Neil Singh
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GEL 136 Research Paper

Changes in Sediment Load and Benthic Macroinvertebrate Communities of the Tuolomne River

Introduction

Much of the Tuolumne River has changed significantly since the construction of dams and melting of the Lyell Glacier. These events have caused significant changes in abiotic stream conditions as well as channel morphology, further exacerbating conservation issues resulting from non-native fish species introduction and changes in sediment load. Such physical and ecological changes have shifted the dynamics of aquatic communities in the Tuolumne and require monitoring to maintain the health and integrity of natural ecosystems and processes.

Prior to the loss of strong springtime melts from the Lyell glacier and damming of the mainstem, the Tuolumne had seasonal flow variability that created unique conditions for local flora and fauna. Combined with California's mediterranean climate, the Tuolumne historically experienced high flows in winter and early spring, followed by a late spring snowmelt recession and low flows in the summer and fall. Such variation causes seasonal fluctuations in flow conditions, chemical composition and water temperature of the Tuolumne as well.

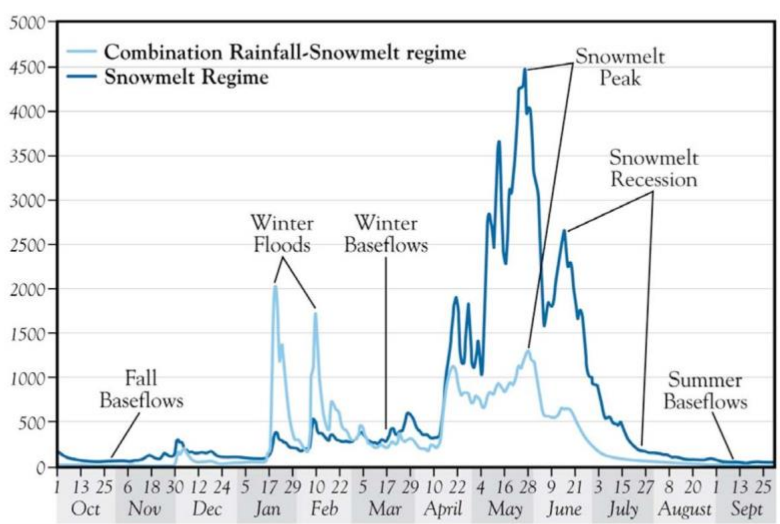


Figure 1 – Rainfall-Snowmelt Regime of the Tuolumne, *Epke et. al 2010*

Endemic species are very well adapted to such changes, and this variability created high levels of complexity and diversity in the Tuolumne (*Confluence*, pg. 41 & Yarnell et. al, 2017). The seasonal disturbance of low and high flows fostered niche partitioning so that local species could either tolerate or quickly take advantage of variable conditions, resulting in highly specialized functional dynamics as well as greater species diversity (Gasith and Resh, 1999). However, this variability has been reduced significantly due to earlier and lower magnitude spring snowmelt and damming, which limit natural flood pulses and trap sediment.

Benthic Macroinvertebrates (BMI's) are an incredibly important part of river and streams and are useful indicators of how such changes have impacted the aquatic ecosystem (Allan & Castillo 2007, pg. 350). They are a food source for fish and other aquatic wildlife, their interactions and diversity reflect stability and diversity of larger organisms, and they act as good indicators of suitable flow conditions (EPA, 2016). BMI's can be categorized into functional feeding groups as well as tolerance indices to examine the biotic impacts of water quality, channel substrate, dissolved oxygen and temperature in a stream (Allan & Castillo, 2007, Chadde 2007). Monitoring these communities determines changes in ecological parameters of the stream channel as well as the feasibility of restoration or conservation efforts.

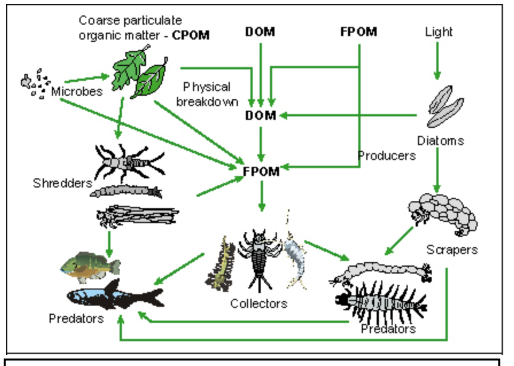


Figure 2 – Food Web Diagram of Benthic Macroinvertebrates

In managing the Tuolumne river, understanding the effects of an altered flow regime is critical to native species conservation. Altering the flow regime changes the sediment load of the stream (Wohl et. al 2015) which can drastically affect water quality and channel substrate. As a result of their sensitivity to such changes, BMI community composition can be used to examine changes in ecological health and sediment supply characteristics of the watershed.

Objectives

This paper will examine how damming and climate change have impacted the Tuolumne by looking at spatial changes in sediment load and benthic substrate in the watershed. The magnitude of such changes will be assessed by analyzing changes in benthic macroinvertebrates populations in terms of functional feeding groups and tolerance taxa from upstream to downstream. The implications of these findings will be used to evaluate future management strategies for the Tuolumne River in the context of climate change.

