Assessment of Large Woody Debris Installations as a Low-cost Solution to Erosion in Urban Streams

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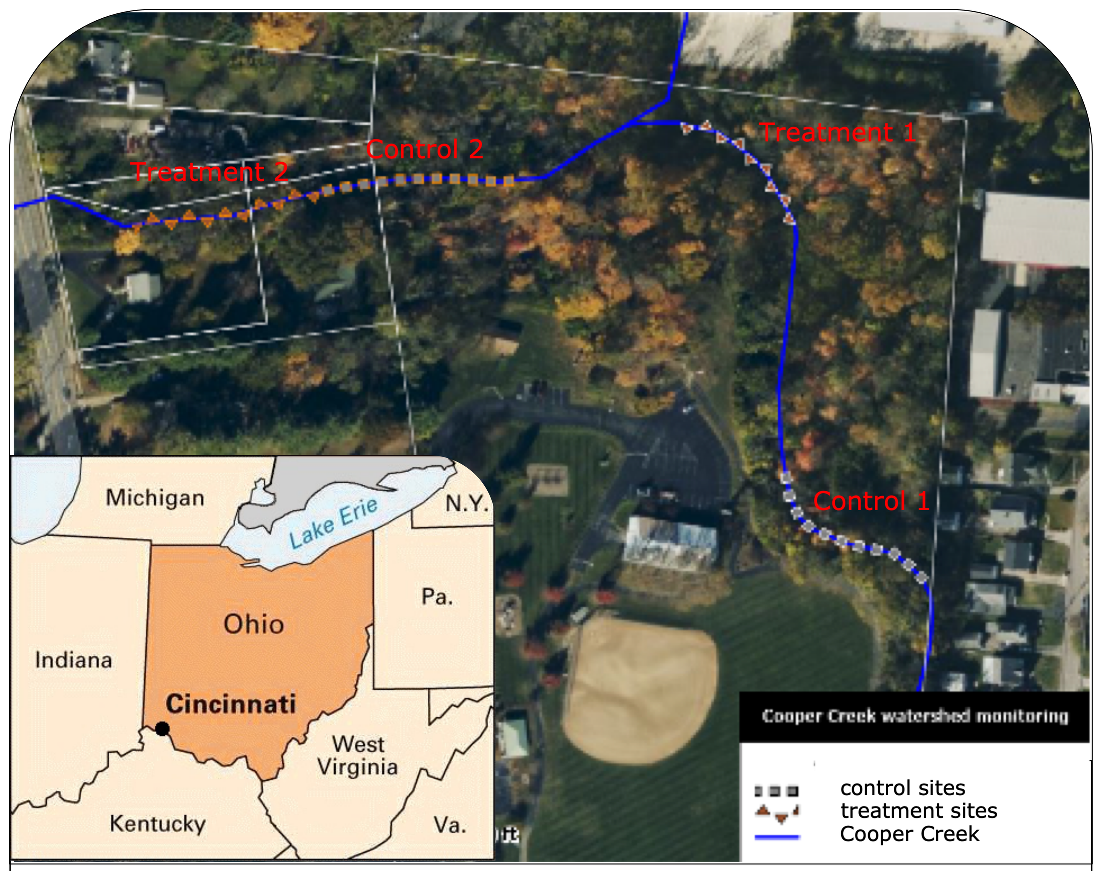
Log jams, like the one pictured above, were installed in Cooper Creek to help slow water velocities, reduce erosion, and create deep pool habitat.

Background Information

Urban streams are exposed to numerous stressors, including frequent erosive flows. These high energy events are caused by excess stormwater runoff that drains from impervious surfaces like asphalt, concrete, and rooftops. The erosive flows caused by this runoff result in stream bank erosion, fine sediment transport, bed mobility, and habitat alteration. The velocity at which the bed begins to mobilize is known as $Q_{critical}$. Restoration projects in urban streams often target a reduction in the frequency of $Q_{critical}$ events. Due to the high cost and disturbance of engineered channel restoration, we are investigating the utility of large woody debris (LWD) installations as a low-cost restoration practice. LWD is naturally occurring in midwestern streams and has documented benefits that include a reduction in flow velocities and erosion.

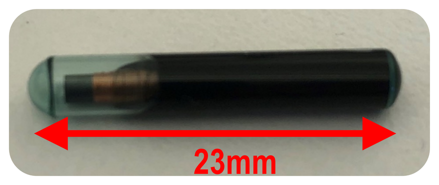
We monitored the movement of rocks in Cooper Creek, an urban headwater stream in Cincinnati, OH, over a two-month period before a LWD restoration project. The goal of this work is to understand how sediment mobilizes under different flow conditions and estimate $Q_{critical}$ prior to restoration. This data will eventually be included in a Before-After-Control-Impact study to assess the effectiveness of this type of restoration.



