COMPARING STREAM INVERTEBRATE ASSEMBLAGES BEFORE AND AFTER WILDFIRE IN YELLOWSTONE NATIONAL PARK

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✦ ABSTRACT

Warmer, dryer climate conditions during the past 3 decades are thought to have increased severe fires in the western United States. Severe fires may change food webs due to altered light levels, nutrient concentrations, and hydrology in streams. To measure how wildfire changes stream food webs, we collected aquatic invertebrates before and after a fire, and calculated their density and biomass. To investigate the effects of wildfire on streams, we collected aquatic invertebrates from Cub and Little Cub Creeks on the east side of Yellowstone Lake before and after the East Fire (Figure 1.). The timing of our study was serendipitous with the fire burning after our first year of collecting samples. Therefore, we collected samples prior to the wildfire (2003), and 1 (2004), 2 (2005), and 9 years post fire (2012). The East Fire was a crown fire that set ablaze >17,000 acres and burned ≥95% of the watersheds of these streams. Working in Yellowstone National Park was opportune, because few other perturbations existed and the effects of wildfire can be easily studied. We analyzed the samples to understand how wildfire altered stream invertebrates. Our specific questions were: 1.) What affect did wildfire have on the density and biomass of aquatic invertebrates? 2.) How did the composition of aquatic invertebrates change before and after wildfire? Results from our study will inform managers about how the food base for fish and many birds (i.e., aquatic invertebrates) changes after wildfire.

Figure 1. Cub Creek 9 years post wildfire.

✦ INTRODUCTION

Warmer, dryer climatic conditions during the past 30 years have been attributed to increases in severe, stand-replacing fires in the western US (Westerling et al. 2006). The 1988 fires in Yellowstone National Park are an example of large, severe, stand replacing fires. Severe fires continue to burn in Yellowstone National Park in recent years, where thousands of hectares of forest were consumed. These stand-replacing fires remove the forest canopy and begin new successional trajectories that persist for decades (Turner et al. 2003). In addition, a shift in the dominant terrestrial vegetation, along with the creation of abundant bare mineral soil can often increase the inputs of important nutrients such as nitrogen into adjacent streams and lakes (e.g., Gresswell 1999). The effects of fire are similar to the response measured by Likens et al. (1970) who discovered large pulses of nutrients exported from watersheds after clear-cutting a forest. Turner et al. (2007) studied terrestrial N cycling in Yellowstone and Grand Teton National Parks after fire and noted that N uptake switch from microbes to plants as succession proceeded. Turner et al. (2007) and climate predictions have prompted us to further investigate how fire will alter aquatic invertebrates in burned watersheds.

Stream food webs may change after wildfire due to altered light levels, nutrient concentrations, and hydrology. Forest canopies open after wildfire increasing light levels that reach streams. Higher light levels along with higher nutrient concentrations can increase stream primary production (Mihuc 2004). Higher primary production may cause bottom-up effects in streams and subsequently change the aquatic invertebrates and fish in these ecosystems. However, changes in hydrology may limit algal, invertebrate, and fish growth (Minshall et al. 2001a). Water levels can change rapidly in burned watersheds, because of the lack of terrestrial vegetation as a buffer. Thus, floods can scour streams in burned watersheds removing algae and invertebrates. Bottom up effects and hydrology may change the energy flux to higher trophic levels, but little is known about the effects of fire on aquatic food webs (Minshall 2003). However, Perry et al. (2003) discovered that wildfire limited the invertebrates available to juvenile Chinook salmon (*Oncorhynchus tshawytscha*) in streams in Yukon Territory, Canada.

