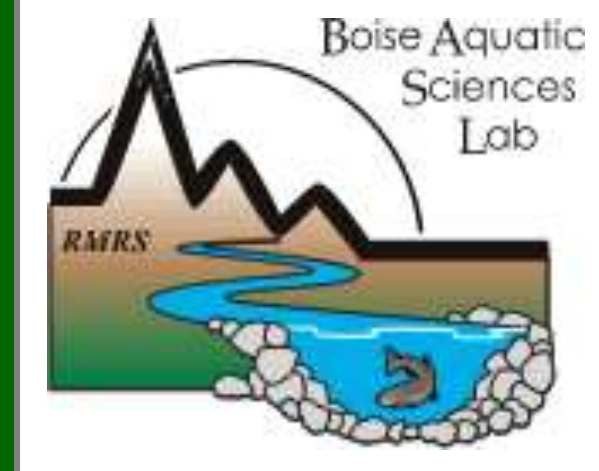


A field assessment of underwater epoxy use in establishing annual stream temperature monitoring sites



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Introduction

Stream temperature regimes are monitored for regulatory purposes and are fundamentally important to aquatic organisms because most are ectothermic (Figure 1). Most stream temperature monitoring occurs only in the summer and for short periods of time because of concerns about annual floods and instrument losses (Figure 2). Summer data provide a limited view of thermal regimes and are expensive to collect because two field trips are required annually for site maintenance (one for sensor deployment, one for sensor retrieval).

