A large-scale evaluation of a cost-effective and simple method to monitor full-year temperatures in mountain streams

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Introduction

Stream temperature regimes are fundamentally important to understanding pattern and process in aquatic communities because most organisms are ectothermic. A stream's natural thermal regime influences freshwater biodiversity via multiple mechanisms that operate at different spatial and temporal scales (Figure 1). With the data we have now, which are mostly summer, we are getting a limited view of thermal regimes in streams.

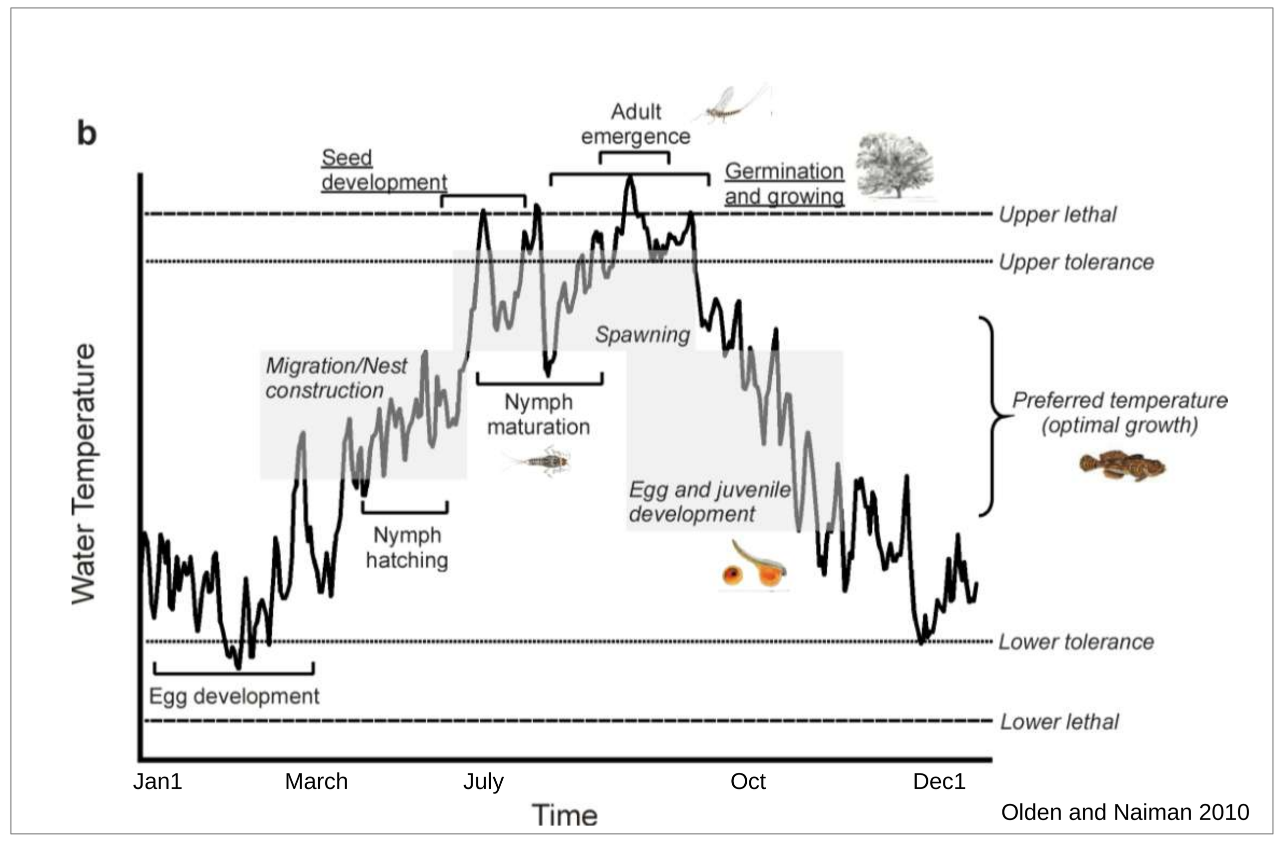

Figure 1. A number of examples in which temperature influences the life-histories of fish, insects, and riparian plants.

