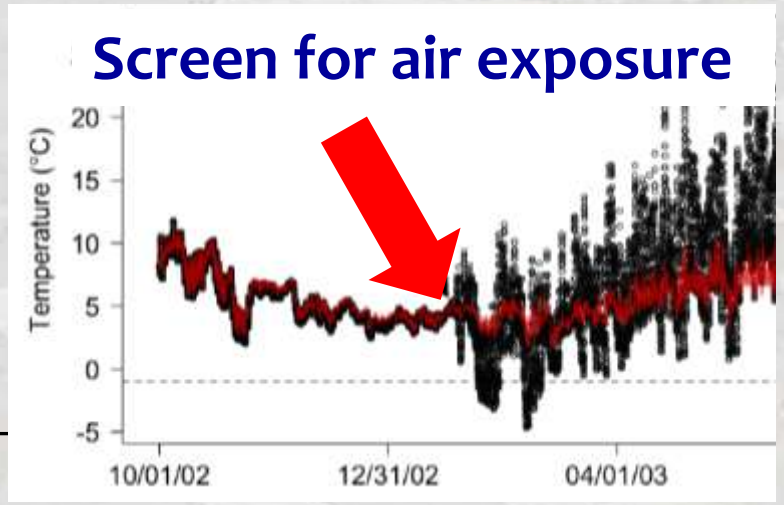



5) Accurate georeferencing/photo archiving

# QA/QC Checks & Database Archiving

## Simple plots show a lot





Have a plan for data archiving. Don't fall behind…

| | A | B | C |
|---|---|---|---|
| | Stream: | Elk Creek | |
| | Georeference: | 610234 E, 4402546 W | |
| | Date | Time | Temp (°C) |
| | 7/15/2005 | 21:23 | 15.59 |
| 7 | 7/15/2005 | 21:53 | 15.11 |
| 8 | 7/15/2005 | 22:23 | 14.64 |
| 9 | 7/15/2005 | 22:53 | 14.32 |
| 10 | 7/15/2005 | 23:23 | 13.86 |
| 11 | 7/15/2005 | 23:53 | 13.55 |
| 12 | 7/16/2005 | 0:23 | 13.24 |

Consistent units ˚F vs ˚C?

Check date & time stamp

Dunham et al. 2005; Sowder and Steel 2012

# Literature Cited…


Dunham, J., G. Chandler, B. Rieman, and D. Martin. 2005. Measuring stream temperature with digital data sensors: a user's guide. RMRS-GTR-150. U.S. Forest Service. http://fresc.usgs.gov/products/papers/1431_Dunham.pdf.

Holden, Z. 2010. Air temperature sensor installation instructions. http://www.fs.fed.us/rm/boise/AWAE/projects/stream_temp/blogs/06ThoughtsOn%20monitoringAirTemperaturesInComplexForestedTerrain.pdf

Isaak, D. J. and D.L. Horan. 2011. An assessment of underwater epoxies for permanently installing temperature in mountain streams. North American Journal of Fisheries Management 31: 134-137. http://www.treesearch.fs.fed.us/pubs/37476

Isaak, D., D.L. Horan, and S. Wollrab. 2010. A visual guide to using underwater epoxy to permanently install temperature in mountain streams. U.S. Forest Service. http://www.fs.fed.us/rm/boise/AWAE/projects/stream_temp/downloads/RMRS_StreamSensorEpoxyProtocol_3_12.pdf

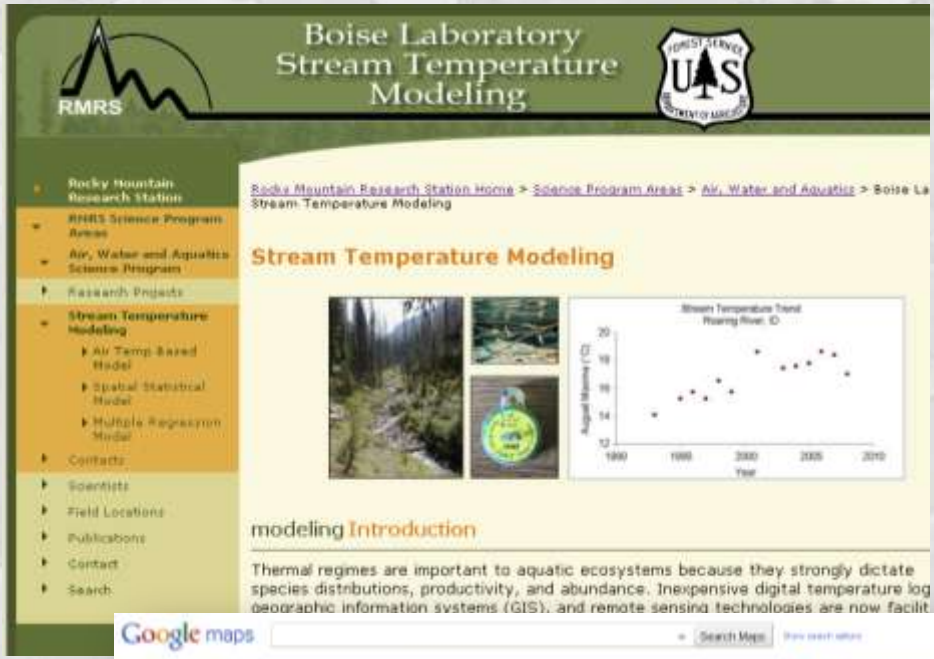
Mauger, S. 2008. Water temperature data sensor protocol for Cook Inlet salmon streams. Cook Inletkeeper, Homer, Alaska. http://inletkeeper.org/resources/contents/water-temperature-data-sensor-protocol

Sowder, C., and E. A. Steel. 2012. A note on the collection and cleaning of water temperature data. Water 4:597-606. http://www.mdpi.com/2073-4441/4/3/597

Ward, W. 2011. Standard operating procedures for continuous temperature monitoring of fresh water rivers and streams, version 1. Washington State Department of Ecology. 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