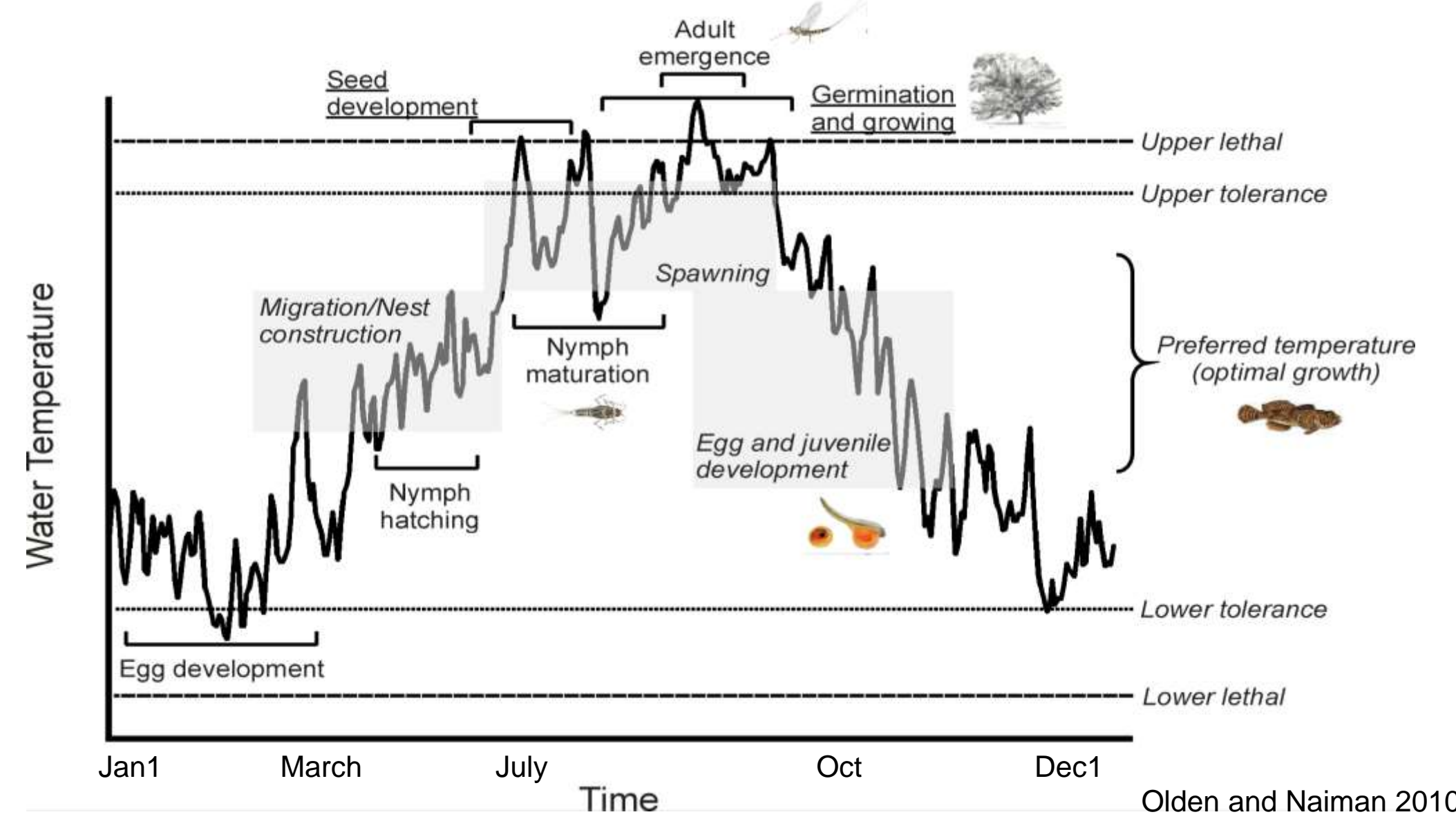
