Recovery of benthic macroinvertebrate communities in the Tuolumne River Watershed following the Rim Fire

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Introduction

The 2013 Rim Fire burned 257,314 acres in the Stanislaus National Forest and Yosemite National Park (InciWeb), making it the fourth-largest California fire on record[1] and the largest on record in the Sierra Nevadas (Sierra Nevada Conservancy). Most of the Rim Fire burned within the Tuolumne River Watershed, a vitally important watershed that provides water and electricity to millions of people, among other benefits (Mount et al. 2010). Because there is still much uncertainty about both the short- and long-term ecological impacts of mega-fires like the Rim Fire (Stephens et al. 2014), it is important to examine the impacts of the Rim Fire on watershed health. Figure 1 shows the Rim Fire burn perimeter in relation to the boundaries of the Tuolumne River Watershed and Yosemite National Park.

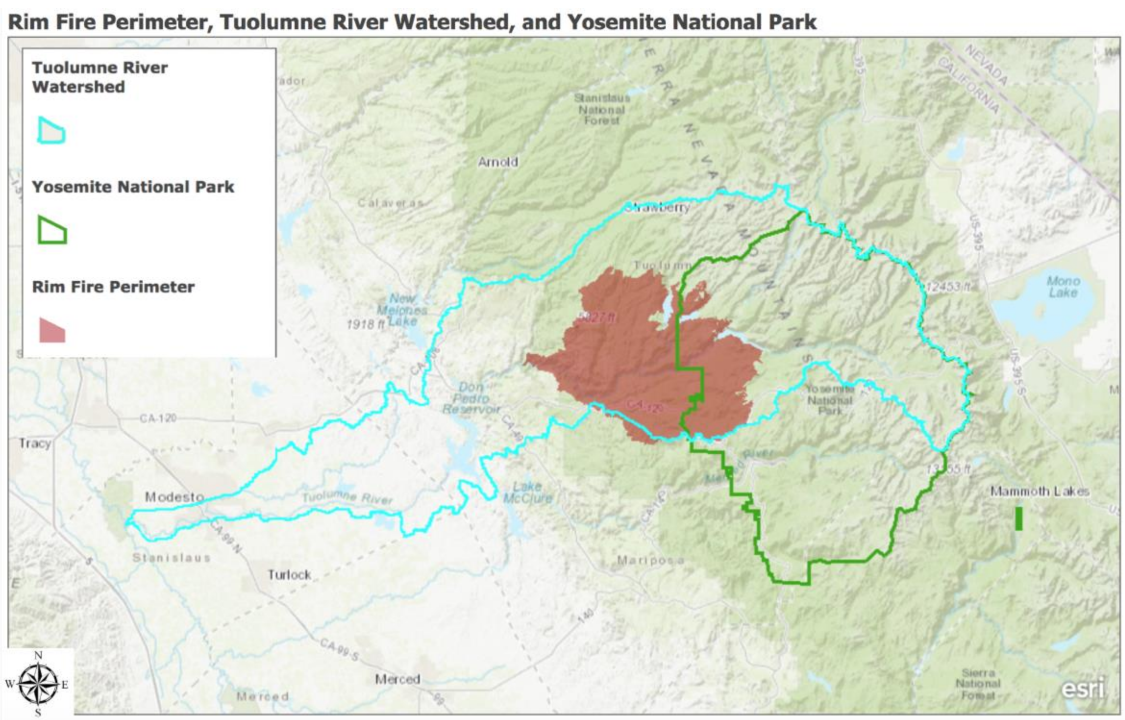

Figure 1 This map shows the Rim Fire burn perimeter in relation to the Tuolumne River Watershed and Yosemite National Park. Almost all of the Rim Fire burn area occurred within the watershed. Where the watershed boundary is the same as the Park boundary, the teal line is shown. Data sources: U.S. Department of Agriculture; Esri Story Maps; LandsNet - Land Resources Division, National Park Service.

[1] At the time, the Rim Fire was the third-largest fire in California history since 1932 (when accurate records starting being kept). Now, the Thomas Fire is the largest California fire on record (InciWeb).

The recovery of benthic macroinvertebrate communities following wildfire is an important indicator of stream health recovery, as benthic macroinvertebrates are relatively sensitive to disturbance, are abundant in most streams, and have long aquatic life stages (Roby and Azuma 1995). A commonly-used indicator for stream health is the proportion of Ephemeroptera, Plecoptera, and Trichoptera, or EPT, because insects in these orders are particularly sensitive to changes in water quality (Wallace et al. 1996).

