FIRE AND BULL TROUT: SPAWNING PATTERNS IN ROCK CREEK AND WESTERN MONTANA

by

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DEDICATION

Dedicated to the memory of my cat Baisey, who was such a great companion. I would also like to dedicate this to the memory of my cousin Derrick Franchuck. He pushed me to be a better version of myself.

ACKNOWLEDGEMENTS

I would like to thank my professor Dr. Bill Kleindl for his contributions to this paper, and who guided me through this work and gave me many thoughtful notes. I greatly appreciate my graduate committee members Dr. Tracy Sterling and Dr. Bob Peterson for their helpful notes for this paper. I would also like to give thanks to the rest of the Land Resources and Environmental Sciences Program faculty that have helped me through my time here and got me to where I am. Also thank you to Patrick Luckenbill of the U.S Forest Service and Brad Liermann of Montana Fish Wildlife & Parks for providing me with much of this data.

I would also like to give a warm thanks to my parents, who introduced me to the outdoors at a young age. To my dad who taught me the value of environmental stewardship and instilled a curiosity in nature to me.

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ABSTRACT

Bull trout (*Salvelinus confluentus*) is a native salmonid species that is listed as threatened under the U.S. Endangered Species Act. Bull trout are a species that seems particularly sensitive to changes in water conditions, requiring cold, clean, and connected habitat. Although information for bull trout habitat requirements exists, the cause for many population declines remains unknown. Therefore, the main objective of my study is to examine the influence that large wildfires >3.64 square kilometers have on bull trout using tributaries for spawning. The influence wildfires have on bull trout was determined by comparing the number of spawning nests called redds annually before and after a fire. I also compared sediment data before and after a fire when available. After the fire, mean redd counts decreased each year in seven of the nine tributaries with available data, except for the North Fork of the Blackfoot River and Skalkaho Creek Sediment data did not align with the fire history data but showed periodic spikes in sediment that exceeded bull trout physiological tolerance. My study shows the decline of bull trout throughout much of Western Montana and should indicate the importance of restoration in conservation priorities.

CHAPTER ONE

INTRODUCTION

Bull trout (*Salvelinus confluentus*) (Richardson,1836) is a native salmonid species that is listed as threatened under the U.S. Endangered Species Act. Although bull trout are found in many locations throughout the western US and Canada, populations have declined in many parts of their range (Reiman et al., 2007). Bull trout is a species that seems particularly sensitive to changes in water conditions, requiring cold, clean, and connected habitat. Although information for bull trout habitat requirements exists, the cause for many population declines remains unknown.

Like other char species, bull trout evolved more than one life history form (Rieman and Macentire, 1993). Resident forms may live in small headwater streams their entire lives, while migratory fish will spend the first several years in headwater streams before migrating to larger rivers or lakes (Fraley and Shepard, 1989). Bull trout display multiple life history strategies, and can be migratory or non-migratory, as well as fluvial or adfluvial (Howell et al., 2016). Non-migratory forms in small headwater streams typically grow 150-300 mm, while migratory adults can grow to 600 mm. (Rieman, 1993). Additionally, different populations can have multiple demographics that alter spawning and migratory behavior (Rieman and Allendorf, 2001). They prefer to spawn in smaller streams, with low gradient and water velocity, and depth above spawning beds typically between 10 cm and 1 m (McPhail and Baxter, 1996).

Bull trout spawn in the fall, between August and November, when water temperatures reach 5-9° °C (Rieman and Macentire, 1993). Adfluvial adults will migrate out of lakes into inlet streams to spawn. Fluvial adults typically migrate to headwater streams. Spawning adults create nests called redds where they will lay and fertilize their eggs (Bowerman et al., 2014). Therefore, bull trout rely on clean gravel of the right size, with minimal sediment that may suffocate the eggs and fry. Bull trout pick spawning sites based on proper substrate conditions (Weaver & Frayley, 1991). The preferred gravel size for bull trout appears like other salmonids, and is proportional to body size, generally 2-6 cm or < 20 mm (Kondolf & Wolman, 1993; McPhail and Baxter, 1996). The larger size of some adult bull trout may accommodate a slightly larger gravel size.