To investigate the effects of wildfire on streams, we collected aquatic invertebrates from Cub and Little Cub Creeks on the east side of Yellowstone Lake before and after the East Fire. Many studies of wildfire compared a burned stream with a reference stream (Minshall et al. 2001b), because collecting samples prior to a wildfire is by chance. Thus, having samples before and after fire will improve our knowledge of the effects of wildfire on stream invertebrates. The timing of our study was serendipitous with the fire burning after our first year of collecting samples. Therefore, we collected data prior to the wildfire (2003), 1 year (2004), 2 years (2005), and 9 years after the fire (2012). Therefore, our study design is ideal to estimate the effects of wildfire on stream invertebrates. The East Fire was a crown fire that set ablaze >17,000 acres and burned ≥95% of the watersheds of these streams. Working in Yellowstone National Park was opportune, because few other perturbations existed and the effects of wildfire could easily be studied. Our specific questions were: 1.) What affect did wildfire have on the density and biomass of aquatic invertebrates? and 2.) How did the composition of aquatic invertebrates change before and after wildfire? Results from our study will inform managers about how the food base for fish (i.e., aquatic invertebrates) changes after wildfire.

✦ Methods

We collected aquatic invertebrate samples in Cub and Little Cub Creeks, tributaries on the east side of Yellowstone Lake, Yellowstone National Park, Wyoming. Cub Creek is a third order stream that is 11.8 km in length and originates in the Absaroka Range near Jones Pass. The 2180 ha Cub Creek watershed was dominated by lodgepole pine (*Pinus contorta*), whitebark pine (*Pinus albicaulis*), and subalpine fire (*Abies lasiocarpa*), and the bedrock was mostly andesite and rhyolite. Little Cub Creek is a first order stream that is 3.0 km in length. The 458 ha watershed is dominated by lodgepole pine. Lightning ignited the East Fire which was discovered on 11 August 2003. The crown fire burned 9510 hectares including 95% of the Cub Creek watershed and 100% of the Little Cub watershed.

To investigate changes in these streams due to wildfire, we collected aquatic invertebrate samples from Cub and Little Cub Creeks. Six Hess samples (0.086 m^2) were collected in each stream every 2-4 weeks during the summers of 2003 to 2005, and in August 2012. We preserved samples in 70% ethanol and identified aquatic invertebrates using a dissecting microscope and available keys (Merritt et al. 2008, Thorp and Covich 2010). We calculated biomass by measuring the first 20 individuals of each taxon and converting lengths to biomass using published regressions (Benke et al. 1999).

✦ Preliminary Results

In Cub Creek, we collected 40 invertebrate taxa of which 37 were insects from 6 orders. Insects were far more abundant (99%) than non-insect invertebrates. Diptera were the most abundant order of insects in the stream (66%), followed by Ephemeroptera (20%) and Plecoptera (12%). In contrast, Ephemeroptera (52%) had the highest biomass, followed by Diptera (18%) and Plecoptera (23%). On average, we collected 13 (range 3-21) taxa in each sample. Average total invertebrate density was 6800 ind/m^2 and biomass was 767 mg/m^2.

Total invertebrate density in Cub Creek was similar the summer before (13,000 ind/m^2) and 2 years after wildfire (7600 ind/m^2), but total density was lower immediately after wildfire (2800 ind/m^2). Total density was also low 9 years post wildfire (3800 ind/m^2). In contrast, invertebrate biomass was similar before (580 mg/m^2) and immediately after wildfire (600 mg/m^2), but biomass was twice as high 2 years after wildfire (1100 mg/m^2). Nine years after wildfire, biomass was intermediate between previous values (760 mg/m^2).

Before the fire, the invertebrate assemblage was primarily composed of Diptera (83%), Ephemeroptera (9%), and Plecoptera (5%) numerically. However, the dominance of Diptera declined immediately after wildfire (54%), and the percent of Plecoptera (15%), and Ephemeroptera (30%) increased. Nine years post fire, the percent of Diptera continued to decline (41%), Plecoptera were similar (17%), and Ephemeroptera became more prominent (38%).

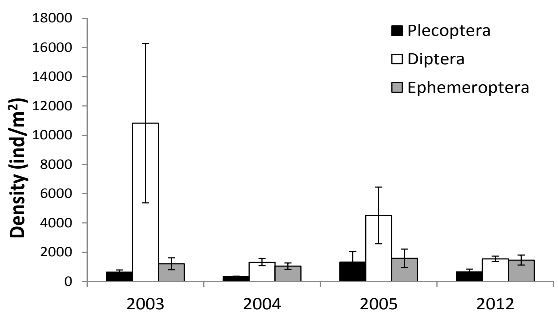

Figure 1. Density of insects in Cub Creek before and after wildfire. Bars are standard errors.