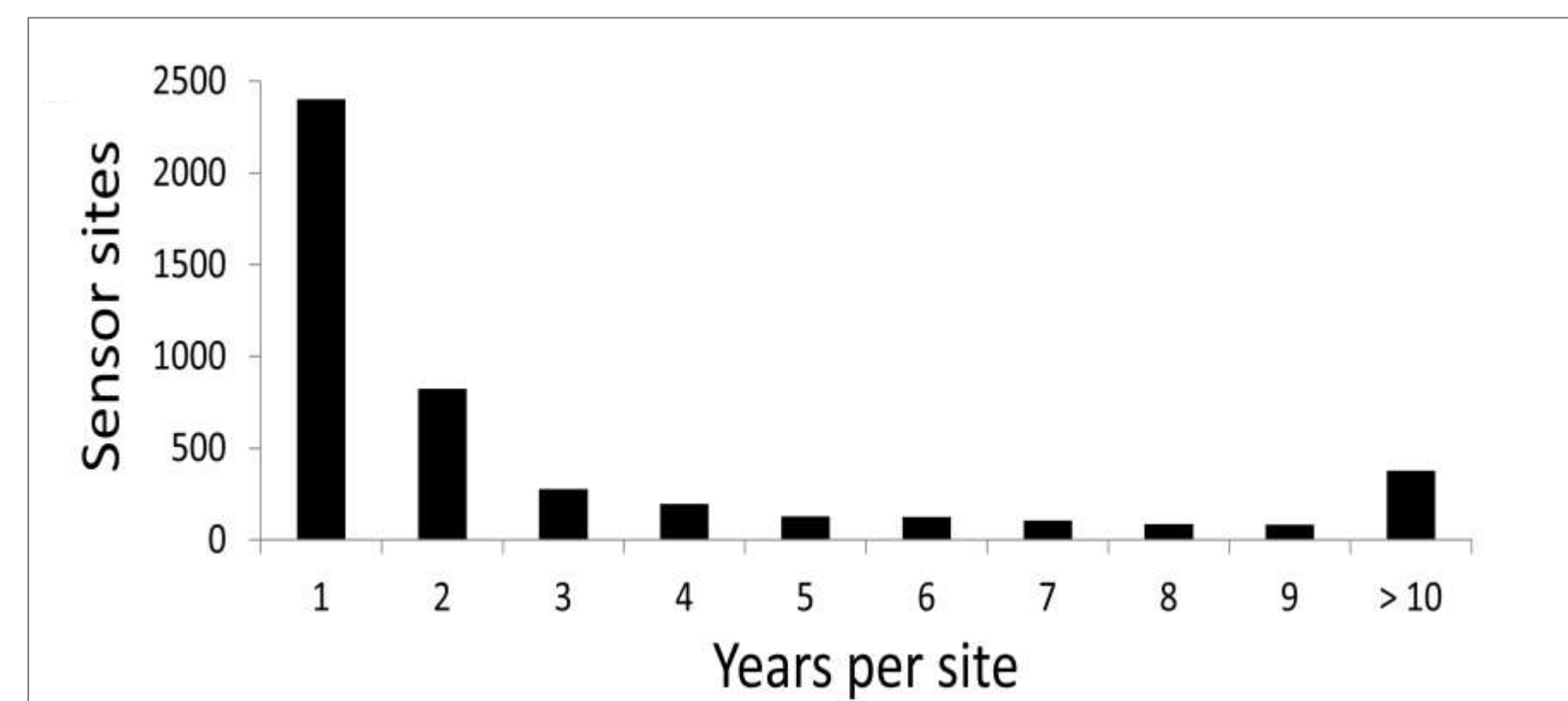