An important component for bull trout habitat is clean gravel that is free of sediment for successful spawning. Juvenile bull trout are sensitive to suspended sediment, and any increase in sediment has a direct effect on the survivability of young (Rieman and Macentire,1993; Weaver & Fraley 1993). Although baseline levels of sediment in streams with large riparian buffers and forest cover usually prevent levels of suspended sediment from becoming a problem for salmonids and spawning, changes in land cover can contribute to an increase in sediment load (De Girolamo et al., 20023). The large-scale loss of vegetation may contribute to soil erosion and add sediment to streams. Multiple factors may be contributing to the loss of bull trout in much of their range (Watson and Hillman, 1997). Introduced species like brown trout (*Salmo trutta*, Linnaeus, 1758) and brook trout (*Salvilinus fontinalis*, Mitchill,1814) can compete against and hybridize with bull trout (McMahon et al., 2007; Al-Chokhachy et al., 2016). Habitat loss by altered water conditions, loss of migration corridors, or changes from land use may also be contributing to population declines (High et al., 2008). Habitat requirements that provide adequate spawning sites, migration routes, and adequate water quality have become less available from land use changes, development, and climate change (Rieman et al., 2007). Watson and Hillman (1997) found an inverse relationship between suspended sediment and bull trout densities in stream sites sampled in Montana, Washington, and Idaho. One contributing factor to habitat loss can come from changes in land cover because of wildfires (Falke et al., 2015).

Wildfires are an important component of disturbance to many ecosystems. Although many organisms living in places that experience wildfires have adapted to withstand or even thrive from the disturbance caused by wildfires, wildfire regime characteristics such as frequency, severity, size, and timing have been altered by climate change and the accumulation of fuels in many forests (Parks, et al., 2016). The ability of species to adapt to changes brought to their environment, including changes in disturbances like wildfire through climate change, is thought to be an important predictor in whether a population or species will survive or disappear (Shoennagel et al., 2016).

Although there is extensive research on the impact of wildfires on terrestrial ecosystems, their effects also extend to aquatic ecosystems (Bixby et al., 2015). Wildfires increase the rates of erosion by reducing plant cover within the watershed. The added erosion within the watershed can contribute excess sediment and nutrients into streams, degrading salmonid habitat (Falke et al., 2019). The extent of habitat degradation will vary from the magnitude, intensity, size, and frequency of the fire, as well as topography, soils, parent rock, the type of vegetation that existed and how well it recovers, and the local climate.

Due to the increasing concern over the decline in bull trout numbers, areas that have been identified as strongholds have been labeled as restoration/conservation areas (Team Montana Bull Trout Restoration, 2000). In Montana, a bull trout restoration plan was created with key stakeholder groups, and the best remaining populations were identified in Montana to prioritize restoration and conservation efforts (Team Montana Bull Trout Restoration, 2000). Primary river systems that were identified were the Kootenai and the Clark Fork Rivers. The Kootenai River is divided into the upper Kootenai, upstream from Libby Dam, the middle Kootenai, from Libby Dam to Kootenai Falls, and the lower Kootenai below Kootenai Falls. The Clark Fork watershed conservation area is divided into the Swan River, Flathead River drainage, and Clark Fork River Drainage. Within the Clark Fork River drainage, exists the Lower Clark Fork downstream of Thompson Falls dam, the Middle Clark Fork from Thompson Falls dam to the Milltown Dam (now confluence of Blackfoot River) and the Upper Clark Fork River above the Milltown dam site, as well as the Bitterroot River, Blackfoot River and Rock Creek.

The upper Columbia River Basin, where the study site of Rock Creek Watershed is located, has undergone a change to less frequent but more severe and extensive fires (Morgan et al., 1996). The Rock Creek Watershed, located in Western Montana has been identified as a major stronghold for bull trout in Montana (Carnefix, 2002; U.S Forest Service, 2013). Bull trout populations have historically been determined by annual redd counts, historic fishing harvest reports, and biologist fish sampling. The Middle Fork of Rock Creek has the highest number of redd counts in the Rock Creek core area (U.S Forest Service, 2013). Populations of bull trout in the Rock Creek were estimated by recording spawning redds, as well as catch per unit effort. Catch per unit effort is a method commonly used by fisheries scientists to estimate populations. Catch per unit effort is defined mathematically as $C/f = qN$, where C is the number of fish caught, f is the unit of effort expended, q is the catchability coefficient or probability of catching an individual fish in one unit of effort, and N is the absolute abundance of fish in the stock

(Hubert and Fabrizio, 2007). From these data, it has been confirmed that Bull Trout in Rock Creek have declined over the past 50 years (US Fish and Wildlife Service, 2014).