Why full-year data are useful

- Accurately defining thermal criteria and realized niches for aquatic organisms
- Characterizing thermal "regimes" instead of summer maxima (Figure 2)
- Building predictive models for assessing thermal patterns during all seasons
- Assessing relative sensitivities among streams to climate forcing
- Developing long-term record reconstructions from several years of monitoring

Objective: Collect more full-year temperature data

Modern digital sensors can provide accurate temperature measurements over multi-year deployments. Collecting full-year stream temperature data in mountain streams has been limited, however, because losing data and sensors to high flows is a concern. Permanent sites that are capable of withstanding large annual floods have required significant infrastructure to keep sensors in places that may also make deployments in remote streams difficult.

We have developed a simple protocol for full-year monitoring (Isaak and Horan 2011; Isaak et al. 2012) that uses underwater epoxy to attach temperature sensors (TidbiT® v2*, Onset Computer) to large rocks in rivers and streams (Figure 3). These rocks provide anchor points and protection from bedload and flood debris. Here, we report on the validation work to develop the epoxy protocol and a large-scale field assessment to evaluate retention success from 2010-2011.

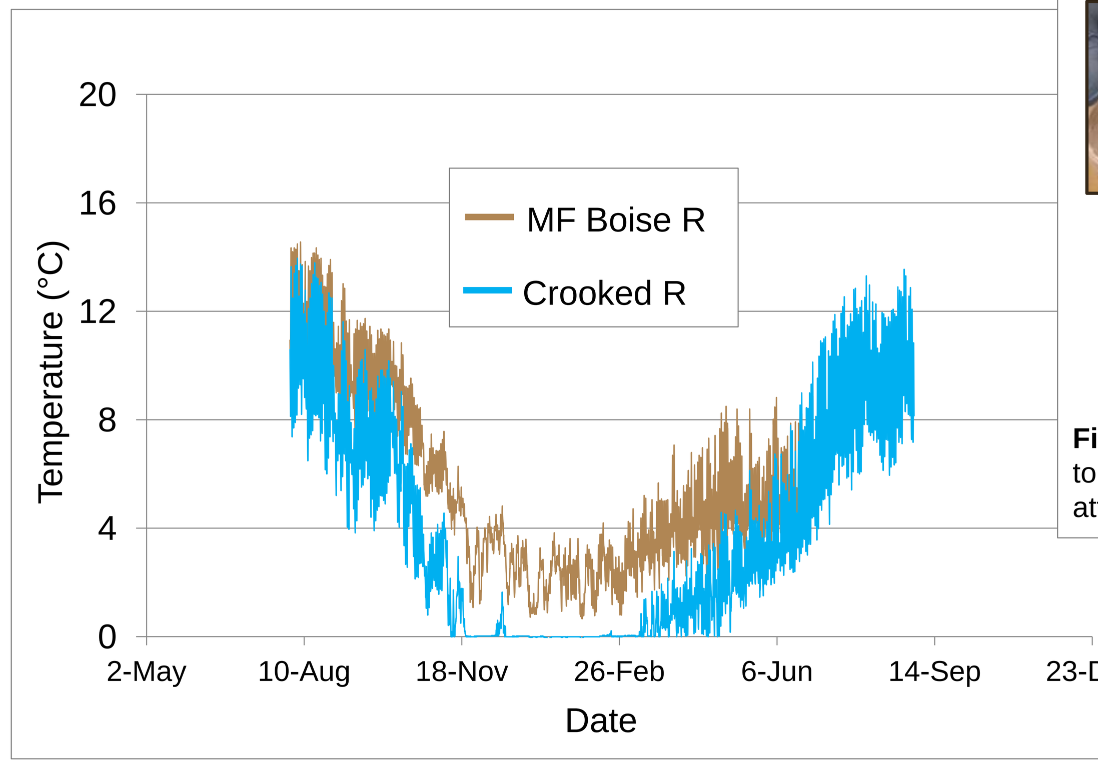

Figure 2. Examples of full-year stream temperature data from two streams in the Boise River basin of central Idaho.