Figure 1. Temperature influences aquatic species throughout the life cycle.

Figure 2. Length of temperature monitoring record at 4,603 unique stream sites across Idaho and western Montana. A "Year" usually consists of 2-3 months of measurements during a summer season. Data are from the NorWeST stream temperature database, and are a composite across state, federal, tribal, and private organizations (Isaak et al. 2011).



Objective: Collect more annual temperature data

Modern digital sensors can record temperature measurements continuously for multiple years (Figure 3). A reliable protocol for establishing monitoring sites could use this capacity and increase the amount and efficiency of temperature monitoring. Here, we describe results from field trials that used underwater epoxy to attach PVC containers with temperature sensors (TidbiT[®] v2*, Onset Computer) to large rocks and cement structures in rivers and streams. The attachment structures provide protective anchors that shield sensors from bedload and flood debris (Isaak and Horan 2011; Isaak et al. 2013; Figure 4).

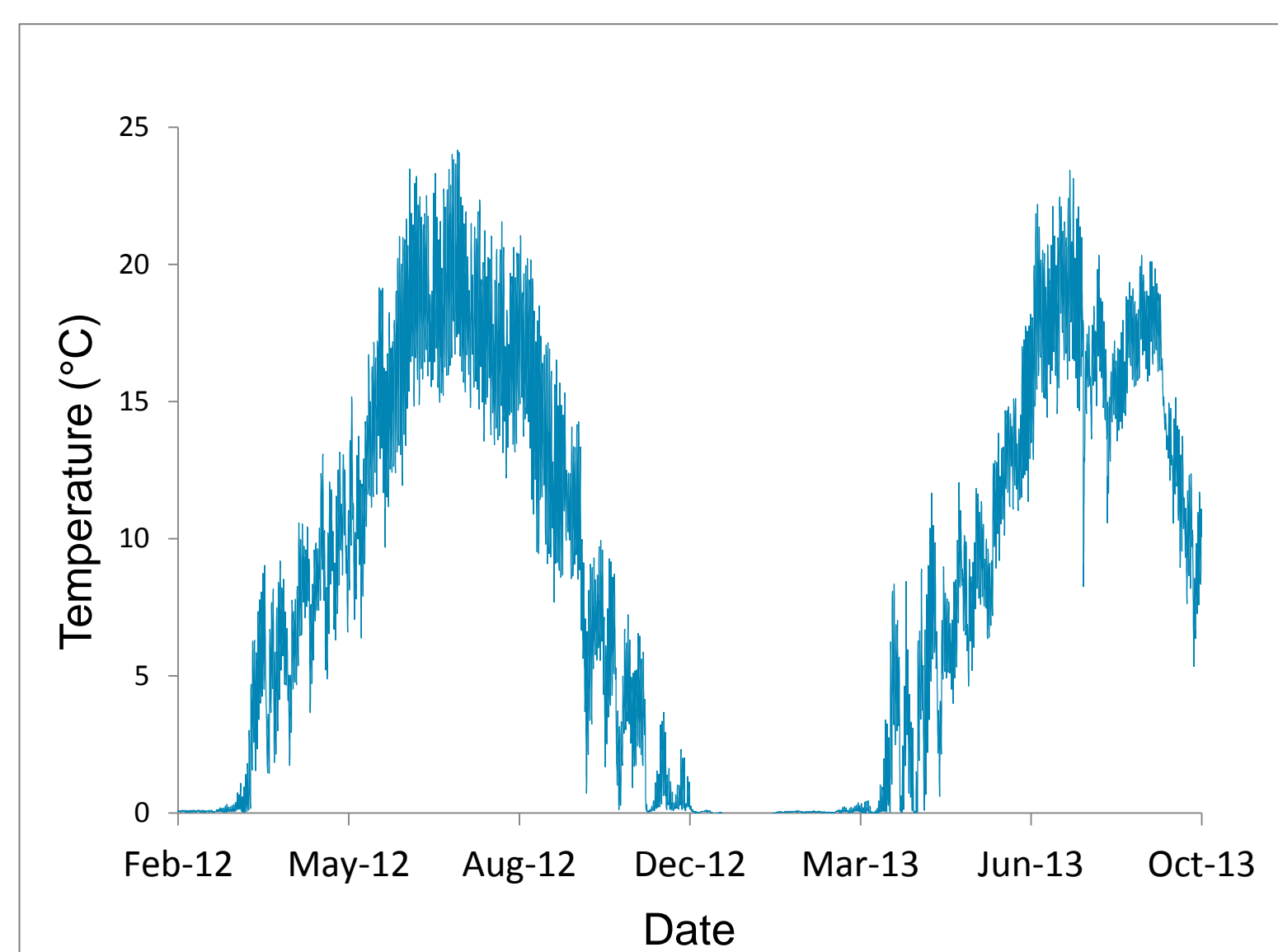


Figure 3. Two-year stream temperature record collected with a single sensor deployment.



Figure 4. A two-part epoxy is mixed and used to cement PVC containers with temperature sensors to large rocks and cement structures in streams and rivers. A removable screw-top provides easy access to the sensor for data retrieval.

Uses for annual temperature data

- Comprehensively define thermal regimes
- Better define thermal criteria for aquatic organisms
- Build predictive models for assessing thermal patterns during all seasons
- Assess relative sensitivities of different streams to climate forcing
- Develop long-term monitoring records for trend assessments

Question # 1: Are stream temperature measurements biased by heat conduction through an attachment rock?

Table 1. Differences between stream temperatures measured with sensors attached directly to rocks and control sensors in the adjacent stream.

Stream site name	Temperature attribute (°C)			Sun exposure
	Minimum	Mean	Maximum	
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)	

Method: At 10 sites, sensors were epoxied to large rocks and control sensors were placed in the adjacent stream. Both types of sensors recorded temperatures simultaneously and were shielded from direct sunlight.

Result: No differences existed between daily maxima, minima, and mean temperatures calculated from measurements with each type of sensor (Table 1).

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

Method: Two sensors with solar shields recorded temperatures simultaneously at the same location. The solar shield was removed from one sensor four days into the eight day recording period.

Results: Temperature measurements overlapped strongly between sensors during the first half of the period. Temperature spikes of 0.5-1.0°C were apparent after the solar shield was removed from one sensor (Figure 5).