In this study, we used surveys of aquatic macroinvertebrates within reaches affected by the Rim Fire to assess recovery of stream health following the fire, between the years 2014 and 2018. Affected areas used in our study include reaches within the Tuolumne River in California as well as several of its major tributaries. To provide reference conditions, we used surveys in Tuolumne Meadows, an upstream area unaffected by the Rim Fire. Results indicate that reaches in our study sites have generally increased in stream health since the Rim Fire; however, the changes seen in the benthic macroinvertebrate communities could have also been due to both the historic multi-year drought and high flows of 2017 and 2018. Further research and more rigorous study designs would be needed to more precisely determine changes in stream health following the Rim Fire.

Methods

Study Area

We conducted our study along the Tuolumne River in California, as well as two of its major tributaries: the Clavey River and the North Fork Tuolumne River. Both tributaries were sampled near the confluence with the main stem Tuolumne. To provide reference conditions, we also used surveys from Tuolumne Meadows, an area unaffected by the Rim Fire (Aha et. al. 2014; Lambert et. al. 2014). Surveys were conducted in 2014, 2015, 2016, and 2018 to capture the recovery period since the Rim Fire.

Macroinvertebrate Sampling

Macroinvertebrate surveys were carried out at the five reach locations along the Tuolumne River and selected tributaries (Figure 2). At each of these sites, aquatic macroinvertebrate species were identified and categorized by order using the McCafferty dichotomous key (McCafferty 1981). Benthic macroinvertebrates were sampled utilizing the Kick Net method (United States EPA 1999). D-nets were held downstream of the sample site along the bottom of the river in order to fully capture the entire assemblage. The number of kicks and time interval varied from year to year, ranging from one to five kicks and 30- to 60-second intervals. To dislodge macroinvertebrates from the substrate, half of the time period was spent rubbing the rocks with our hands underwater and the other half was spent kicking the area. At the end of the time interval, samples were placed into a small bucket and elutriated. Samples were then sorted and identified to order in the field. Samples were not retained for further analysis in the lab, but returned to the stream.

Calculating Percentage of EPT Taxa

To provide a metric for stream health, we calculated percentage of EPT taxa for each location and by each year. To calculate EPT for each site, we summed individuals within the orders Ephemeroptera, Plecoptera, and Trichoptera, divided by total individuals sampled, and multiplied by 100 to get a percent. To obtain one EPT value for site locations in which multiple reaches were surveyed, EPT values for each reach within a site location were averaged. A scatter plot was then made showing percentage of EPT taxa versus year (2014 to 2018) for each site, and a linear regression was performed for each site to show overall trends in EPT.

Results

Figure 2 summarizes and displays the data from the benthic macroinvertebrate surveys.