Figure 3. We mix a 2-part epoxy to use on sensors that are then attached to large rocks in streams.

Initial field tests using underwater epoxy

Question # 1: Are stream temperature measurements affected by heat conduction through the attachment rock?

	Temperature attribute (°C)			
Stream site name	Minimum	Mean	Maximum	Sun exposure
Canyon Creek	0.10	0.00	-0.06	high
Grimes Creek, rock 1	-0.01	-0.02	-0.08	high
Grimes Creek, rock 2	0.06	0.02	-0.03	high
Little Rattlesnake Cr	0.07	0.02	-0.15	medium
Mores Creek, rock 1	0.11	0.07	0.16	low
Mores Creek, rock 2	-0.11	-0.07	-0.02	high
Mores Creek, rock 3	-0.13	0.10	0.31	low
Mores Creek, rock 4	-0.03	0.01	0.16	high
No Name Creek	0.13	0.09	0.03	low
Rattlesnake Creek	0.02	0.00	0.00	medium
Average difference	**0.02**	**0.02**	**0.03**	
95% CI	**(-0.05, 0.09)**	**(-0.02, 0.06)**	**(-0.07, 0.13)**	

Table 1. Differences between stream temperatures measured with sensors attached to rocks and control sensors. Differences were calculated by subtracting the control temperature values from the rock temperature values.

Method: At 10 sites during the summer of 2010, we epoxied 2 sensors to large rocks and placed 2 sensors adjacent to the rocks in flowing sections of the stream as controls.

Results: Comparisons of daily maxima, minima, and means between rock-mounted sensors and control sensors suggested temperature measurements were not biased by attachment to rocks (Table 1).

Question # 2: Are stream temperature measurements affected by direct sunlight hitting the sensor?

Method: Solar shields (Figure 4) were removed from 1 of 2 epoxied sensors at several sites 4 days into an 8-day field trial in July 2010.

Results: Temperature measurements overlapped strongly among the sensors during the first days of the trial, but temperature spikes of 0.5-1.0°C were observed immediately after the solar shield was removed from a sensor (Figure 5).

Figure 4. Two potential means for shading a stream sensor from solar radiation: TidbiT with a piece of neoprene zip-tied to the sensor (left) and TidbiT encased in a PVC housing (right).

