The Effects of Sediment Transport and Deposition on Stream Flow and Ecology Following a High Intensity Fire Along the Tuolumne River.

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Introduction

Historically, fire has naturally played a sustained role in the Sierra Nevada Mountains up until the past hundred years. Prior to the 20th century suppression efforts, fire return intervals were recorded at less than 50 years and more commonly less than 20 years (McKelvey, 1996). Within Yosemite National Park, American Indians once set fires to promote the growth of plants they relied on for food, medicine, and producing materials for baskets and shelter construction. Lightning strikes were also a source of natural fires that prevented overgrowth and unhealthy forests. By 1970, scientists realized the negative impacts fire suppression methods were having on the health of the forests. As a way to reintroduce fire to the area the National Park Service has utilized careful prescribed burns for the past 40 years to clear unsafe debris and for ecological restoration purposes (Than, 2013).

Despite these new efforts, on August 17, 2013 a large wildfire, termed the “Rim Fire,” started within the central Sierra Nevada region. The Rim Fire was the third largest in California’s history and burned roughly 257,000 acres of forest (Lopez, 2014). Started by a hunter’s illegal fire, the Rim Fire was exacerbated by the weather conditions at the time that included a heat wave and drought. Despite the efforts of over 5,000 firefighters the fire is estimated to have caused $54 million in damages (Howard, 2014). While the human-incurred costs are extensive, the impacted ecosystem bore the most significant losses. One of the largest ecosystem stressors that often accompany large fires are increased quantities of sediment eroded from hillslopes that is then transported to, and through, river systems post-fire. This research paper aims to combine previously examined post-fire stream hydrology and geomorphology with a recent study of the Tuolumne River in an effort to determine the sedimentation and stream effects following the Rim Fire.

Methods:

To determine fine sediment transport and deposition behavior along the Tuolumne River, the V* method was used to estimate the fraction of pool volume filled with fine sediment. Sue Hilton and Thomas Lisle (1993) claim V* measurements provide a fairly accurate index of sediment supply when stream conditions are uniform across sample sites. They outline the following criteria sample reaches must meet:

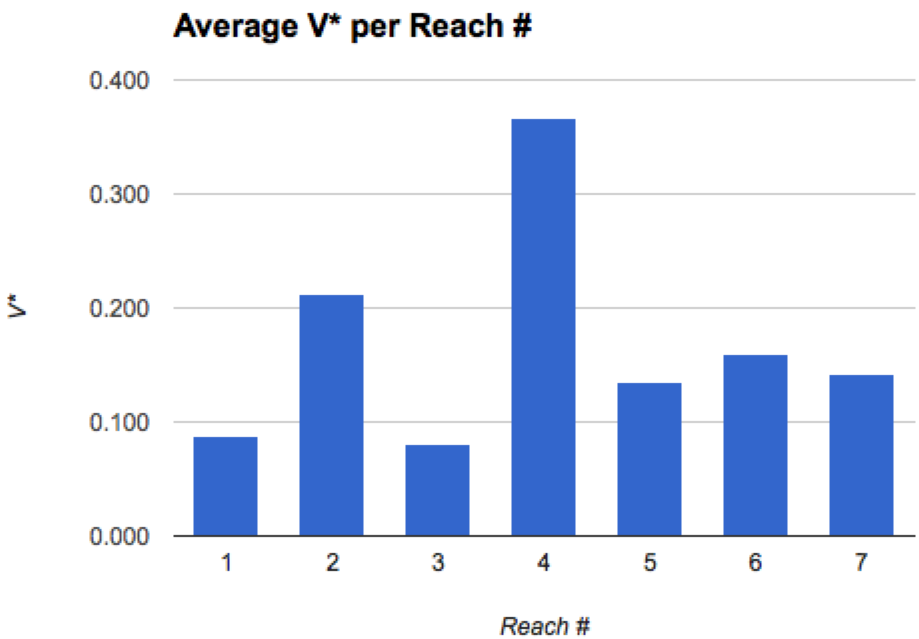
- There must be a wide range in particle size between armor layers and fine sediment in pools (sediment supply needs to include moderate levels of sand and fine gravel).
- Stable banks must consist of densely rooted alluvium, bedrock or armored colluvium.
- The stream must be a single thread (no braided channels).
- Gradients must be less than 5% (no step pools or bar pools).

