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REPLY

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Reply to comment by S. P. Ferguson and C. D. Rennie on "A mechanistic model linking insect (Hydropsychidae) silk nets to incipient sediment motion in gravel-bedded streams"

Lindsey K. Albertson[1], Leonard S. Sklar[2], and Bradley J. Cardinale[3]

[1]Stroud Water Research Center, Avondale, Pennsylvania, USA, [2]Earth and Climate Sciences, San Francisco State University, San Francisco, California, USA, [3]School of Natural Resources and Environment, University of Michigan, Ann Arbor, Michigan, USA

Correspondence to:
L. K. Albertson,
lalbertson@stroudcenter.org

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1. Introduction

We thank Ferguson and Rennie for their interest in our experimentally calibrated model of sediment stabilization by caddisfly silk nets [*Albertson et al.*, 2014a]. In that study, we used laboratory flumes to evaluate model predictions by measuring the shear stress at the threshold of sediment motion under a variety of caddisfly species composition treatments over a range of sediment grain sizes. Ferguson and Rennie are primarily concerned with the method we used to correlate pump motor dial speed to flow velocity and ultimately local boundary shear stress. Specifically, the authors point out that "…three of the four estimated shear stress values were determined based on pump speeds that are outside of the range of tested values. Therefore…represent extrapolated data." The authors posit that the linear fit we used to correlate pump dial speed with velocity may not accurately capture the relationship and thus may incorrectly estimate values of critical shear stress for treatments in our experiment. We agree that extrapolation is not ideal, that other functions such as the power fit that they suggest could also be fit to the data and that the functional form chosen may influence the interpretation. This discussion highlights the need for future research at the interface of ecology and geomorphology to rely on interpolation rather than extrapolation when possible. Below we detail how and why we made our choices.

2. Response to Criticism of Data Interpretation

2.1. The Need for Extrapolation

To estimate shear stress as a function of motor speed, we measured velocity profiles in the near-bed region along the centerline of the flume using an Acoustic Doppler Velocimeter (ADV). To calibrate the stress-motor speed relationship across the range of critical shear stresses that caddisfly nets might produce, we used a sediment bed identical to the experimental beds, except with grains cemented into place. This allowed us time to measure a stable velocity profile without changes in bed configuration due to sediment movement. We found that a minimum motor speed dial setting of 20 was required to overcome the static head and generate steady flow in the flume. As shown in Figure 9 [*Albertson et al.*, 2014a], we were able to measure approximately log-linear velocity profiles at motor speed dial settings between 20 and 50. We chose to use extrapolation in the way that we did because motor speeds higher than 50 caused the flow to become too aerated to obtain reliable velocity measurements. In particular, flow aeration reduced the signal-to-noise ratio reported by the ADV to values below the quality control threshold. In the experiments with mobile sediments and caddisflies present, we observed initial sediment motion at motor dial speeds as high as 61. Hence, for flow conditions with motor speed dial between 51 and 61 we had to rely on an extrapolation using a fit to the measurements made at motor speeds between 20 and 50.

2.2. The Choice Between the Linear and Power Function Fits to the Data

As Ferguson and Rennie point out, our shear stress versus motor speed data could be fit by a power function instead of a linear function. We considered this option in our initial data analysis but rejected it for reasons described below. Comparing the two regressions, the goodness of fit statistics are almost identical. Although the power function fit is marginally better, both fits are highly significant. Specifically, for 22 mm grains our results show $p = 0.0108$ and $R^2 = 0.979$ for the linear fit and $p = 0.0070$ and $R^2 = 0.986$ for the power fit. However, three additional considerations support our decision to use the linear relationship.

First, using the power fit for the extrapolation to higher pump speeds nearly doubles the estimate for the critical shear stress for the polyculture caddisfly treatment, compared to the linear fit. Given that the effects of caddisfly nets on sediment stability have only recently been established [*Statzner et al.*, 1999; *Cardinale et al.*, 2004; *Albertson et al.*, 2014b], the linear fit represents the conservative choice that avoids a possible overestimate of the effects. Second, for a calibration curve, the prediction interval is the most relevant statistic to evaluate the estimated uncertainty [*Helsel and Hirsch*, 2002]. At the high motor speeds where extrapolation was necessary, the power fit prediction interval is 7 times larger than the linear fit. Third, the critical shear stress estimates we obtained with the linear fit are within the range of those measured for a similar study that correlated hydropsychid caddisfly biomass to critical shear stress for grains in the range of 20–40 mm diameter [*Statzner et al.*, 1999, Figure 7]. Hence, the linear relation is more conservative, less uncertain, and in the range of previous measurements obtained by different methods.

2.3. Local Versus Bulk Properties of the Flow

Ferguson and Rennie also question whether our results are consistent with the theoretical expectation of a linear relation between pump speed and discharge. We did not measure discharge nor did we attempt to characterize the velocity structure of the flow outside our narrow zone of measurement. Because the flume has a small width-to-depth ratio, wall roughness influences the local flow velocity throughout much of the rest of the flow. Wall roughness may help explain the linear fit, but we are unaware of a mechanism that would explain the power relationship with an exponent as big as 3.5. We measured log-linear velocity profiles only in the near-bed region along the centerline of the flume and reasoned that initial sediment motion would correlate best with the bed shear stresses at the center of the flume, where wall effects are least influential. It may be that for the bulk flow a different relation between total shear stress and pump speed may apply, particularly at higher discharges where the fraction of the total shear exerted by the walls is larger. However, for our purposes, the empirical finding of a highly significant linear relation between shear stress and motor speed in the near-bed region along the channel centerline provides a sufficiently robust calibration technique.

3. Conclusion

We appreciate the constructive comments of Ferguson and Rennie and acknowledge that there are other ways to fit the limited data we were able to obtain. However, uncertainty in the absolute values of our estimates of critical shear does not alter our main finding that the model predictions are broadly consistent with the experimental data. Regarding the specific estimates of shear stress we reported, we noted in the discussion that "because all of our calculations and comparisons were made relative to controls that had no caddisflies, we are certain that the results reveal relative, if not absolute, effects of caddisflies on sediment movement" [*Albertson et al.*, 2014a]. This statement was intended to encourage readers to use caution in applying the absolute values of our estimated critical shear stresses, especially given the difficulty of accurately measuring shear stress and the variety of methods that can be used [e.g., *Wilcock*, 1993, 1996].

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The data for this paper are available from the authors.

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