Discussion

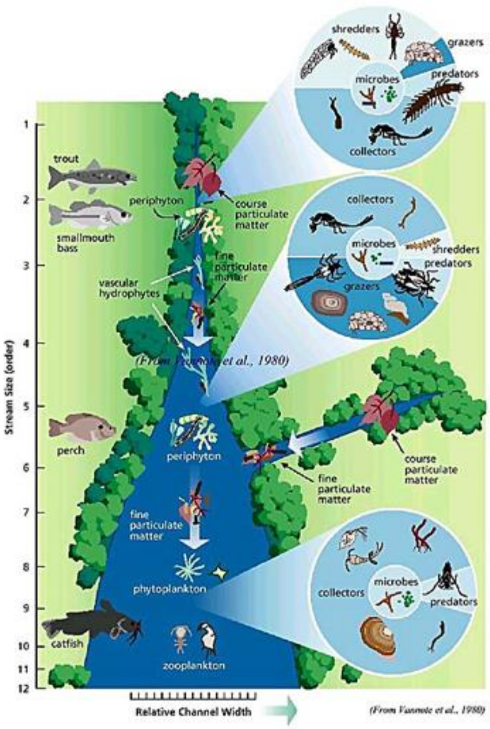
According to several studies conducted on the Tuolumne, the upper reaches of the river had the highest level of biodiversity, while the Tuolumne mainstem had the lowest level of biodiversity (Jasper et. al 2014, Lambert et. al 2015 & Hall 2006). This difference is likely a result of the less regulated nature of the upper reaches, while the mainstem had daily fluctuations of flow resulting from controlled flood pulses for whitewater rafting and hydropower. Such pulses created unsuitable flow conditions and sediment substrate composition for historic BMI communities (Feld & Hering 2007).

However, the mainstem of the Tuolumne had a higher coarse-grain percentage than other reaches of the Tuolumne (Lambert et. al 2015, EcoGeo, 2016). Coarser substrate is typically considered preferable habitat for invertebrates (Harrison et al. 2007). Low diversity and stream health values likely persisted in the mainstem below Hetch-Hetchy due to the daily flow variation. Lower biodiversity was also observed in upper reaches of the Tuolumne closest to the reservoir (Jasper et. al 2014). Cooler year-round water temperatures and finer substrate above the Hetch-Hetchy dam likely contributed to this lessened diversity values.

BMI diversity approaching the reservoir is likely very low due to significant changes in channel morphology and water depth. As previously stated, macroinvertebrates in the Tuolumne are more accustomed to varying temperature conditions. The deepness of the reservoir coupled with its fine sediment layer prevents plant life from establishing and lowers oxygen levels in the water, inhibiting BMI diversity (Allan & Castillo 2007, Extence et. al 2013).

Habitat quality and many abiotic conditions were ranked much lower in reaches downstream of Hetch-Hetchy and the powerhouses compared to upstream conditions (Hall, 2006). Water temperature and conductivity were lower in reaches above the damming structures and DO was higher in upper reaches. This indicates that the unregulated reaches above Hetch-Hetchy reservoir provide much better habitat for BMI diversity than downstream areas. Additionally, most tolerant taxa were found below Hetch-Hetchy, and higher sensitive taxa percentages (measured as EPT, or Ephemeroptera, Plecoptera, Trichoptera percent over all taxa) were found upstream of the mainstem and below New Don Pedro Dam (Lambert et. al 2015).

Figure 3 – Illustrated depiction of theRiver Continuum Concept, *Vannote et al. 1980*



These results do not comply with the River Continuum Concept (Vannote et. al 1980), which describes the changes in biodiversity seen along a river going from upstream to downstream. Differences in abiotic factors of the stream as well as nutrient inputs throughout the river change the composition of invertebrate communities, shown here in Figure 3. More plant matter is added into streams in upper reaches than grow there, and shredders and collectors typically prevail because of a higher fraction coarse organic particulate matter (CPOM) than dissolved organic particulate matter (DOM – see Figure 2). As the channel increases in width and depth downstream, less CPOM can enter the river from riparian vegetation and DOM becomes prevalent, leading to dominance of BMI communities by collectors and predators. According to this concept, the middle reaches of the river (those with intermediate amounts of CPOM and DOM) should yield the highest amount of diversity.

If this was the case, the mainstem of the Tuolumne should have had more BMI diversity, but the historic gradient of widening channel morphology, particulate matter and flow rates has been disrupted by damming. Because of this, BMI community composition changes much more rapidly going downstream of the Hetch Hetchy, and this gradient would likely only be observed between tributary inputs and dams. This also explains why there was a higher amount of BMI diversity below the La Grange dam, where flow variation isn't as severe from recreational pulses and the Tuolumne is able to reestablish this continuum to some degree. Shortening of suitable habitat for diverse BMI composition and disrupting the river continuum has serious considerations for wildlife in higher trophic levels.

Conclusions

The changes in benthic macroinvertebrate diversity along the Tuolumne likely occurred from daily changes in discharge volume near damming sites in the mainstem of the Tuolumne. Furthermore, damming of the Tuolumne disrupts sediment deposition, channel width and general bed morphology of the river, impacting BMI diversity beyond unsuitable flow conditions.

The impacts of climate change on snowmelt timing from the Lyell snow field could significantly change the natural flood pulses observed in the upper reaches of the Tuolumne, which could exacerbate conditions for macroinvertebrates and those that feed on them throughout the river. Reducing the amount of flood pulses generated for recreational purposes and hydropower must be considered to increase BMI diversity along the mainstem. Compromises between recreational-use stakeholders and power suppliers could be made to time some recreational pulses with hydropower releases to reduce disturbance stress.

Restoring channel substrate to include a wide range of grain sizes with more medium-sized grains would generate more diverse habitat for invertebrates. Management of sediment loads in the Tuolumne will also be a very important consideration in the context of climate change. Increased drought periods and drought severity lead to more fires and greater fire severity, which can drastically change the sediment load within individual reaches of the watershed for years. (Sankey et. al 2017)

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