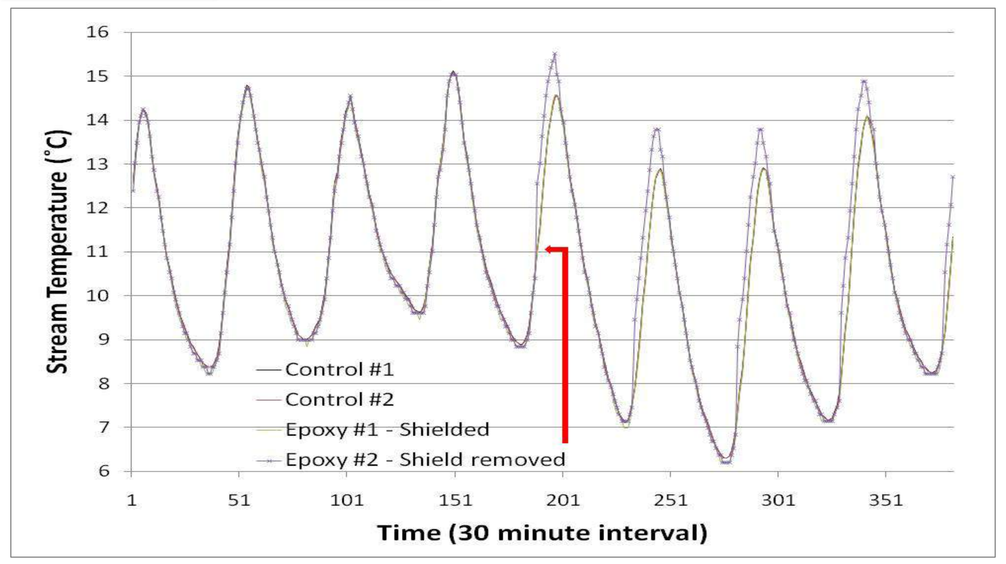

Figure 5. Assessment of direct sunlight on temperature sensor measurements at one site. On day 5 (at time interval 185), the solar shield was removed from one of two epoxied sensors to assess the effectiveness of the solar shield.

A large-scale field test to assess sensor retention rates

Question # 3: What is the retention rate of epoxied sensors across a diversity of stream types and slopes?

Method: During summer 2010, we deployed 281 temperature sensors in streams ranging in channel slope from 0.1% - 16% across the northwest U.S. (Figure 6). Sites varied from low-gradient meandering valley streams, to steep high-mountain streams (Figure 7). In 2011, we visited 125 of those sites to evaluate sensor retention success after a relatively high snowmelt runoff in the spring of that year.

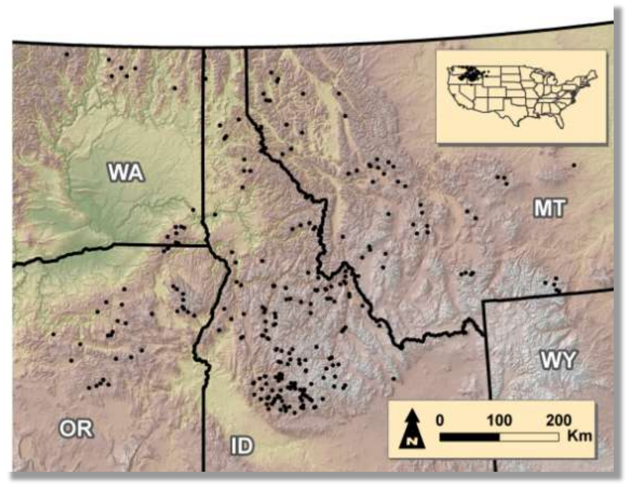

Figure 6. Stream temperature sites (n=281) throughout the northwest U.S. where sensors were attached to rocks using underwater epoxy.

Figure 7.   Example of differing stream gradients and sensor locations.

Results: Retention success was inversely related to channel slope. Retention rate averaged 83% where slopes were < 7% (87/105), which is typical of most fish-bearing streams. Overall success was 78% (97/125) (Figure 8). Future assessments will examine the role that other factors may play in retention rates, including training, experience, and rock size (Figure 9).