V* measurements were done using a standard graduated V* probe driven into fine sediment deposits by hand along transects. The calculation is included below:

$$V^* = \frac{fine\ sediment\ volume}{pool\ water\ volume + fine\ sediment\ volume}$$

The Tuolumne River V* measurements used three or more parallel transects per pool depending on the pool length along with multiple depths measured along each transect based on pool width.

Results:



Reach 1 - Tuolumne Meadows
Reach 2 - Tuolumne Meadows
Reach 3 - Preston Pool Side Channel
Reach 4 - Early Intake
Reach 5 - South Fork of the Tuolumne
Reach 6 - Confluence of South Fork & Clayvey
Reach 7 - Main Stem of the Tuolumne

Discussion:

Although our measurements did not completely align with the V* data from the Eddy Sharks' (2014) study, changes in sedimentation were clear following samples downstream which potentially imply relationships between fine sediment deposition and transport rates with macroinvertebrate and subsequently fish diversity and abundance.

Macroinvertebrates not only suffer from declines in their primary producer food sources, but also from altered substrate composition, increased instability of the substrate and consequent drift, lower oxygen concentrations in the water column due to suspended sediment, and deposition on gill structures (Wood et.al., 1997). The Ephemeroptera, Plecoptera, and Trichoptera orders of macroinvertebrates, commonly called “EPT,” are especially impacted by these effects. EPT orders generally rely on available oxygen, prey sources, and primary producers which are all impacted by sedimentation. One specific hardship is the loss of interstitial refuge space. Many macroinvertebrates use these interstitial spaces between course sediment to hide from predators, when excess fine sediment is introduced into the system, these spaces are filled and macroinvertebrates are inclined to leave their original niche to find safety (Harrison et.al., 2007). Some orders, such as Chironomidae, Oligochaeta, and Sphaeridae are adapted to take advantage of fine sediment and flourish during sedimentation events in which EPT orders decline. Oligochaeta and Sphaeridae are able to burrow into the sediment for shelter while Chironomidae make use of the fine sediment to construct cases and tubes to live inside (Wood et.al., 1997). Unfortunately, EPT orders are the most productive food sources for aquatic fishes and their presence or absence plays a vital role in the suitability of a space for fish habitation (Harrison et.al., 2007)

Sediment also disrupts fish during their most vulnerable states as eggs and larvae. As sediment fills interstitial spaces between course sediment, there is a lack of intergravel flow necessary to oxygenate eggs. This reduces egg survival and can prompt premature hatching of larval fish, increasing the likelihood that they will be unable to avoid predation. Extreme sedimentation events can entomb eggs before they even have a chance to develop, and sediment loading of ideal spawning gravels decreases the amount of available spawning habitat to begin with, leaving only few spaces where eggs are capable of being deposited (Wood et.al., 1997).

Conclusion:

The effects of sediment deposition and transport on stream flow and ecology are not necessarily clear, however, many relationships can be made between sedimentation, morphology and species abundance. In order to further support the link between sediment supply and ecogeomorphology, more V* measurements in the same sample sites are needed. Despite the gaps in comparable measurements, some conclusions may still be drawn from the above analyses. First, it seems as though sediment levels have lowered throughout the Tuolumne watershed, which indicates that the river is transporting sediments downstream at a rate greater than deposition. The significance of this observation lies in the fact that the river is showing characteristics of restoration to it's previous state. Second, macroinvertebrate levels follow the expectations made in the Eddy Sharks' (2014) study, which implied that the high levels of sedimentation following the Rim Fire affected macroinvertebrate species and lowered the EPT % along the Tuolumne. This statement is further supported by the fish populations observed along the river, which reflect a greater abundance in species that do not rely on EPT macroinvertebrates. Finally, sediment samples at the confluence of the Clayvey River and South Fork Tuolumne River indicate transport of ash deposited from the Rim Fire, which further supports the claim that post-fire river processes begin to revert to original stream conditions within a few years after the high intensity event.

Future studies would benefit from sampling in the same regions along the Tuolumne River, but might also appreciate incorporating stratigraphic samples of the soils along the river banks where ash deposits may reside, which could signify further recovery processes attributed to river ecogeomorphology.

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