Effects of Prescribed Fire on Water Quality and Stream Dwelling Crayfish (order: decapoda)

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Fires are a common disturbance in terrestrial ecosystems, occurring with increased frequency and duration in North America (Higuera & Abatzoglou, 2020). Fires are less volatile in the humid southeast than in the dry western United States, but they are still an important ecological and management issue (Hanby et al., 2012). Alabama's different terrestrial ecosystems are dependent on fire, from the longleaf pine ecosystem to the mixed pine and hardwood forests in the Appalachian Mountains (Varner et al., 2000). Although many studies have investigated the ecological effects of fires, few studies have evaluated the effects of fire on aquatic systems and their fauna. Specifically, no studies have quantified the effects of fire on stream-dwelling crayfish. Prescribed fire causes an increase in nutrient and heavy metal concentrations in water immediately after the fire (Klimas et al., 2020). Heavy metals are of particular concern because crayfish can bioaccumulate metals, including copper, zinc, lead, and others, in their bodies that can cause mortality and interfere with daily activities in high concentrations (Sherba et al. 2002). The brain of the crayfish reflects the environmental availability of the examined heavy metals in water. High zinc, lead, and copper concentrations lead to pathological changes in the crayfishes' olfactory midbrain (Heiba, 2006). This research is particularly important in Alabama, which has the highest crayfish biodiversity in North America, with 99 species (Schuster et al., 2022).

To evaluate how runoff from a wildfire or prescribed burn might affect water quality and stream-dwelling crayfish, we designed two experiments. The first experiment evaluated water quality and compared the effects of burnt versus non-burnt vegetation and woody debris runoff on water quality parameters, including dissolved oxygen, pH, conductivity, total suspended solids, ammonia, nitrite, nitrate, alkalinity, hardness, chloride, sulfate, aluminum, zinc, copper, and iron. To evaluate the effect of fire exposure on water quality parameters, we collected leaf litter for unburned and burned treatments. We used a concentration of 20 g leaf litter / 1 L of water in all experiments (Duan et al., 2014), mimicking a runoff event through a litter layer into a stream (Figure 1). Each trough used in the experiment was 40 gallons (150 L). This required 3 kg of burned or unburned leaf litter per treatment. Water was exposed to burnt or unburnt litter and was sampled for relevant water quality parameters over 24 hours.

In the first experiment, we found that water exposed to fire debris runoff was higher in dissolved oxygen, pH, total suspended solids, and conductivity over a 24-hour period. Across both treatments, ammonia was high (reaching toxic levels) in the first 6 hours, nitrite was high in the last 4 hours, and nitrate remained zero. Over the entire 24 hour period, there was no difference in aluminum ($t_{(18)} = 1.80$; $p = 0.089$), copper ($t_{(18)} = -1.05$; $p = 0.306$), or zinc ($t_{(18)} = -0.728$; $p = 0.476$) across treatments, but water exposed to burnt litter had significantly higher concentrations of iron ($t_{(18)} = 3.229$; $p = 0.005$; Figure 2). Water exposed to unburnt leaf litter was higher in chloride than water exposed to burnt leaf litter. Repeating this experiment could lead to more statistically significant data. Exposure to high concentrations of heavy metals is known to have sublethal and lethal effects on crayfish. Still, the findings of this initial study reveal that of the four metals tested, only iron was found in higher concentrations in water exposed to burn versus unburnt leaf litter.

The second experiment evaluates the effects of fire debris runoff on crayfish standard metabolic rates. For this experiment, we trapped and collected crayfish in coordination with US FWS, acclimated and held them in laboratory aquatic habitats and systems, and cared for them daily. Standard metabolic rate was tested using the same experimental design as the water quality experiments (Figure 1) and used Loligo systems intermittent respirometry. Repeating the methods of the first experiment, we collected 50 kg of riparian vegetation, leaf litter, and woody debris to create a 3 kg burnt litter layer for exposure. We ran preliminary experiments to hone a methodology that mimicked a rainfall and runoff event

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through post-wildfire or post-prescribed burn fire debris. Experiments evaluating the effect of burnt runoff on crayfish metabolic rates are still ongoing due to unanticipated crayfish disease issues.

Fire events are occurring with increasing frequency and duration, and their effects on stream ecosystems and stream-dwelling fauna have not been quantified. This novel research can be used by managers when considering the relationship between fire events, water quality, and crayfish physiology.

