Student Researcher: Jodie Montgomery

Faculty Advisor: Dr. Zachary Mitchell

Project Title: Effects of catastrophic wildfire on stream macroinvertebrate communities in northern New Mexico

Description of Research Problem and Research Objectives:

In the western United States, catastrophic wildfires grow more prolific each season (Rust *et al*., 2018). Climatic change alters forests through rising temperatures, changes in precipitation, earlier snowmelt, and increasing forest fire frequency and severity (Rugenski & Minshall, 2014). Alterations to forest and watershed habitats from severe fires can significantly impact stream ecosystems, resulting in water quality degradation, reduced oxygen availability, and increased turbidity (Mellon *et al.,* 2008; Rust *et al*., 2018). The outcome of this degradation poses significant consequences to stream ecosystems and aquatic communities, specifically in headwater streams (Mellon *et al.,* 2008).

The Upper Pecos watershed, or Pecos Headwaters, is part of the larger Rio Grande Basin in northern New Mexico. Historically, this landscape has seen significant changes due to the impacts of human activities, wildfires, changes in climate, and other natural processes (Kennemore. 2019). While fire is ordinary and often necessary in the form and function of montane ecosystems, the intensity, frequency, and size of fires can significantly impact water quality and aquatic ecosystems (Mellon *et al.,* 2008; Kennemore. 2019).

The impact of wildfires on aquatic ecosystems, such as the Viveash fire in 2000 and the Tres Lagunas fire in 2013, is significant. Following these fires, areas including the upper Pecos River and watersheds experienced substantial amounts of sediment, ash, and debris. Which negatively affected aquatic communities and significantly altered surrounding landscapes Kennemore. 2019). Widespread runoff is a common outcome of catastrophic wildfires. When fire consumes ground cover, it removes the natural barriers that typically absorb precipitation. This altered landscape leads to runoff-related challenges in the affected regions, drastically impacting aquatic communities (Kennemore. 2019).

Macroinvertebrates in tributaries serve as an essential food source for several fish species in downstream water systems (Mellon *et al*., 2008). Habitat alteration caused by wildfire significantly impacts aquatic communities, specifically immobile organisms, such as many aquatic insects that have not reached adult stages (Gresswell, 2011). Loss of vegetation cover following fire events may affect aquatic habitats by becoming atrophic, raising primary production due to increased sunlight reaching the streambed (Rugenski & Minshall, 2014; Gresswell, 2011). As a result, this change may shift aquatic macroinvertebrate feeding functionality between the more dominant shredders to filter feeders or collectors and gatherers. This change in dominant species could impact riparian wildlife and fish in downstream systems (Mellon *et al*., 2008; Rugenski & Minshall, 2014). This provides a substantial opportunity for

further research regarding population dynamics associated with water quality after fire events in high-elevation streams.

The objective of this study is to evaluate the effects of the Hermits Peak and Calf Canyon wildfires of 2022 (the largest documented wildfires in New Mexico's history to date) on stream macroinvertebrate community structure in the Pecos Wilderness in Northern New Mexico. We hypothesize that catastrophic wildfire events will negatively influence the development and reproduction of macroinvertebrates, resulting in decreased diversity and abundance in areas impacted by the wildfire. In addition, water quality, seasonality, and fire intensity will affect survival rates. Macroinvertebrates are a vital component of stream ecosystem form and function, and this study can assist in a greater understanding of how macroinvertebrate communities respond to wildfire events.

Similar studies report negative correlations between diversity and levels of disturbance between stream ecology and fire events, while other studies contradict these findings. A 2001 study of benthic macroinvertebrates' response to fire in Idaho showed a significant increase in macroinvertebrate biomass ten years after a fire, with no change in density (Mellon et al., 2008). Meanwhile, macroinvertebrate densities in a managed forest in Arizona decreased after a fire and remained reduced for three years (Mellon et al., 2008). We predict that macroinvertebrate communities within the burn boundary will exhibit lower abundances and decreased species richness compared to sites that did not experience a fire. We expect greater species richness and abundance declines in sites that experienced moderate to high burn severity compared to low burn severity sites. Catastrophic wildfires are increasing in intensity, frequency, and duration. The Hermits Peak and Calf Canyon fires of 2022 remain the most catastrophic in New Mexico's recorded history. Few studies have assessed the impacts of extreme wildfire events on macroinvertebrate community structure. There is a significant concern regarding how these wildfires may affect aquatic ecosystems, and continued research to understand how wildfire events influence stream ecosystem form and function is greatly needed.

