Relationship Between Streambed Mobility And Invertebrate Abundance In Mountain Streams

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Abstract

I studied the relationship between streambed mobility and invertebrate abundance in mountain streams. I collected invertebrates and I measured different variables on the streambed. I calculated the difference between critical shear stress and ambient shear stress. This difference is termed sub-critical shear stress, and I compared the sub-critical shear stress with invertebrate abundance. I hypothesized that sub-critical shear stress influences invertebrate abundance on the streambed, and that geomorphic conditions influence invertebrate habitat. I found that there was no significant relationship between sub-critical shear stress and invertebrate abundance. I also found that there was a significant relationship between velocity and invertebrate density, indicating that velocity has an effect independent of streambed mobility.

Background and Introduction

Shear stress is a measure of the force that the water exerts on the streambed. The most important variable that influences shear stress is water velocity near the streambed, which relates to water depth and the slope of the streambed (Leopold et al., 1964). At a low shear stress, particles on the streambed do not move. Increasing shear stress leads to a threshold called critical shear stress at which particles begin to move. The critical shear stress depends on particle size, and on particle density.

Many previous studies have been conducted relating velocity and particle size to invertebrate abundance. There have been few direct studies that combine velocity and particle size. In general in mountain streams, the shear stress is high and there is variation within the streambed (Statzner, 1981). The composition of the particles (sand, gravel, cobble or boulder), which is related to shear stress, can influence invertebrate abundance. For example, Bourassa and Morin (1995) found that invertebrate densities are higher on gravel than they are on sand. One possibility is that streambed mobility is controlling invertebrate abundance.

I predicted that where the actual shear stress was much lower than the critical shear stress, there would be a greater abundance of invertebrates. Research shows that more invertebrates exist on stable streambeds than on unstable streambeds (Death and Winterbourn, 1995; Winterbottom et al. 1997). There may be a low invertebrate abundance with increasing streambed mobility (Duncan et al., 1999).
Methods

The fieldwork for the study was conducted in the headwaters of Boulder Creek, a first order stream, near Eldora, CO. The dates of the fieldwork were July 12-16, July 18, and July 22. I conducted the study over a 100 m reach with 20 sites. The dominant particle sizes in the streambeds were cobble and boulder. The average width of the stream was approximately 5 m.

![Figure 1. Slope of the 100 m study reach. Locations of 20 transects where measurements were made are denoted.](image)

To calculate ambient shear stress, or \( \tau_{am} \), for each transect I used the equation \( \tau_{am} = \rho gh s \) with the units of (N/m²), where \( \rho \) is the density of water (1000 kg/m³), \( g \) is the acceleration of gravity (9.81 m/s²), \( h \) is the ambient depth, and \( s \) is the slope. I placed a tape measure along the stream reach at randomly selected cross sections. I measured slope at 2 m intervals using an abney level and a stadia rod. I therefore had fifty slope measurements along the 100 m study reach (Figure 1). I graphed slope versus upstream distance for the reach, and visually separated the reach into 3 sections with distinct slopes. I measured the maximum depth at random cross sections along the river with a stadia rod.

To calculate the critical shear stress for each transect I used the equation \( \tau_{cr} = \kappa g(\rho_{sed} - \rho)D_{50} \) (Shields, 1936) with the units (N/m²) where \( \tau_{cr} \) is the critical shear stress,
\( \kappa \) is the von karmon constant 0.03 (Pitlick and Van Steeter, 1998), \( g \) is the acceleration of gravity (9.81 m/s\(^2\)), \( \rho_{sed} \) is the density of sediment, \( \rho \) is the density of water (1000 kg/m\(^3\)), and \( D_{50} \) is the median particle size. I determined \( D_{50} \) by measuring the length of the median axis of each particle at each site. I then calculated the median particle size by conducting a particle size distribution using a Wolman Pebble Count Sheet. \( D_{50} \) is relevant to critical shear stress because critical shear stress is different for each particle size. Density of particles varies little and therefore is less important.

I calculated density of the sediment, which is expressed as mass/volume (kg/m\(^3\)). To calculate mass I weighed the sediments on a scale. To calculate the volume I put the sediments into a graduated cylinder filled with water and judged the change in the level of the water. I calculated density for sand, gravel, and cobble. I used the density of cobble for the density of boulder.