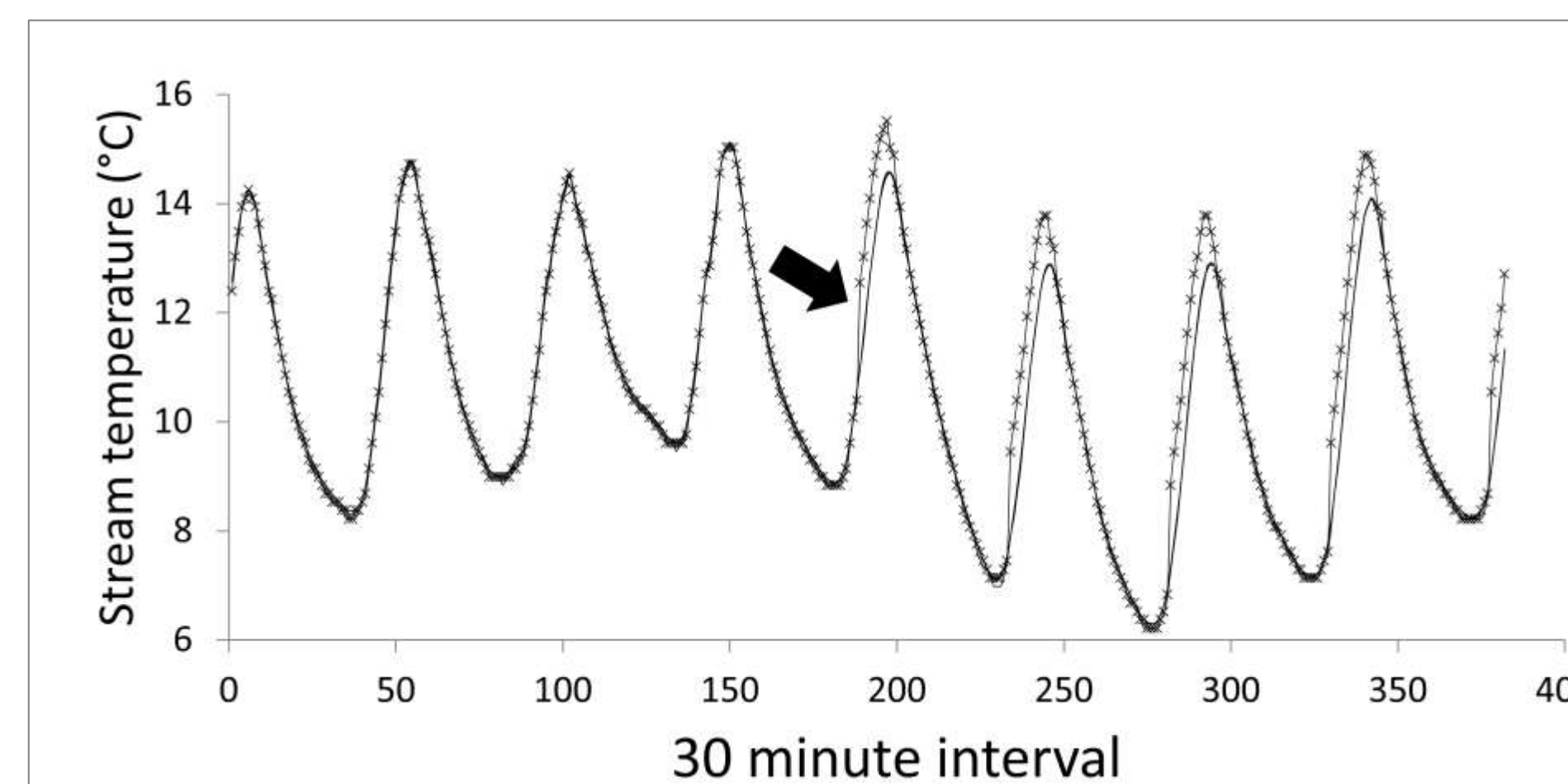


Figure 5. Assessment of sunlight on temperature sensor measurements. On day 5 (black arrow) the solar shield was removed from one sensor. Temperature measurements spiked immediately after sunlight struck the unshielded sensor.

Question # 3: What percentage of epoxied sensors are successfully retained at sites one- and two years after initial installation?

Method: During summer and fall low flow seasons from 2010-2012, underwater epoxy was used to establish 563 temperature monitoring sites in streams and rivers that ranged in slope from 0.1% - 16% across the northwest U.S. (Figures 6 and 7). During the summers of 2012 and 2013, a subsample of sites was revisited to determine one-year and two-year sensor retention rates (Figure 8).

