Anthropogenic impact on benthic macroinvertebrates as indicators for stream health in the Tuolumne River

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Introduction

Water quality is an important factor to monitor since it is is an integral part of an ecosystem that can affect the aquatic organisms living in it. The health of a stream aids in the understanding of the aquatic ecology in a system because certain animals require specific stream conditions in order to survive (Meyer 1997). Healthier streams with better water quality can hold a more diverse assemblage of aquatic life (Wallace 1996). Anthropogenic activity can lead to major ecosystem changes that cause a loss in habitat heterogeneity and a decline in water quality (Meyer 1997). The degradation of habitat is a serious threat to many native populations which is why there are many methods to determine how healthy a stream is.

Benthic macroinvertebrates (BMI) are bottom dwelling aquatic animals that spend a portion of their life on the bottom of a stream and comprises mostly of aquatic insects. They are found around rivers, lakes, and streams typically attached to stones, logs, sediment, and aquatic plants. In addition to aquatic insects, BMI also includes snails, worms, leeches, clams, and mussels. These organisms provide valuable information about water and habitat quality as biological indicators. There is a wide variety of benthic macroinvertebrates that can tolerate varying levels of dissolved oxygen and pollutants in the water which can cover a large range of habitat conditions (Mandaville 2002). Although other organisms, such as fish, can be used as biological indicators, this method is a better tool due to ease of sampling as well as limited mobility in BMI. It is also a better alternative method to analyzing physical and chemical parameters since those measurements only account for the variables at one point in time instead of accounting for fluctuations over time (Mandaville 2002). Methods of utilizing benthic macroinvertebrates to analyze stream health include methods like EPT index (Ephemeroptera, Plecoptera, and Trichoptera), Shannon's Diversity Index, and the Family Biotic Index (FBI). This paper will focus on the EPT index as an indicator for the health of a system because healthy systems can support a large, diverse community of macroinvertebrates including those intolerant to pollutants and unfavorable conditions while less healthy bodies of water can only support pollutant tolerant species. If the biological parameters in a system are healthy, then the physical and chemical parameters are likely also healthy. We hypothesize the assemblage of benthic macroinvertebrates in the Tuolumne River will consist of a low abundance of intolerant taxa due to the highly degraded environment.

Background

The Tuolumne River flows from the western slope of the Sierra into the San Joaquin River in the Central Valley. The lower reach of the Tuolumne River, between La Grange Dam and the confluence with the San Joaquin River, is of particular interest due to the anthropogenic impact of nearby land use and dams. During the Gold Rush, the Tuolumne River was an active site for mining in the upper reach which resulted in large amounts of silt and sediment moving down the river and burying important habitat for invertebrates (Epke et. al. 2010). The miners required food which led the land surrounding this portion of the river to be predominantly used for agricultural which has allochthonous carbon inputs such as run off from fertilizer and pesticide (Epke et. al. 2010). Dams were built along the river to control the stream, runoff storage, and production of energy. The construction of the LaGrange Dam has significantly impacted the water quality in the lower reach of the Tuolumne by reducing flow from the upstream reaches, block fish passage, and drastically alters the overall ecology of the Tuolumne

River (Epke et.al. 2010). This type of environment can be stressful to most aquatic organisms, so it is important to study what can survive there and to understand what management options can be implemented to improve the system.

Parameters

The EPT Index is a reliable method to determine stream health by looking at the species richness of aquatic insects from three orders: Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies). These three orders of benthic macroinvertebrates are vulnerable to polluted waters and will have low species richness in unhealthy bodies of water (Wallace et. al. 1996, Figure 1).

The EPT Index is determined by counting the number of different taxa observed in the orders Ephermeroptera, Plecoptera, and Trichoptera including species, genera, or families (Kitchin 2005). There are two ways to quantify this index that were used in this paper: counting the total number of different taxa that belong to the intolerant invertebrates to get a number of taxa or dividing the number of intolerant taxa by the total number of taxa found to get a percentage (Figure 2). High species richness of these sensitive aquatic insects represent a stream in excellent health (Figure 3 and 4).

Macroinvertebrates can be sampled in a variety of ways such as riffle-kick, sweep net, and leaf-pack. A riffle-kick collection involves placing a net on the stream bed and disturbing the substrate to dislodge organisms. With a sweep net collection, a net is swept along different structures in the habitat and catches the insects. Leaf pack collection can only be conducted in regions with high flows where leaf packs are collected and rinsed to dislodge insects (NCDEQ 2016).