The difference between the ambient shear stress and the critical shear stress is the sub-critical shear stress. The sub-critical shear stress was calculated as \( \tau_{crit} - \tau_{amm} \) or \( \tau_{sub} \) (N/m\(^2\)) for each transect. At each site I also measured the velocity along the thalweg with a current meter at 0.4 times the depth above the streambed, bank full width, and bank full depth. On each sampling day I measured the discharge (m\(^3\)/s) at a transect with fairly uniform flow characteristics located 74 m upstream from the start.

In order to calculate invertebrate abundance, I measured the density [number of invertebrates per unit sampled area (#/m\(^2\))] and biomass [the mass of the invertebrates per unit sampled area (g/m\(^2\))] of invertebrates that I collected using a 0.083 m\(^2\) Surber sampler. In the field, I preserved the invertebrates in 70% ethanol in the field and removed detritus, then in the lab I removed any remaining detritus. First I calculated the density by counting the number of invertebrates at each site. Then I oven dried the invertebrates in the 70% ethanol at 60°C and weighed the invertebrates with a balance to have a dry mass to calculate the biomass.

### Results

At the study site, the smallest discharge was 0.27 m\(^3\)/s, the largest discharge was 0.38 m\(^3\)/s, and the average discharge was 0.34 m\(^3\)/s. The shortest bankfull width was 4.2 m, the longest bankfull width was 7.8 m, and the average bankfull width was 5.6 m. The shallowest bankfull depth was 0.4 m, the deepest bankfull depth was 1.1 m, and the average bankfull depth was 0.6 m. The lowest velocity was .02 m/s, the highest velocity was 1.1 m/s and the average velocity was 0.5 m/s.

Figures 2-5 show the results. Figure 2 shows sub-critical shear stress against invertebrate density. Figure 3 shows sub-critical shear stress against invertebrate biomass. Figure 4 shows velocity against invertebrate density. Figure 5 shows velocity against invertebrate biomass. I graphed velocity against invertebrate abundance because velocity may have a direct influence on invertebrate abundance. In the statistical analysis of results, F values with a probability less than 0.05 are considered significant.
Figure 2 shows that there was no significant relationship between sub-critical shear stress and invertebrate density (F value probability = 0.12). Figure 3 shows a graph of sub-critical shear stress against invertebrate biomass. In this graph, there is no significant relationship (F value probability = 0.91). Figure 4 shows a graph of velocity against invertebrate density. This graph indicated that there was a significant relationship between velocity and invertebrate density (F value probability = 0.04). Figure 5 shows a graph of velocity against invertebrate biomass. The relationship between velocity and invertebrate biomass is of no significant relationship (F value probability = 0.49).
Figure 2. Relationship between sub-critical shear stress and invertebrate density.

Figure 3. Relationship between sub-critical shear stress and invertebrate biomass.
Figure 4. Relationship between velocity and invertebrate density.

Figure 5. Relationship between velocity and invertebrate biomass.
Discussion

This study finds that there is no relationship between sub-critical shear stress and invertebrate density or biomass. There are several reasons why sub-critical shear stress shows no relationship to invertebrate density and biomass.

Particle size and particle size distribution are important factors in the distribution of invertebrates on the streambed. Invertebrate abundance varies over a broad range of particle sizes. There could be more than one peak for sediment sizes among the range of sites for D₅₀ (Poff et al., 1993). Cobble was the dominant particle size for the sites in general. Particle size and particle size distribution relate to my project, in that, on the streambed, shear stress may never reach critical when the distribution of particle sizes is such that particles can not move. Since the streambed does not move invertebrate abundance should be higher under those stable conditions. For example, small particles might be stuck behind bigger particles and it would require higher shear stresses to move the smaller particles. It is possibly more important to study the alignment of particles since invertebrate abundance changes with different types of particle alignment.

Sub-critical shear stress, or streambed mobility, may not control invertebrate abundance. Further research on the other variables and on combinations of the other variables that relate to invertebrate abundance needs to be done. It is possible that invertebrate abundance is controlled by multiple factors (Death and Winterbourn, 1994). Invertebrate density and invertebrate biomass are difficult to understand in terms of their controlling factors and their relationship with their surrounding environment.

In my study, I addressed the role of streambed mobility in invertebrate abundance. My study has shown that either there is no significant relationship between sub-critical shear stress and invertebrate abundance, or that different methods for calculating sub-critical shear stress and invertebrate abundance might be needed to demonstrate a relationship.

In conclusion, my data shows that velocity plays an important part in invertebrate abundance, but not through its influence on streambed mobility. At a higher velocity, there are coarser particles present to provide more living space for invertebrates. The relationship between the higher velocity and invertebrate density indicates that the importance of velocity does not relate to streambed mobility. The relationship is the most important result from my study.

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References