The biomass distribution of invertebrates in Cub Creek differed from the distribution based on density. Before fire, Plecoptera had the highest biomass (46%) followed by Ephemeroptera (28%), and Diptera (20%). Immediately after wildfire (2004), the percent of biomass from Plecoptera and Diptera both decreased to 9%, and Ephemeroptera increased (80%). In 2005, Ephemeroptera had the highest biomass (44%), followed by Diptera (29%), and Plecoptera (26%). Nine years after fire, Ephemeroptera continued to dominate (52%), and the percent of Diptera (18%) and Plecoptera (12%) both decreased.

The invertebrate assemblage of Cub Creek changed before versus after fire. For example, we only collected *Drunnella grandis* (Ephemerellidae) before wildfire. In contrast, we only observed *Podmasta* (Nemouridae), and leeches after wildfire. Still other taxa we only observed during a single year after the fire (*Taenionema*, Taenionptergidae; *Claassenia*, Perlidae; *Cinygma*, Heptageniidae). Interestingly, two new taxa appeared 9 years post fire: *Paraleptophlebia*, Leptophlebidae and *Pericoma/Telmatoscopus*, Psychodidae. Despite these changes, the average number of taxa collected in a sample was similar among years.

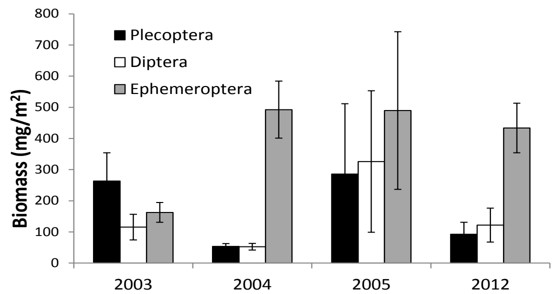

Figure 2. Biomass of insects in Cub Creek before and after wildfire. Bars are standard errors.

We collected 44 invertebrate taxa in Little Cub Creek of which 38 taxa were insects in 5 orders. The assemblage was dominated by insects (88%), but non-insect invertebrates composed 12% by abundance. Diptera were the most abundant order of insects (44%) followed by Ephemeroptera (21%) Coleoptera (15%), and Plecoptera (6%). According to biomass, Ephemeroptera (29%) and Diptera (29%) were the dominant insects, followed by Coleoptera (19%), and Plecoptera (12%). On average, we collected 13 taxa per sample (range 5-21). Overall, mean invertebrate density was 12,500 ind/m^2 and mean biomass was 1755 mg/m^2.

Total invertebrate density was lowest before wildfire (6000 ind/m^2). Immediately after wildfire, densities increased to 11,000 ind/m^2. Nine years after wildfire, total density was even higher (21,600 ind/m^2). Similarly, biomass also increased after wildfire. Insect biomass was similar before and immediately after wildfire (1000 ind/m^2), but densities were >2 times higher in 2005 (2300 ind/m^2) and 2012 (2600 mg/m^2) in Little Cub Creek.

The composition of invertebrates by abundance changed through time. Before wildfire, Diptera (40%), Coleoptera (18%), Plecoptera (10%) and Ephemeroptera (6%) were the most abundant orders of insects in Little Cub Creek. Immediately after wildfire, Diptera were by far the most abundant order (63%), and Coleoptera (9%), Plecoptera (6%), and Ephemeroptera (5%) all had lower abundances. Nine years after wildfire, Ephemeroptera were the dominant order (41%). Additionally, the percent of

Diptera decreased (25%), Coleoptera increased (24%), and Plecoptera remained similar (6%).