In the Rock Creek watershed, the number of redds reported has declined from an average of 500 in streams around a century ago, to about 50 (US Fish Wildlife and Service, 2014). Other bull trout strongholds like the South Fork of the Flathead River have also been declining (Kanda and Allendorf, 2001). There are existing hypotheses around the cause of decline, including water irrigation, climate change, and invasion of brook and brown trout (Al-Chokhachy et al., 2016). Although some studies have been conducted examining the impact of wildfire on bull trout populations, none have examined the effect to the Rock Creek watershed (Falke et al., 2015, Rieman et al., 1997, Sestrich et al., 2011).

Much of the landscape where bull trout are native has experienced a change to the fire regime over the last century or more (Wasserman and Mueller, 2023). Climate change is increasing fire size, severity, and intensity in many places globally (Wasserman and Mueller, 2023). Since the end of the 20th century, the Rock Creek watershed has experienced several wildfires, with hundreds of thousands of acres burning (Figure 1). Many of the tributaries that have been identified as receiving historically high use for bull trout spawning have been largely burned over (Figure1). Examining what, if any, impact these fires have had on habitat degradation could contribute to restoration strategies and management efforts in protecting bull trout populations in Rock Creek and other areas.

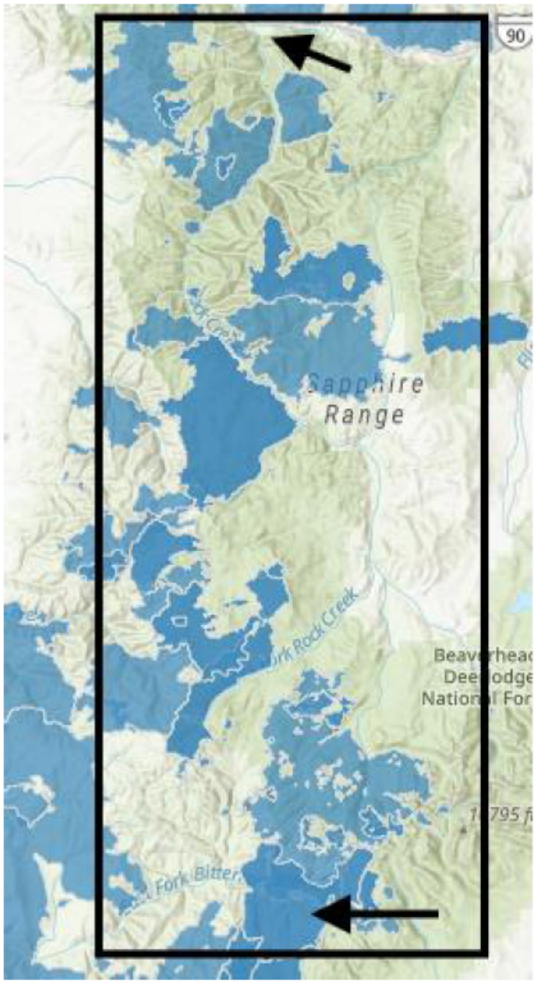


Figure 1: Blue area indicates historic fire area. Top arrow is the confluence of Rock Creek with the Clark Fork River and the bottom arrow is the headwaters near the Middle Fork of Rock Creek. (National Interagency Fire Center. n.d)