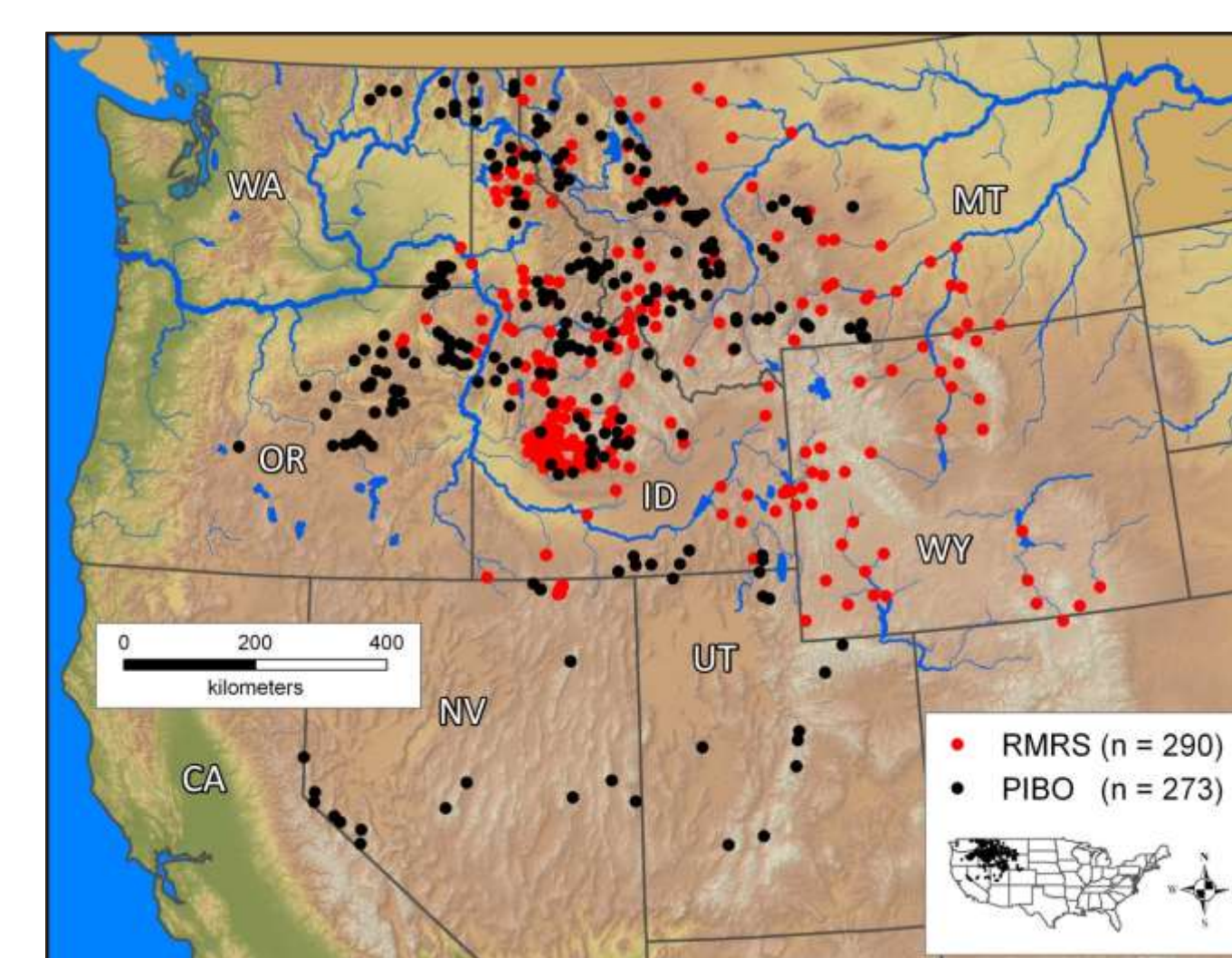


Figure 6. Annual temperature monitoring sites (n = 563) on streams and rivers in the western U.S. established using underwater epoxy.



Figure 7. Examples of large rocks used as protective anchors for annual temperature monitoring sites.

Results: One-year retention rates at 72 sites were 88% in low-gradient streams (< 3%) and 81% in steep streams (Figure 8a). Two-year retention rates at 35 of the successful first-year sites were 100% (Figure 8b). The most important factor affecting the likelihood of successfully establishing an annual monitoring site was the quality of initial site selection (Figure 9).