Results

In a study conducted by Brown and May from 1993 to 1997, an average of seven taxa belonging to the orders Ephermeroptera, Plecoptera, and Trichoptera were found in the Tuolumne River and in similar lower reach systems indicating fair stream health (Figure 5). The lower reaches had much lower EPT taxa in comparison to upper reaches in this experiment (Brown and May 2000).

In the 2014 Ecogeomorphology class, the lower portion of the Tuolumne had relatively high diversity with 62.1% of sampled invertebrate orders that belonged to intolerant taxa (Jasper et. al. 2014, Figure 6). It had a higher EPT index than the main steam but lower than the Tuolumne Meadows.

Discussion

The Tuolumne River is heavily regulated by dams and hydropower stations that disrupts the flow of water from upstream to downstream which negatively impacts the lower reach resulting in low EPT species abundance and poor stream health in 2000 (Epke et. al. 2010). Despite the high levels of anthropogenic activity in the lower reach, there is a high abundance of EPT taxa in 2014 which indicates a healthy stream. There is currently a habitat restoration plan in place for the Lower Tuolumne River with the focus of restoring chinook salmon populations; however, there are many more indirect benefits to create a healthy stream. This project was created in 2000 with the goal to emulate the natural flow regime by disturbing the environment to maintain habitat heterogeneity, gradually release water to mimic natural spring snowmelt, and maintain spawning habitat (TERAC 1999).

Conclusion

The lower reach of the Tuolumne River is susceptible to many anthropogenic impacts which negatively impacts the biological, chemical, and physical properties of an aquatic system.

Utilizing the EPT index as biological monitors for stream health, it was determined that the negative impact of anthropogenic activities such as mining and agriculture has been partially mitigated. It is likely caused due to a habitat restoration project to recreate natural stream conditions that allow organisms to thrive in the conditions they are adapted for. It is important to continue this effort to recreate natural conditions in systems that are regulated by dams. Although it is impossible to completely restore the habitat to its pristine conditions, it is crucial to rehabilitate the habitat to mimic historic conditions. Dams are necessary in California to provide water to a large population (TERAC 1999). In order to account for native populations in the stream, dams must be regulated in a way that imitates the natural system.

Literature Cited

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Figures

Figure 1. Larval forms of (a) mayflies, (b) stoneflies, and (c) caddisflies.

$$\frac{Total\ EPT\ Taxa}{Total\ Taxa\ Found} \times\ 100\% = \%EPT$$

Figure 2. Formula for calculating percent EPT.

	Good	Moderate	Poor
% EPT	>50%	20-50%	<25%

Figure 3. Thresholds for determining percent EPT under Piedmont conditions (Figure from NCDEQ 2016).

	Number of EPT Taxa
Excellent	>27
Good	21-27
Good-Fair	14-20
Fair	7-13
Poor	0-6

Figure 4. Thresholds for determining EPT criteria with number of taxa under Piedmont conditions (Figure from NCDEQ 2016).

	Number of EPT Taxa
Valley	7
Transition	13
Foothill	13
Mountain	13

Figure 5. Mean number of Ephermeroptera – Plecoptera – Trichoptera Taxa found in Sacramento-San Joaquin river sorted by sample types. The Lower Tuolumne River is included in the valley sample.

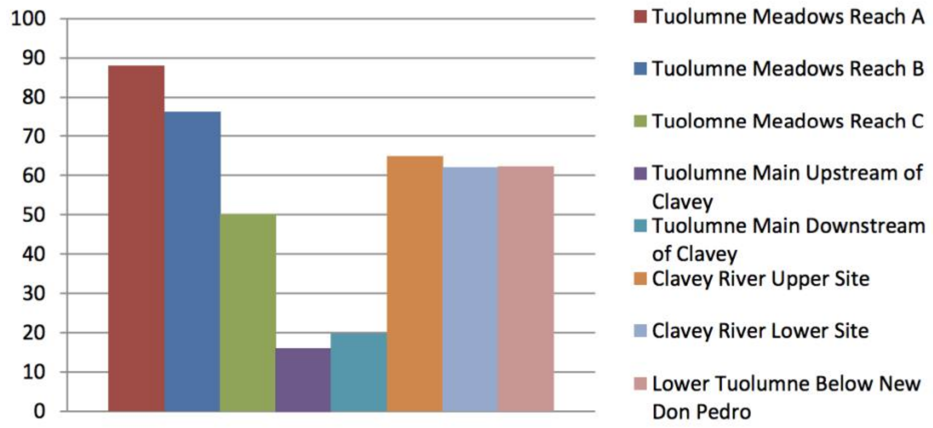

Figure 6. Ephermeroptera – Plecoptera – Trichoptera percentage throughout the Tuolumne River (Figure from Jasper et. al. 2014).