Cooper Creek has ≈40% impervious surfaces in its watershed. We monitored bed mobility in 4 reaches: 2 treatment reaches that have since been restored with large woody debris and 2 control reaches.

Tracking Bed Erosion

320 rocks were collected from Cooper Creek classified by their size (b-axis in mm size classes) and shape (flat or round) into 8 categories (32 round, 64 flat, 64 round, 128 flat, 128 round, 256 flat, 256 round, and 512 flat). B-axis size classes were based on pebble counts that identified the d_{35} to d_{85} particle sizes.



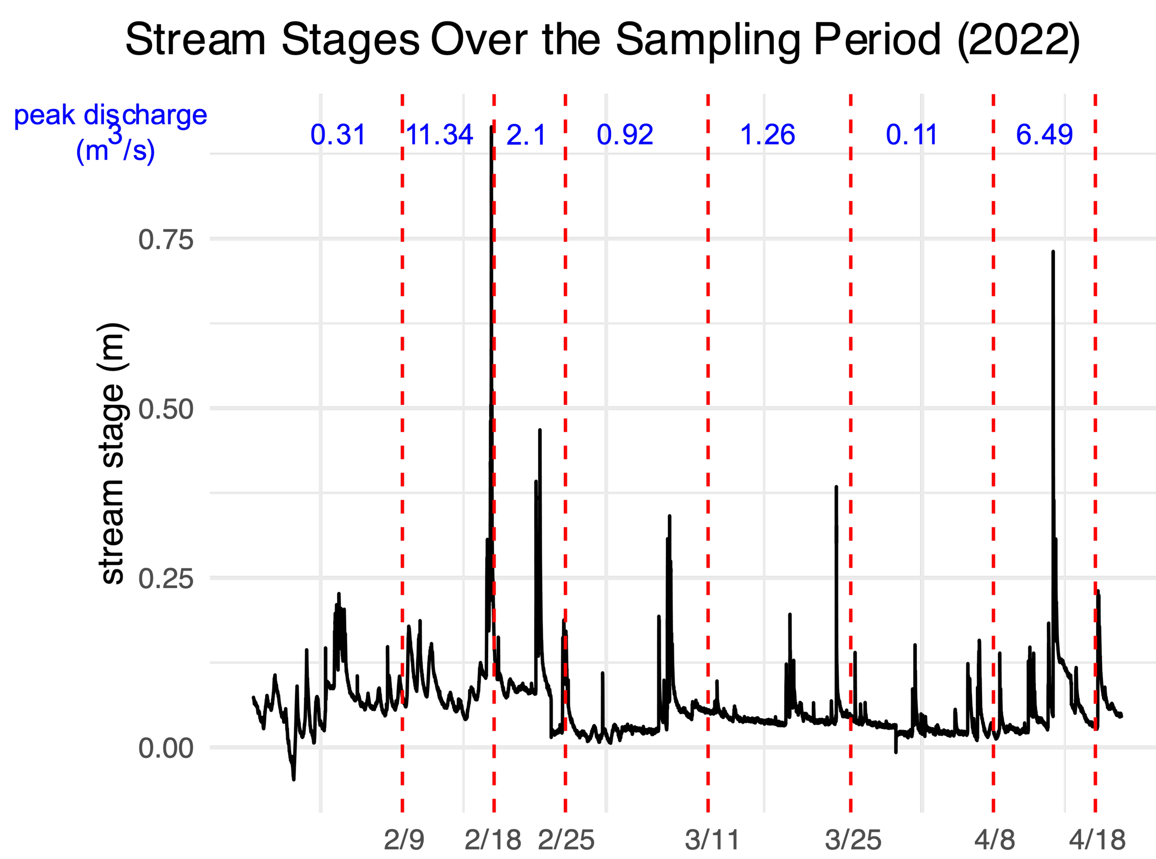
A PIT tag (shown above) was glued into each rock which gave them unique identification numbers and a means of relocation.

Rocks were returned to Cooper Creek and relocated after 7 storm events using a backpack PIT tag reader. If a rock moved 25cm or more, it was classified as having mobilized.