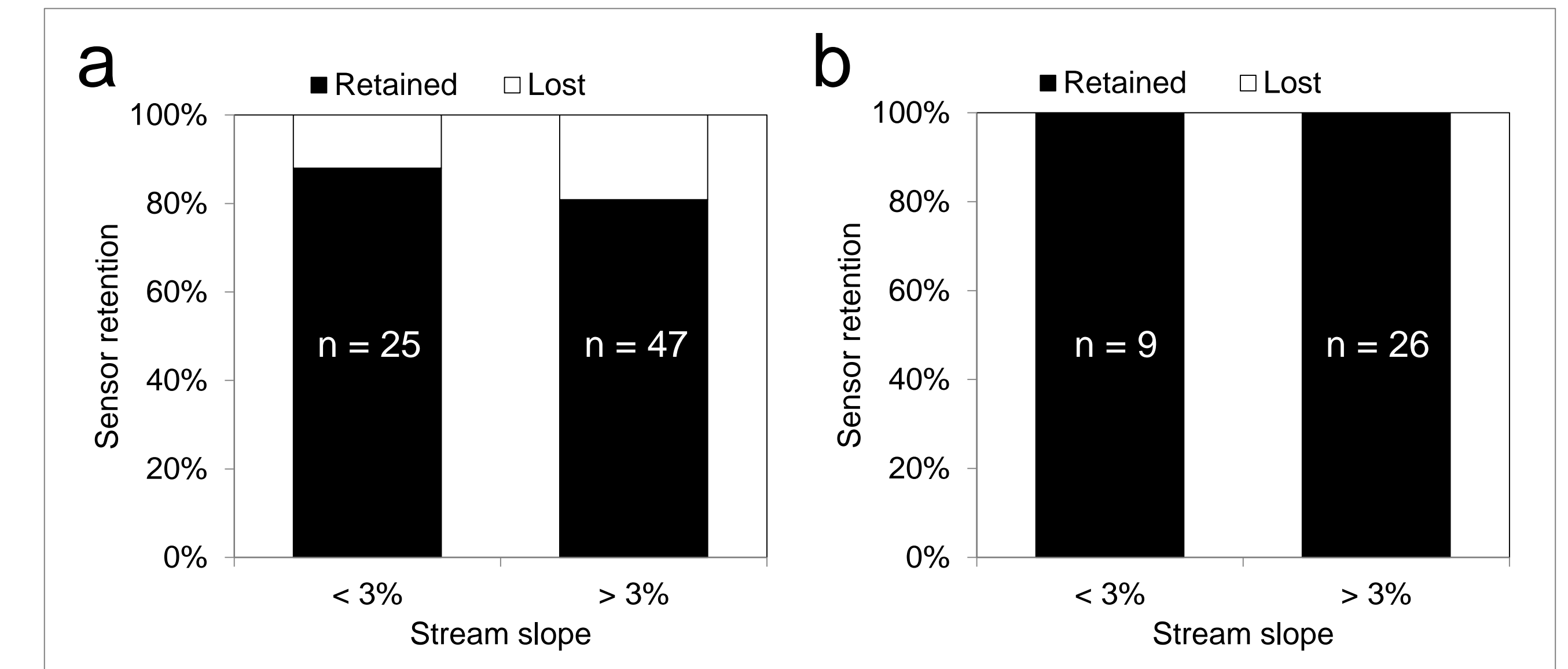


Figure 8. Sensor retention rates at one-year (a) and two-year (b) intervals by stream slope. The numbers in the columns are the number of stream sites within a slope class.