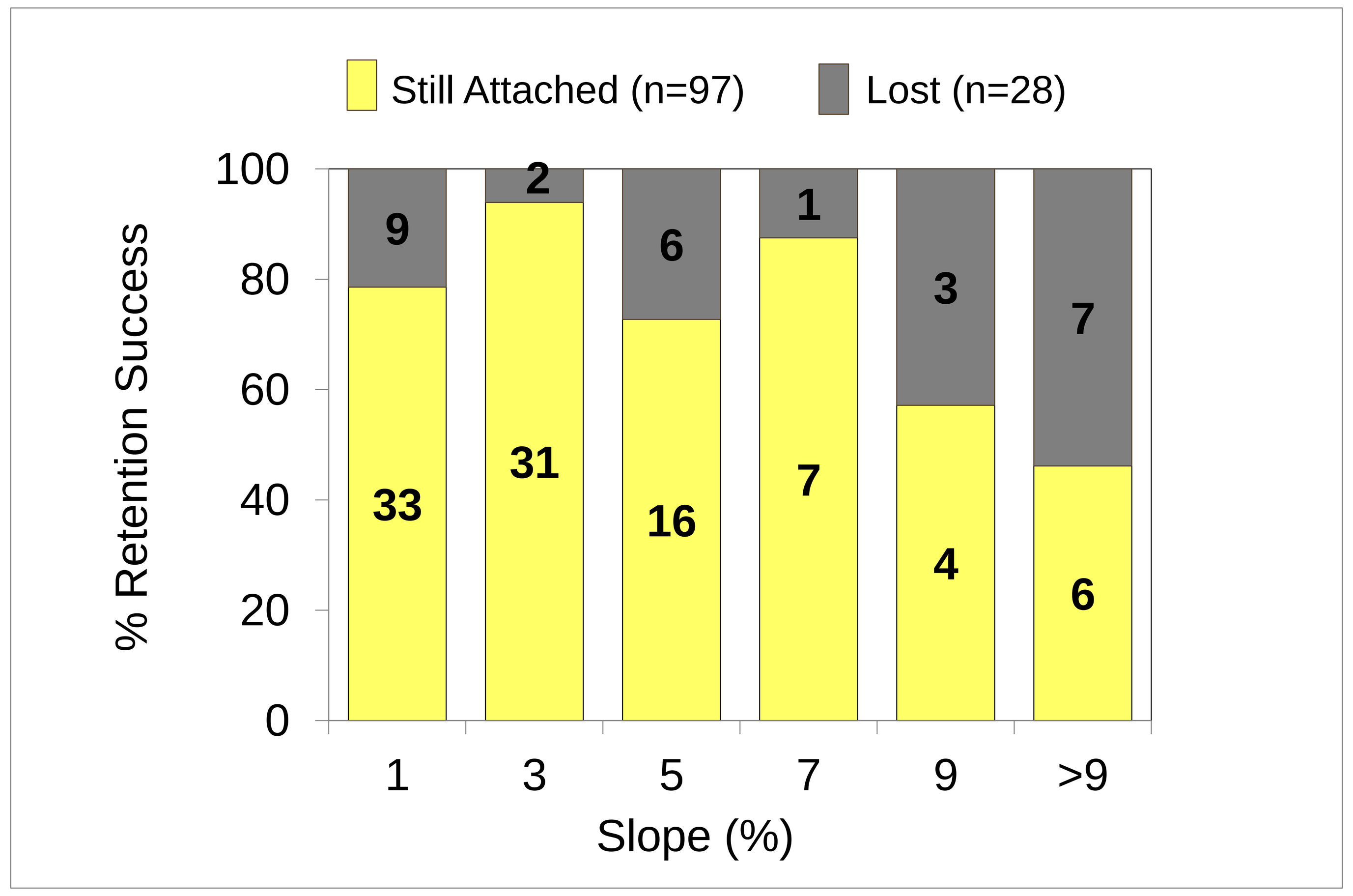

Figure 8.   Sensor retention at 125 sites established in 2010 that were revisited in 2011. The numbers in the columns represent the number of sites that were instrumented at that stream slope.

Figure 9. Critical to sensor retention is choosing either a large boulder relative to the size of the stream or a cement bridge pylon.

Conclusions

Our results indicate that underwater epoxy is viable for installing temperature sensors in a wide range of mountain streams where large substrates and suitable attachment sites can be found. This technique reduces the cost of temperature monitoring by reducing the number of site visits to ≤ 1 per year rather than the current norm of 2 per year when collecting only summer data. Using this technique, up to five years of temperature measurements may be obtained, given current memory and battery capacities of modern temperature sensors, for $130 in equipment costs (primarily the cost of the sensor).

During the summer and fall of 2011, more than 400 additional stream sites were instrumented with temperature sensors using underwater epoxy to continue expanding the regional temperature monitoring network. Data from this network will contribute to improved understanding of stream thermal regimes, alterations associated with climate change, and the thermal ecology of aquatic organisms.

References

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*Mention of trade names does not imply endorsement by the U.S. Forest Service.