Reviewed manuscript: From regular to random: a unifying framework for step-pool spacing

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Summary and Contribution:

The authors present a geometrically informed approach to addressing a relatively long-standing problem in steep stream geomorphology: are step-pools spaced in a regular or random fashion? I read the preprint with a lot of interest and appreciate the authors overall approach to the problem, particularly the fact that both outcomes (regular vs. random and variants in between) are generally treated as equally possible. I am very supportive of this work and believe it represents and important contribution to the step-pool and steep mountain stream literature.

Based on several readings of the manuscript, I offer primarily minor comments that can be addressed readily, but also offer a few more substantial thoughts that perhaps may take a bit more effort. On these points, I do not have any serious criticisms of the authors work, and look forward to seeing their responses and revisions. I want to thank the journal editors and authors for the opportunity to review the submitted manuscript, and for your patience as I completed my review. I hope that my comments are helpful to the authors.

Comments (generally ordered by line number)

Introduction: I think it would be helpful if the authors explicitly define “regular” and “random” in the context of this paper. Later on in Section 3, a set of definitions are given in relation to the coefficient of variation. But the authors also invoke a Poisson process to define the random reference line used in several figures, essentially defining random as consistent with a Poisson process. Being explicit would be helpful.

Lines 10-11. I appreciate the fact that the authors have compiled a comprehensive data set to test their proposed framework, and I applaud them for doing so. However, on face value I think it is tricky to place numerical simulations in the same category as the field-based and experimental observations. Whereas I think the numerical work that has been done has helped to advance step-pool science – to me that is clear. Nonetheless, the numerics are biased in terms of the rules/mechanisms implemented which effect step spacing. To be clear, I have no issue with use of the numerical results to test the framework presented here. At the very least, some level of background context on the numerical simulations and specifically the algorithms developed to drive the associated simulations can be discussed so readers understand these in relation to field-based and experimental observations. My fundamental difficulty is weighting field-based, experimental and numerical simulations equally when considerating the results illustrated in the authors organizing framework (an additional comment is provided below in relation to the framework, and what it represents).

Lines 21. Can the authors add references documenting the > 3% slope statement. A tremendous amount of fieldwork by numerous teams over the past four decades went into identifying this approximate minimum slope.

Lines 21-23. I am curious why in referencing resistance to flow the authors do not mention or discuss the work by A.D. Abrahams and colleagues (1995, Water Resources Research)? Their research focused squarely on developing what is called the "maximum resistance to flow" hypothesis through a careful set of flume experiments and field-based observations. Their work seems relevant. Going one step further, their research seems relevant from the point of view of building the background discussing formative mechanisms. I understand the authors are focused on mechanisms which support perspectives based on step spacing "regularity" vs. "randomness". In a real sense, step sequences which maximize flow resistance can be assocaited with "regularity". I encourage the authors to consider spending a bit more time spent discussing the broader relevant literature here, and throughout the Introduction. The paper as submitted is relatively focused, so there is reasonable room to expand where it might be warranted and without distracting too much from the paper's focus.

Lines 41-43. Great sentence.

Lines 44-47. It would be helpful if the authors could define their "framework" in more explicit terms. How would the authors describe their framework? Is it mathematical? Conceptual? Would they describe it as a regime space detailing how step spacing variability correlates (or co-varies since individual data points represent the same step sequence) with minimum spacing? I think one or two phrases inserted in the right locations, or one or two new sentences would be more than adequate here to address the comment.

Lines 64. Use of the term bedform (here and elsewhere) for steep streams is not usual per my understanding. As I understand, Montgomery and Buffington (1997, Geological Society of America Bulletin) made it more customary to refer to river bed architectures in gravel and boulder-bed streams as "channel-reach morphology", or "channel type".

Lines 72-73. I am unclear on the end of the sentence - "..with matching, typically random, spacing." The word matching is throwing me off. Can the authors clarify?

Lines 78-79. I think it would be helpful for all readers if you could simply write out the ratios you refer to in the sentences when discussing "standard deviation relative to the mean", and "minimum spacing between steps relative to the mean".

Lines 84. I think it is a clever approach to model "random" steps as a Poisson process. Can you use any of the published data to test this probabilistic/statistical approach? For example, if a pool exclusion zone based on hydraulics is a pervasive physical mechanism which limits step spacing (I agree that it has to be important), do we see steps within an exclusion zone along step sequences which are classified as "random" in the presented comparative framework? Basically, I am asking if the authors can provide some additional justification for the Poisson modelling approach for the "random reference line" in addition to Curran and Wilcock (2005, Water Resources Research). I am not calling the approach in doubt, but my past fieldwork biases my perspective a bit because I cannot recall measuring a step-pool sequence where I thought downstream steps were not in some way influenced by the upstream step(s). Again, this represents my own personal bias.

Figure 2. I think it is interesting that the comparative framework regime space shows no clear correlation with local bed slope (or at least none that I can discern from visual interpretation only). Given that several

previous published papers frame step-pool geometry around slope, I think the result of Figure 2 deserves some discussion.

Figure 3. Nice result, made more impactful by labeling each point by the inferred mechanism from each publication.

Lines 120. I am not sure what “and match expectations” means at the end of the sentence.

Lines 121-123. A conclusion consistent with the implications of this statement was reached when plotting Whittaker and Jaeggi (1987) in the anti-dune stability field. Many of the reported points do not fall in the stability field – see Chartrand and Whiting (2000, Earth Surface Processes and Landforms, Figure 9a).

Lines 134-136. This is a very important point – thanks for raising it. Can you report the variation in sample size for the datasets compiled and reported here? My general understanding is that it is common for step-pool sequences to contain anywhere from ~4-10 step-pool units. If this is correct, does this influence the conclusions drawn here (I suspect not since I believe the trends in the comparative framework are clear, and make physical sense)? Or is the sample size of the compiled data sets at least worthy of mention as a potential and inherent limitation? To be fair to the authors, I personally have never seen a step-pool sequence in nature with more than apprximately 15 step-pool units. And these cases define the end of the distribution from the fieldwork I have completed. My observational geography may be biased.

Lines 142. Why is a roughness-based mechanism “likely” in relation to other mechanisms? It would help to explicitly frame out the reasons and rationale in support of the statement.

Lines 155-165. I think this is an important paragraph – thanks to the authors for focusing on the subject points of the paragraph. I note that at least two prior publications have put forth specific analysis of how step-pool geometry has changed in time along the Rio Cordon, for example, following flood events (see Lenzi, 2001, Earth Surface Processes and Landforms; Chartrand et al., 2011, Geomorphology). Given this is a focus of the paragraph, a broader discussion folding in this work may be merited.

Appendices: Thanks for including the three appendices. They helped me better understand some of the analysis sitting behind the results.