Description of Methodology Employed:

Macroinvertebrate community and water quality assessments were conducted throughout tributaries of the Pecos River within the boundary area of the Hermits Peak and Calf Canyon fire in the Pecos Wilderness. Macroinvertebrate communities will be sampled within unburned, low-burn, moderate-burn, and high-severity burn locations, selected within the study area based on the burn severity level. Tributaries that will be sampled within the Pecos River watershed include Rio Mora, Windsor, Tecolote, Cabo Lucero, Santillanes, and Falls creeks. Macroinvertebrate sampling and various environmental data will be collected and recorded every four weeks from April 2023 until October 2023.

Study Site and Selection

Sampling began in April 2023 and continued until October 2023. A total of 18 sites were selected within six tributaries of the Upper Pecos and Tecolote watersheds. Each sample site was

strategically selected based on its location and level of soil burn severity (sourced from Arc GIS online database; HPCC Soil Burn Severity For Analysis) within the burn boundary of the 2022 Hermits Peak and Calf Canyon fires in Northern New Mexico. Thirteen study sites were selected in the Tecolote watershed region and five within the Upper Pecos headwaters. Samples were taken from Windsor Creek, a tributary of the Pecos River, outside the burn area to provide baseline macroinvertebrate community data.

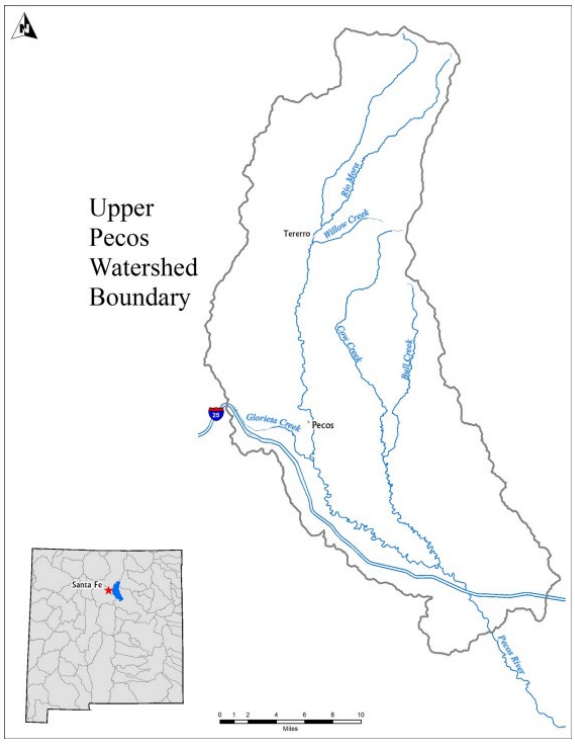

Figure 1: Upper Pecos Watershed Boundary. (source: Upper Pecos Watershed Association). Figure 2: Tecolote Watershed. (source: Hermit's Peak Watershed Alliance)

Macroinvertebrate Sampling

Macroinvertebrates were collected from riffle mesohabitats using D-frame kick nets randomly placed at four locations within each site. Macroinvertebrates were counted and identified to the lowest reasonable taxonomic level in the lab at ENMU. Macroinvertebrates and environmental data were recorded once per month, starting in April 2023 and ending in October 2023.

Table 1: Each cell represents the number of sites sampled on a specific date for each burn category.

Burn Category	April	May	June	July	September	October
High Severity	1	4	5	4	4	3
Low Severity	1	5	5	3	3	2
Moderate Severity	1	4	4	5	3	3
Unburned	0	3	4	3	1	1

October 2022

While scouting for sample sites in the area, we collected samples from Windsor Creek. This site flows directly into the upper Pecos River and is located in a non-burn-affected region. These samples were used to understand better the baseline community structure in a non-burn affected region.

April

Our first initial sampling and scouting occurred on April 25th, 2023. A total of three sites were sampled. Samples were taken from Mora Rio (Trailhead, moderate burn severity), Tecolote (Cabin – high severity), and Cabo Lucero (Jolly Jeep – low severity) creeks. Access to sites within property boundaries, landowner permission, and high flood waters resulted in fewer samples/site availability.

May

Samples were collected from 16 total sites. Sites were added and removed due to landowner permission and reassessment of access to creek areas. Three locations along Cabo Lucero were sampled (Home Sites 1 (high) and 2(moderate) and Jolly Jeep (low). Private property and lack of landowner permission led to the removal of one other site along Cabo Lucero. Six sites were sampled along Tecolote Creek (Blue Haven Campsites 1 (low), 2 (moderate), and 3 (unburned), Cabin (high), Washout FS Road (high), and an additional site was added at an accessible location found while scouting (Bridge (low)). Other sites were added to increase the number of sampling sites, resulting in areas along Santillanes Creek (1; low), (2; moderate), (3; high), and Falls Creek (unburned). Three locations along Mora Rio were sampled (Trailhead; moderate, 2; low, and 3; high). The fourth site along Mora Rio was removed due to access issues, primarily difficulties due to water levels and site location. Windsor (unburned) Creek (used for baseline data) was sampled once more.