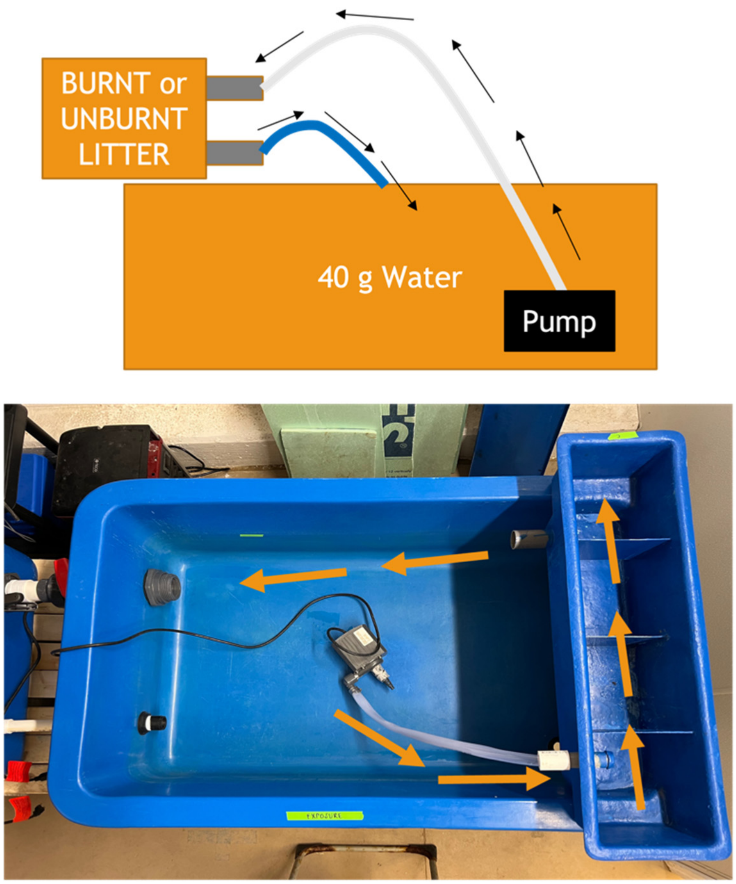

Figure 1: Side and top view of experimental design simulating a runoff event through a leaf litter layer. Arrows represent the direction of water flow.

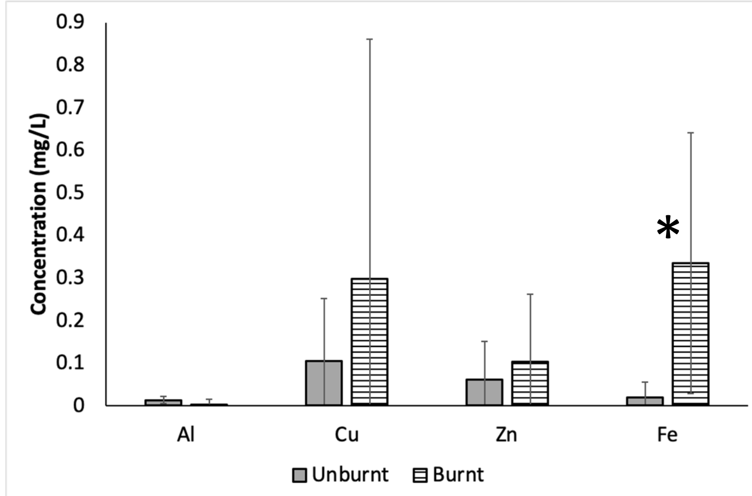

Figure 2: Concentrations of aluminum (Al), copper (Cu), zinc (Zn), and iron (Fe) in water exposed to 3 kg of unburnt leaf litter (grey) and 3 kg of burnt leaf litter (white and black stripe). Statistical differences in treatments are denoted with an asterisk.

Statement of Research Advisor

In the wake of the 2020 Australian mega-fires, conversations within the international astacology community have been happening with regard to the need to evaluate the effects of wildfires on crayfish. Fortuitously, Josiah had already combined his interests in prescribed fire management and crayfish ecology and proposed these experiments to Dr. Stoeckel and me. While others internationally are doing field-based evaluations of wildfire effects on crayfish populations, Josiah is the first to propose laboratory experiments evaluating the effects of fire on crayfish.

- Kaelyn Fogelman, School of Fisheries, Aquaculture, and Aquatic Sciences

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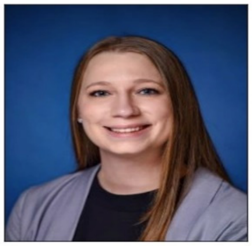
Authors Biography

Josiah Gullatte is a senior-year student pursuing a major in Wildlife Ecology & Management with a minor in Fisheries and allied aquaculture at Auburn University. He is a certified burn boss and a technician in the Crustacean and Molluscan Ecology Lab (CAMEL) under Dr. Jim Stoeckel.



Kaelyn Fogelman is a post-doctoral research fellow in the School of Fisheries, Aquaculture, and Aquatic Sciences. Her research is on stress physiology and the implications of climate change on imperiled and aquatic invertebrates.

Dr. Stoeckel is an Associate Professor in the School of Fisheries, Aquaculture, and Aquatic Sciences at Auburn University. His lab focuses on crustacean and molluscan ecology with a range of research topics within the fields of conservation, ecotoxicology, ecophysiology, and invasive species.