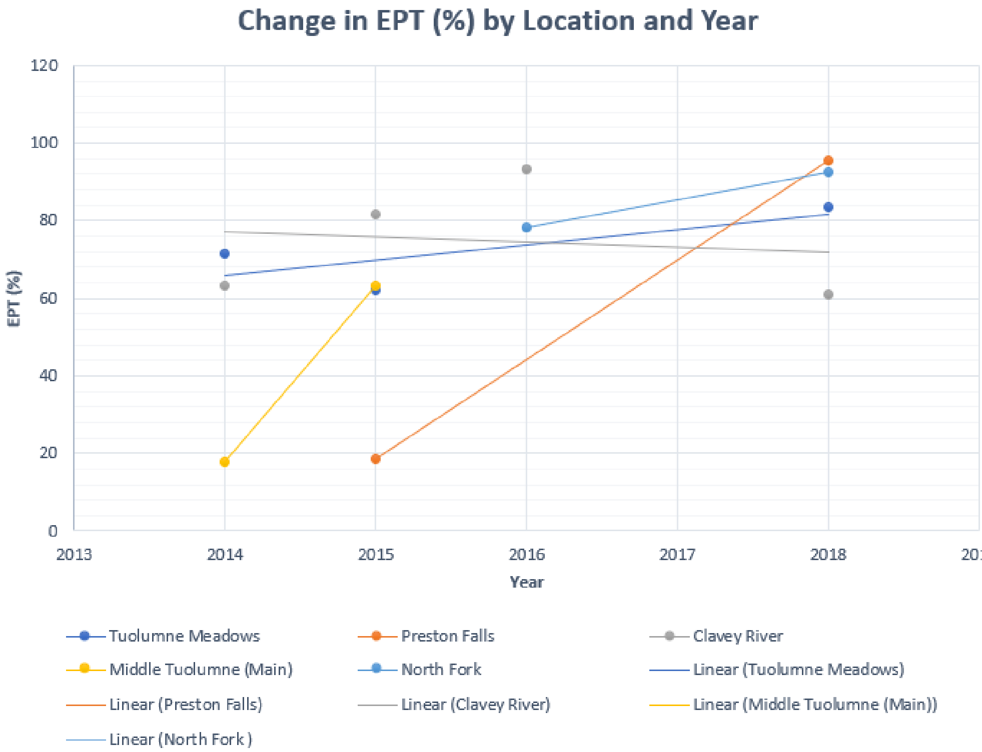

Figure 2 This figure shows the percentage of EPT taxa vs. time in years for each site location (excluding 2017, when no surveys were conducted). The percentage of EPT taxa is calculated as [(E+P+T) / Total Individuals] * 100. A linear trend line was attributed to each site to show the general trend of EPT populations at each site location since the Rim Fire. A positive slope indicates an increase in EPT taxa.

Results indicate that stream quality within the Tuolumne River Watershed has generally increased or maintained since 2014 (Figure 2). EPT values for the Tuolumne Meadows reference site increased gradually from 2014 to 2018 (slope = 3.95%), while the areas affected by the Rim Fire—such as Preston Falls and North Fork Tuolumne River—experienced a larger magnitude of change over the same time period (slope = 25.76%). The exception to this trend is the Clavey River site, which experienced almost a net zero change in EPT from 2014 to 2018 (slope = -1%). It is important to note that from 2014 to 2016, the Clavey River site's EPT did increase from 61% to 94%, but then decreased back to 61% from 2016 to 2018. No data was collected for 2017 for any site locations, including the Clavey River. However, each site besides the Clavey River experienced an increase in EPT from 2016 to 2018, indicating that other factors may be responsible for the shift in EPT along the Clavey River.

Discussion

Intolerant macroinvertebrates that require specific stream conditions can be negatively affected by wildfires. A change in the sediment deposition, water quality, and channel morphology indirectly caused by wildfires can make areas inhospitable to such species (Minshall 2003). Other studies on benthic macroinvertebrates following wildfires have found that the number of intolerant species immediately declines following a fire, but can increase again once the ecosystem begins to recover from the effects of the disturbance (Roby and Azuma 1995; Minshall et al. 2001; Tronstad et al. 2011).

Three of our four sites within the Rim Fire burn area—the North Fork Tuolumne River, the main stem of the Tuolumne River within the middle reaches, and the area just below Preston Falls—showed an increase in the percentage of EPT over time. These increases were greater than that of the reference Tuolumne Meadows site, but with limited data, the significance of these trends cannot be accurately assessed.

Our fourth site, Clavey River, showed a slightly decreasing trend in EPT over time; however, the site showed an increase in EPT between 2014 and 2016, was not sampled in 2017, and then decreased in 2018. These changes in EPT could have been caused by other confounding factors. For instance, between 2016 and the winter of 2018, the Tuolumne River Watershed shifted from drought conditions to abnormally high rainfall conditions (California Department of Water Resources 2017). This shift in flow could have increased erosion along the unregulated Clavey River, negatively impacting macroinvertebrate habitat and scouring egg nests from substrate. However, the North Fork Tuolumne River is also an unregulated tributary, so the fact that the Clavey River is unregulated does not by itself account for the differences seen in our data for this site. A more rigorous study would be required to identify all of the complex factors that could have contributed to the shift in EPT at the Clavey River site.

Without benthic macroinvertebrate data from before the Rim Fire, we do not have baseline values that can be used to understand previous benthic macroinvertebrate assemblages. This also means it is difficult to determine the magnitude of the effects the fire had on macroinvertebrate communities. It should be noted that not every stream will be affected by the fire equally, meaning that EPT values will not consistently change across sites (Minshall 2003). The time it takes the ecosystem and macroinvertebrates to fully recover following a fire can vary as well (Minshall 2003; Jackson and Fuereder 2006). Impacts to benthic macroinvertebrate communities following wildfires can persist for at least a decade: Roby and Azuma (1995), for instance, found significant differences between aquatic macroinvertebrate communities in burned and unburned reaches 11 years following a wildfire. Since it has been less than five years since the Rim Fire, benthic macroinvertebrate communities are likely still recovering and will continue to recover for years to come.

Conclusion

In this study, we examined changes in benthic macroinvertebrate communities of the Tuolumne River Watershed following the 2013 Rim Fire in order to assess recovery of stream health. Results showed that percentage of EPT taxa generally increased in our study sites, indicating that stream health has increased; however, other factors besides the fire, such as the historic multi-year drought and high flows of 2017 and 2018, have most likely also impacted benthic macroinvertebrate communities. Further research with more rigorous methodologies in the same sample sites could provide more information on the recovery of macroinvertebrates communities.

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