June

All 18 sites were sampled. Eighteen areas total due to removing a site along Cabo Lucero Creek private property and site access issues to the farthest site along Mora Rio.

July

15 out of 18 sites were sampled. Three sites, including Cabo Lucero and Santillanes, were not sampled due to creeks drying. All sites along Tecolote Creek were sampled (Blue Haven Camp 1, 2, 3, bridge, cabin, and FS road). All sites along Mora Rio were sampled. Santillanes site 1 was dry and was therefore not sampled. The Santillanes sites that were not dry were sampled, and Falls Creek was also sampled. Cabo Lucero home site 1, Jolly Jeep, was sampled. However, home site number 2 was dry and was not sampled. Cabo Lucero and Santillanes sites were not flowing, and samples were taken from shallow isolated pools. Cabo Lucero sites were 100% mud/sand from recent flooding/runoff. Sites not sampled: Windsor Creek (unburn). Cabo Lucero (Home site 2; high), Santillanes (site 1; low).

August

Due to scheduling/personal conflicts, only the Mora Rio trailhead (moderate) site was sampled in August.

September

11 out of 18 sites were sampled. All sites on Mora Rio were sampled. The majority of sites that were not sampled are due to creeks drying. These areas include Cabo Lucero (home site 2), Santillanes (all locations), and Falls Creek. Tecolote Blue Haven Site 3 was not sampled due to construction on the property, and the primary sample site was manipulated/destroyed due to construction that impedes natural flow to the creek. Cabo Lucero and Santillanes sites were not flowing, and samples were taken from shallow isolated pools. Sites not sampled: Windsor Creek (unburned). Cabo Lucero (Homesite 2; high), Santillanes (site 1; low, 2; moderate, 3; high), Falls Creek (Unburned), Tecolote (Blue Haven site 3; unburned).

October

9 out of 18 sites were sampled. All Mora Rio sites were sampled. 5/6 Tecolote sites were sampled. Similar to the September sampling, most sites were dry, with no standing or flowing water. All Cabo Lucero sites were dry, having no water. All Santillanes/Falls Creek sites were dry, having no water. Tecolote Blue Haven Site number 3 was manipulated by construction and was no longer flowing. Of the 18 sites, Tecolote and Mora Rio were consistently sampled from April to October 2023. These sites represent three high severity, three low severity, two moderate severity, and two unburned soil burn severity locations.

Water Quality and Habitat Assessment

Several environmental variables were recorded throughout the study, including canopy cover, riparian vegetation cover, stream length and width, discharge, substrate composition, water temperature, and dissolved oxygen.

Data Analysis

In our comprehensive analysis, we employed a multi-faceted approach to assess the impact of burn severity on aquatic macroinvertebrate communities. We focused on three key aspects: total abundance, diversity, and the percentage of EPT (Ephemeroptera, Plecoptera, Trichoptera) taxa. For each aspect, we first standardized the data by the number of sampling

events to account for variability in sampling effort. Total abundance was calculated by summing the counts of individuals in each burn category. At the same time, diversity was evaluated using the Shannon-Wiener Diversity Index, which considers species' abundance and evenness. The percentage of EPT taxa, known as indicators of aquatic health, was determined by the proportion of these taxa relative to the total macroinvertebrate count in each category. Statistical analysis was performed using the Kruskal-Wallis test to compare these metrics across different burn severity levels. This non-parametric method was chosen for its suitability for data that do not necessarily follow a normal distribution. It provides a robust framework for assessing the ecological impacts of burn severity on these vital freshwater communities.

Description of Results

***Data analysis is still ongoing. ***

In our study, we conducted a series of analyses to examine the impact of burn severity on aquatic macroinvertebrate communities, focusing on diversity, total abundance, and the percentage of EPT taxa. In total, 12,864 individuals from 8 orders and 36 families were collected during the project period. The diversity analysis, represented by the Shannon-Wiener Diversity Index and standardized by the number of sampling events, showed values ranging from 0.34 for High Severity to 0.45 for Unburned areas. Despite the apparent differences, the Kruskal-Wallis test revealed no significant disparities (p-value ≈ 0.59), suggesting that family-level biodiversity is not strongly affected by burn severity.

The total abundance analysis, adjusted for sampling effort, revealed that the average number of individuals per event ranged from 352.86 in high-severity areas to 896.00 in low-severity areas. Again, statistical testing showed no significant differences between burn categories (p-value ≈ 0.36), indicating that the number of macroinvertebrates is consistent regardless of the intensity of the burn.

When evaluating the percentage of EPT taxa, which serve as bioindicators of stream health, we observed a non-significant trend where less severely burned or unburned areas had higher percentages of EPT taxa. Specifically, the EPT taxa comprised 40.24% in High Severity, 45.22% in Low Severity, 60.42% in Moderate Severity, and 68.84% in Unburned areas. Despite the upward trend with decreasing burn severity, the Kruskal-Wallis test did not show significant differences (p-value ≈ 0.25).