Questions:

- What magnitude of flow mobilizes the bed?
  - Estimate $Q_{critical}$
- What characteristics affect a rock's likelihood of mobilization?
  - i.e., size, shape, or starting reach

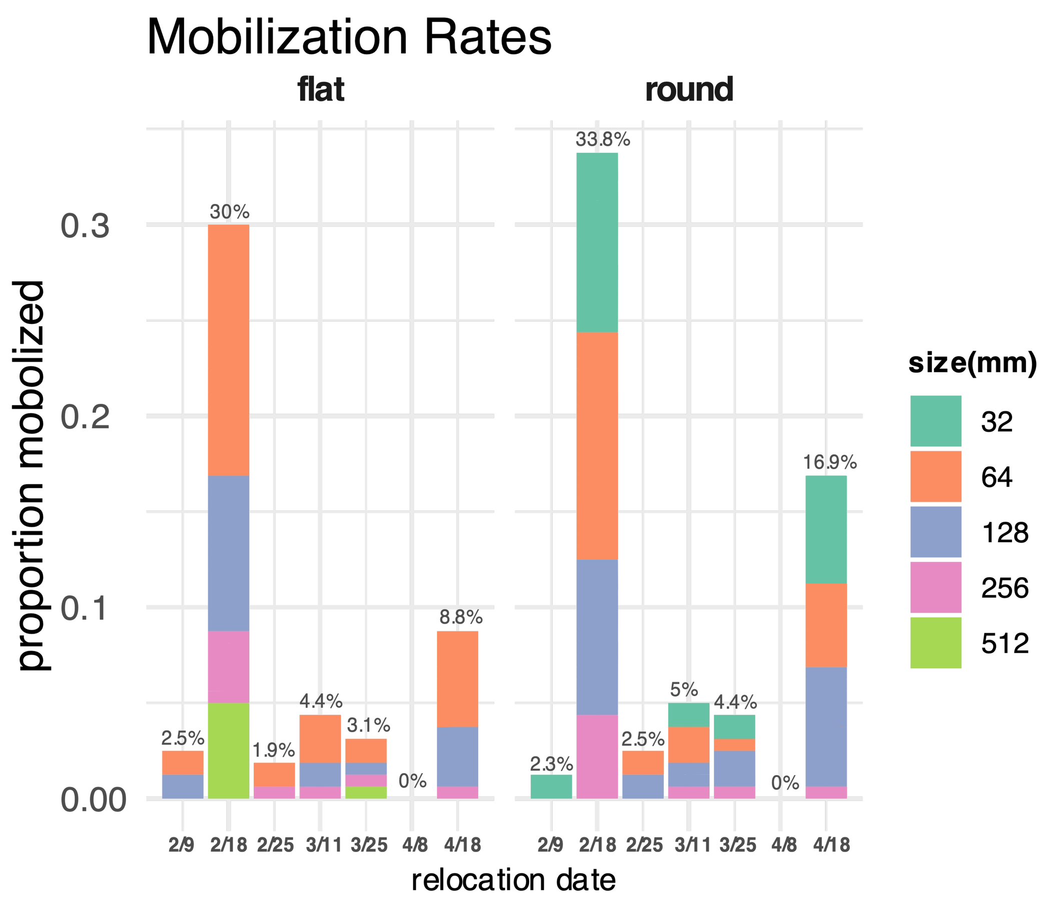
Quantifying Storm Events



Level loggers recorded stream stage at 5-minute intervals over the sampling period (sampling event indicated by red dotted lines).