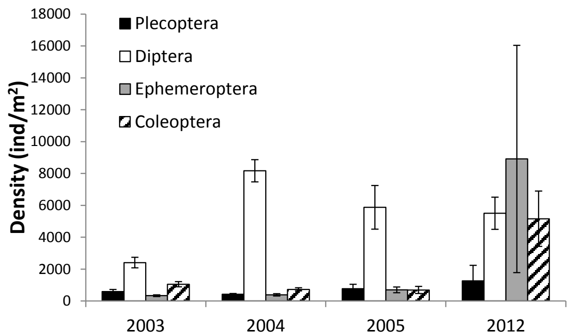

Figure 3. Density of insects in Little Cub Creek before and after wildfire. Bars are standard errors.

The distribution of invertebrates according to biomass in Little Cub Creek also varied through time. Before wildfire, Diptera (31%) were the dominant insect order, and Plecoptera (20%), Ephemeroptera (21%), and Coleoptera (22%) composed similar fractions. After wildfire, Diptera made up a greater percent of biomass (44%), Ephemeroptera remained similar (19%), and Coleoptera (11%) and Plecoptera (10%) decreased. Nine years after wildfire, Ephemeroptera (46%) were the dominant insect according to biomass and Coleoptera (28%) biomass was higher than previous estimates. The percent biomass of Diptera (9%) was much lower 9 years post fire, but the fraction of Plecoptera (11%) biomass remained similar.

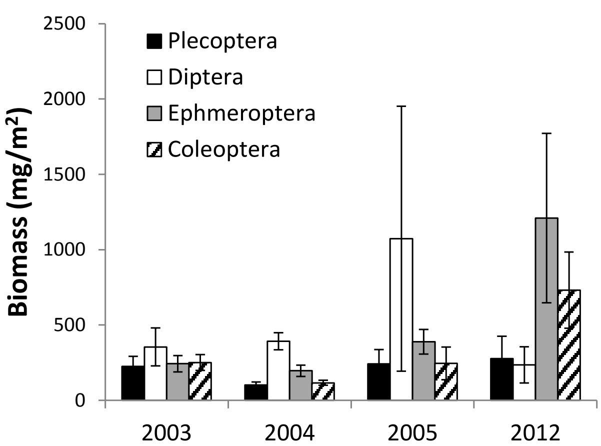

Figure 4. Biomass of insects in Little Cub Creek before and after wildfire. Bars are standard errors.

The invertebrates that composed the assemblage in Little Cub Creek changed through successional time. For example, we only observed *Acerpenna* (Baetidae) and leeches before wildfire. *Suwallia* (Chloroperlidae) and *Rithrogena* (Heptageniidae) were only present before and immediately after wildfire, but we did not collect these taxa 2 years or 9 years post fire. In contrast, we only observed *Megarcys* (Perlodidae), *Podmasta* (Nemouridae), an unknown Leuctridae, Dolichopodidae, and *Epeorus* (Heptageniidae) after wildfire. Three new taxa appeared 9 years post wildfire; *Paraleptophlebia* (Leptophlebidae), *Dicosmoecus* (Limnephilidae), and *Hydroptilla* (Hydroptilidae). Despite these changes, the average number of taxa collected in each samples was similar among years.

✦ MANAGEMENT IMPLICATIONS

Wildfires can greatly change landscapes, ecosystems, communities, and population, but these natural events are unpredictable and difficult to study. Previous studies have investigated the effects of fire by comparing streams in burned watersheds to unburned reference streams (e.g., Minshall et al. 2001a). In our study, we were able to compare pre- and post-fire conditions in the same streams, because a fire unexpectedly burned ≥95% of the watersheds after our first field season.

Several factors likely determine the extent to which stream processes will be affected after wildfire. For example, more sever fires and fires that burn the majority of a watershed tends to have a greater impact on streams (Minshall 2003). In Cub and Little Cub Creeks, most of the watersheds were burned by a crown fire, which likely affected the stream to a greater extent. Smaller streams with higher gradients and vegetation cover are also predicted to be affected to a greater degree after fire (Minshall 2003). Cub Creek is a 3rd order forested stream that drops 51 m per km of stream length. Little Cub Creek is a 1st order stream in a forested watershed that drops 35 m in elevation per km of stream length. Therefore, the East fire likely had a large effect on processes within Cub and Little Cub Creeks.