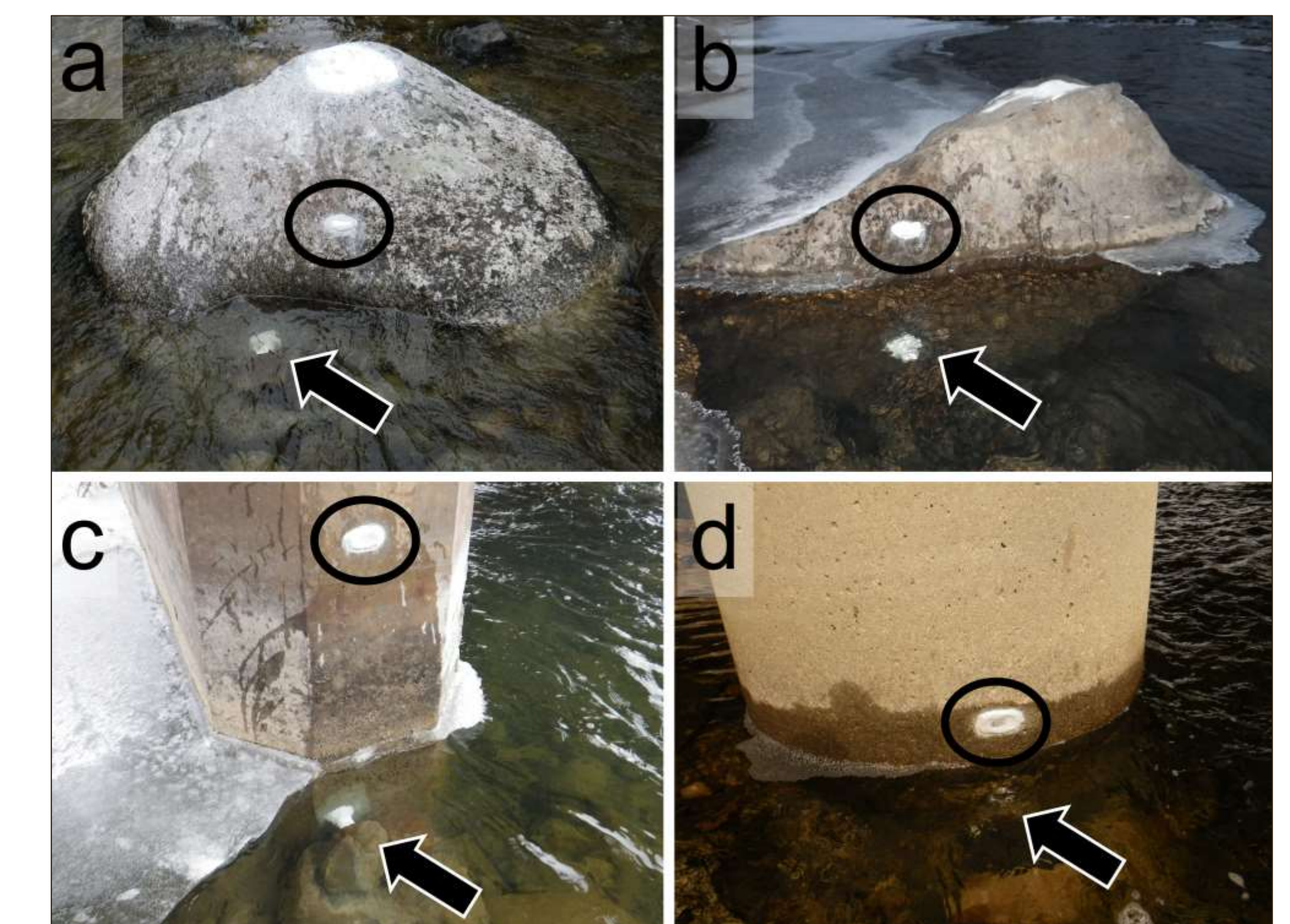


Figure 9. Examples of large rocks (a and b) and cement bridge supports (c and d) that provide good sensor attachment sites. Each site has a flat downstream attachment surface that is shielded during floods from bedload movement and debris. Arrows point to the PVC solar shield containing a sensor; circles highlight metal forestry tags used to monument a site. Suitable attachment sites could also include rocks used to stabilize eroding banks and roadbeds, stone culvert bases, and wing-walls along bridges.

Conclusion

Our results indicate that underwater epoxy provides a reliable means of establishing temperature monitoring sites in many rivers and streams. The epoxy technique should make annual temperature monitoring routine and reduce the cost of data acquisition because it requires fewer site visits. Moreover, the equipment required to establish a monitoring site is inexpensive (~\$10 for epoxy and PVC shield; \$40 - \$120 for a temperature sensor), so large monitoring networks can be developed with modest budgets. An installation requires about 20 minutes by a trained technician and can be done in a wide range of stream temperatures (2°C - 20°C).

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¹Mention of trade names does not imply endorsement by the U.S. Forest Service.