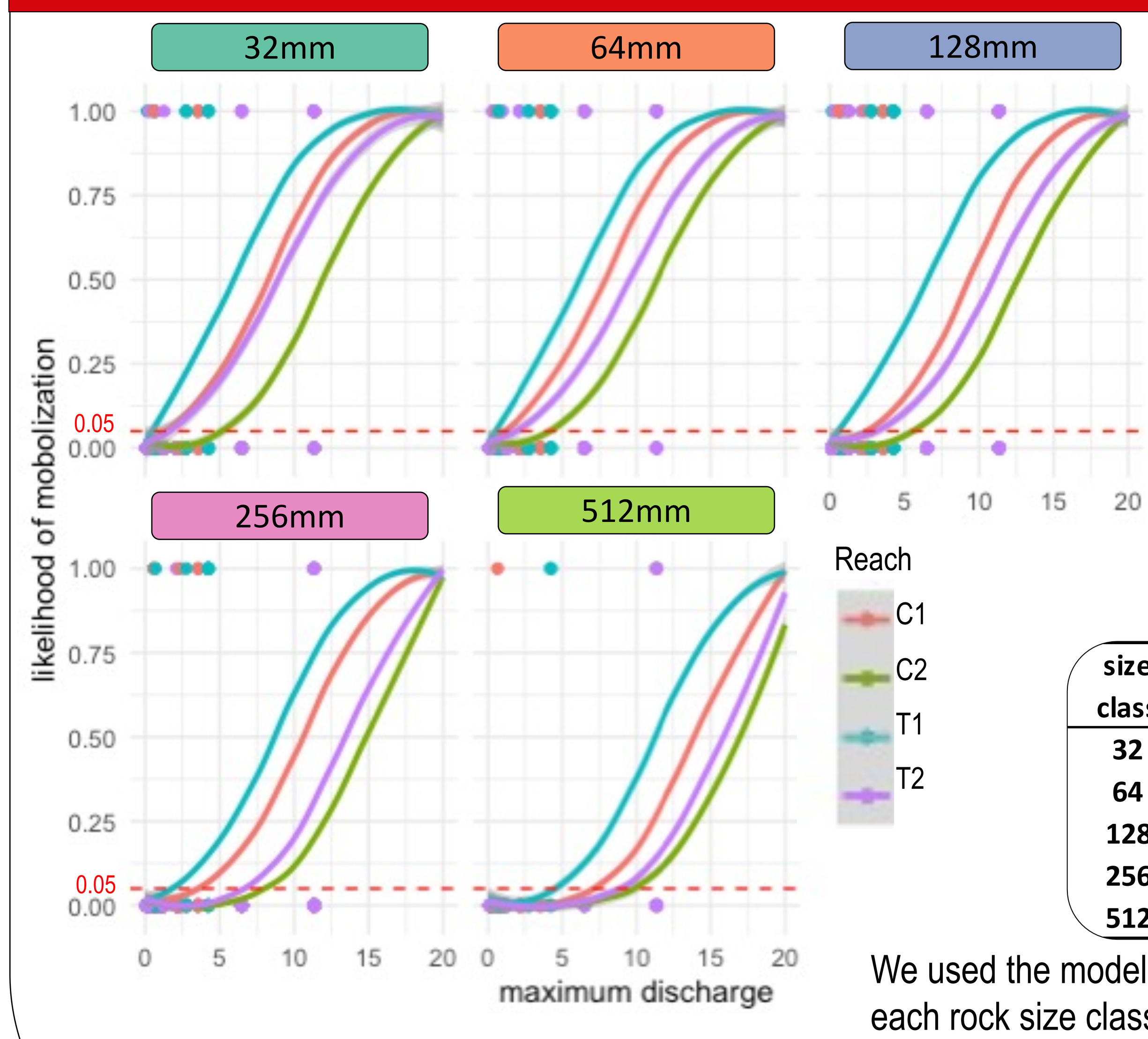
Level logger data was paired with manually collected discharge measurements to create a discharge rating curve. The rating curve allowed us to estimate the maximum discharge during each storm event.

Mobilization Rates



Two storm events produced a peak discharge strong enough to mobilized a significant amount (5%) of the tagged. The most severe storm event occurred on 2/18/22 and had a peak discharge of 11.3 m^3/s at downstream sites and 4.2 m^3/s at upstream sites. Smaller rocks are moving more frequently, however shape does not affect mobilization rates.

Analysis



We used a Bayesian generalized linear mixed effects model to understand how rocks are moving in each reach during storm events. After model reduction, the remaining parameters were size class, maximum discharge, and reach as fixed effects and rock ID number was treated as a random effect. The final model explained significantly more deviance than the null model (χ^2=342.04, df=5, p<0.01). Shape did not explain significant deviance in the model and was therefore removed during model reduction.

size	Qcritical estimates (m3/s)			
class	C1	T1	C2	T2
32	3.94	0.88	7.43	6.80
64	4.29	1.23	7.78	7.15
128	4.99	1.93	8.48	7.85
256	6.39	3.33	9.88	9.25
512	9.19	6.12	12.68	12.05

We used the model parameters to estimate $Q_{critical}$ (m^3/s) for each rock size class in each reach using a 5% likelihood of mobility as the $Q_{critical}$ threshold (red dotted lines). Shape not was considered when calculating these estimates because it was removed from the model.

Conclusions

This analysis provides insight into how the stream bed of Cooper Creek mobilizes different flow events. It demonstrated that larger rocks mobilizes less frequently than smaller ones and that flat and round rocks mobilize at similar rates during high flow events. Differences in $Q_{critical}$ estimates between reaches suggest difference in hydrologic or geomorphic conditions that affect erosion.

LWD restoration took place on 4/29/2022 and we have already begun collecting data in the post restoration period. The full BACI study also includes monitoring of wood stability, stream habitat, nutrient concentrations, fine sediment transport rates, and fish and macroinvertebrate communities.

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