These collective insights paint a picture of resilience among macroinvertebrate communities against varying burn severities. The consistent metrics of diversity and abundance imply an ecosystem capable of withstanding the immediate aftermath of fires. However, the subtle gradation in EPT taxa percentages signals a potential ecological susceptibility requiring further exploration. It is imperative to acknowledge that the absence of marked differences may arise from the study's limited temporal and spatial breadth, alongside the intrinsic variability of natural ecosystems.

For future research, it is essential to consider the temporal dynamics of these communities and their potential delayed responses to burning (*currently underway*). Expanding studies to incorporate multiple years post-burn and including various aquatic habitats will enhance our understanding of the long-term ecological effects of fire. A deeper dive into individual species' life histories and adaptive strategies could elucidate the underlying mechanisms of the resilience observed. Integrating advanced techniques such as metagenomics could also reveal subtle shifts in biodiversity and ecosystem functions that traditional metrics might overlook. Controlled experiments to parse out the influence of confounding factors, such as water chemistry and physical habitat changes, will further clarify the direct impacts of burn severity on these vital freshwater communities.

Figure 3: Pie charts representing the relative abundance of aquatic macroinvertebrate orders within different burn severity categories. Each chart displays the proportion of the total count of individuals identified to the order level, with the total count for each burn category indicated in parentheses. The categories are as follows: High Severity, Low Severity, Moderate Severity, and Unburned. Each segment's color corresponds to a specific order, as indicated in the legend below the charts.

Figure 4: Example of soil burn severity in the Upper Pecos Watershed. Right: Rio Mora high burn severity sample site. Left: Mora Rio low burn severity sample site.

Provide a paragraph on who will benefit from your research results. Include any water agency that could use your results:

Our study contributes toward a greater understanding of the relationship of wildfires to the functionality and development of macroinvertebrate communities and stream ecosystems. If a negative correlation is found, there may be an additional need for conserving and restoring National Forest and State land and aquatic resources. Therefore, our findings could benefit the United States Fish and Wildlife Service, the New Mexico Department of Game and Fish, and the United States Forest Service.

Describe how you have spent your grant funds. Also provide your budget balance and how you will use any remaining funds. If you anticipate any funds remaining after December 14, 2023, please contact Carolina Mijares immediately. (575-646-7991; mijares@nmsu.edu)

Funding was spent on purchasing sample tools (e.g., D-Frame kick nets, collection vials), field equipment (YSI-dissolved oxygen, discharge, canopy cover measuring equipment), and laboratory supplies (e.g., sample vials, ethyl alcohol). The remainder of the funds were also used to pay Jodie Montgomery 39 weekly hours over the fieldwork season (April-October 2023), including travel reimbursements for mileage accrued on personal and department vehicles to travel to and from study sites. All funds have been expended.

List presentations you have made related to the project:

- April 2023 - Poster Presentation - Eastern New Mexico University Student Research and Creativity Conference (SRCC)
- November 2023 – Poster Presentation - 68th Annual New Mexico Water Conference

List publications or reports, if any, that you are preparing. For all publications/reports and posters resulting from this award, please attribute the funding to NM WRRI and the New Mexico State Legislature by including the account number NMWRRI-SG FALL2022.

Because our final sampling occurred in October, the results of our research are still in progress. Posters displayed for presentation purposes were attributed to the NM WRRI student research grant. Additional reports or publications will properly acknowledge NM WRRI and the New Mexico State Legislature (NMWRRI-SG-FALL2022).

List any other students or faculty members who have assisted you with your project.

We are sincerely grateful to the students and faculty that have assisted with this project, including field and lab work. Students contributing to this project include Li Zheng, Kyle Montgomery, Joshua Gonzalez, Zane Seidel, and Amber Sandoval. Faculty who has assisted in macroinvertebrate identification includes Dr. Darren Pollock.

Special Recognition Awards or Notable Achievements:

- May 2023 - NM WRRI "New Mexico Water eNews" edition.
- June 2023 - Eastern New Mexico University - Student Success Story – "ENMU Student Seeks Wildfire Impact on Aquatic Communities."

Degree Completion and Future Career Plans:

Since being awarded the NM WRRI Student Water Research Grant, I have maintained full-time enrollment in my degree and will graduate with my Bachelor of Science in Fish and Wildlife Sciences in May 2024. I have been fortunate to present this research through poster presentations at two conferences, including the 68th Annual New Mexico Water Conference in Albuquerque. After graduating, I plan to continue my studies through a graduate program in New Mexico. I aim to focus my work on a career in aquatic restoration and land management. I look forward to building a career that improves the health and well-being of wildlife and ecosystems.

References

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