Previous studies reported that aquatic invertebrate densities increased after wildfire (Albin 1979; Roby and Azuma 1995; Gresswell 1999). Similarly, invertebrate density in Little Cub Creek increase after wildfire. In fact, densities were nearly 4 times higher 9 years after wildfire. In contrast, invertebrate densities in Cub Creek were highest before wildfire. A flood in July 2004 greatly reduced the abundance of invertebrates in Cub Creek during that year. Minshall et al. (2001b) noted that density was lower in burned streams compared to reference streams in Idaho. In this stream, densities were likely lower because of scouring and runoff in the stream channel, similar to what we observed in 2004.

We did not observe a change in taxa richness after wildfire in Cub or Little Cub Creeks. Invertebrate richness is generally thought to decrease in burned compared to reference streams (Gresswell 1999, Roby and Azuma 1995, Minshall et al. 2001b). Roby and Azuma (1995) found that invertebrate richness was lower in burned streams for the 11 years that they collected samples. In contrast, taxa richness was similar in burned and reference streams 10 years after fire in Idaho streams, which may have been caused by lower water levels during drought (Minshall et al. 2001b).

Wildfire can alter the composition of stream invertebrates. In burned Idaho streams, disturbance adapted insects, such as *Baetis* and Chironomidae, increased in abundance after wildfire (Minshall et al. 2001b). Similarly, Chironomidae density increased in Little Cub Creek after fire. Conversely, the density of more sensitive taxa can decrease after wildfire. For example, Ephemeroptera (Minshall et al. 2001a) and Trichoptera (Albin 1979) densities were lower in burned compared to unburned streams. The density of Ephemeroptera in Cub and Little Cub Creeks generally increased after wildfire. Ephemeroptera did particularly well after the 2004 flood in Cub Creek, where they were some of the few invertebrates that survived a scouring flood. In particular, the density of Ephemeroptera with flattened bodies (Heptageniidae) increased density after wildfire. The body form of these genera may have allowed them to persist through floods and other scouring events that occurred after the fire while other taxa were swept away. Similar to Albin (1979), Trichoptera densities in Cub and Little Cub Creeks decreased immediately after fire. These filter feeders may have been negatively affected by the initial increase in fine sediments that often occurs after wildfire (Minshall et al. 2001a). However, Trichoptera densities were highest 9 years after wildfire and we collected 2 new genera of Trichoptera in Little Cub Creek. The ability to withstand floods and increased fine sediments may have been at least partially responsible for the changes we observed immediately after fire.

Two opposite forces affect streams after wildfire. First, more nutrients and light typically increase primary production in streams. Increases in in-stream food resources may cause bottom-up effects that increase stream invertebrates and their consumers (e.g., fish). Second, the loss of vegetation and forest on the landscape can alter the hydrology of a watershed. The lack of terrestrial primary producers can cause variable discharge, scours, and floods. In unburned watersheds, the primary producers slow the movement of water through the watershed creating a slow and decreased release of water through the growing season. In Cub Creek, hydrology controlled the invertebrate assemblage in 2004 by likely reducing biofilm and removing invertebrates. However, bottom-up effects dominated in 2005 when there were no major floods and invertebrate densities were higher.

Fire may also impact fish in burned streams through food web effects. When bottom-up effects predominate in burned streams, more food (i.e., invertebrates) may be available to fish. However, when hydrology dominates burned streams, less food may be available to fish. Yellowstone cutthroat trout (*Oncorhynchus clarkii bouvieri*) spawn in Cub and Little Cub Creeks for 2 to 3 months each year. Although the adults do not live in these streams, juvenile cutthroat trout rear here. Aquatic invertebrates are likely the dominate food for these young trout. Juvenile cutthroat trout were likely washed out of the stream in 2004 when Cub Creek was scoured; however, these fish may have enjoyed an abundant food source in 2005. High densities of aquatic invertebrates may translate into higher growth rates and ultimately higher survival rates when these fish migrate downstream to Yellowstone Lake.

✦ Acknowledgements

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