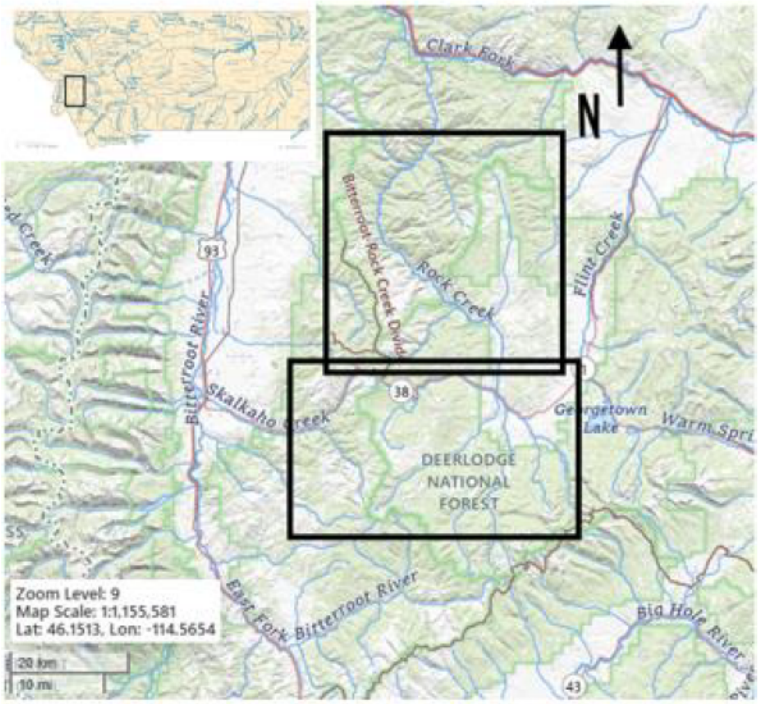


Figure 2: Location of Rock Creek Watershed in Montana.(U.S. Forest Service. (n.d.). *Maps & publications: Historic fire maps*.)

One of the most recent fires in the Rock Creek watershed was the Meyers Fire. This fire began in July of 2017, and burned 251 square kilometers (U.S Forest Service, n.d). Lightning ignited two fires, one near Green Canyon Lake on Whetsone Ridge, and was named the Whetstone Fire, the other in the upper Meyers Creek drainage, named the Meyers Fire. These fires eventually grew together, and just became known as the Meyers Fire. The fire burned a mosaic of different intensities, with some areas experiencing high intensity across large areas (Howe et al., 2022).

Although bull trout have evolved in fire-prone landscapes, the change in fire regimes likely has added stress or altered their behavior (Rieman et al., 1997). More intense fires that leave less vegetation are more prone to loss of soil, adding sediment to the streams more commonly than they have in the past (De Girolamo et al., 2022). Therefore, the primary objective of my study is to examine the impacts of wildfire on bull trout habitat, particularly the impacts the Meyers Fire had on the Middle Fork of Rock Creek watershed. Specifically, my study aims to examine changes in bull trout spawning use, estimated by redd counts in primary spawning tributaries of Rock Creek and western Montana following large (>3.64 square kilometers) wildfires. Habitat quality by measurement of water quality post-wildfire and assess the suitability of water quality for bull trout spawning. This will be determined by using existing sediment data, as well as spawning redd data and wildfire history data. Assessing watershed-scale impacts on stream habitat provides a broader perspective on the factors contributing to bull trout decline

In this paper, I will use existing bull trout and other salmonids data to examine the likelihood that the Meyers Fire affected the local bull trout population in the Middle Fork of Rock Creek. The questions that I will examine include the following:

1. Have the number of spawning redds changed after the occurrence of wildfire?
2. Has there been a change in water quality to the Middle Fork of Rock Creek following the Meyers Fire?
3. If water quality has changed, have any parameters exceeded the threshold of bull trout habitat requirements?
4. What were the likely impacts to bull trout in the Middle Fork of Rock Creek following the Meyers Fire?

METHODS

Study Area

Rock Creek Watershed is in Western Montana. It originates in the Anaconda and Sapphire Ranges. The elevation ranges from 10,407 Warren Peak at 45°59'11.1"N 113°27'35.6"W in the headwaters of the Falls Fork of Rock Creek, to the confluence with the Clark Fork River at 3,523 feet at 46°43'28.7"N 113°40'57.4"W. The main channel below drains roughly 88 kilometers. The watershed in total covers approximately 2,202 square kilometers (Figure 2).

The Rock Creek watershed can be divided into a lower segment, where the confluence of the Ross Fork, Middle Fork, and West Fork come together to flow as the main stem of Rock Creek through the Rock Creek Canyon (Figure 2). The lower or main fork has many tributaries, with some of the larger ones including Stony Creek, Willow Creek, Hogback Creek, Welcome Creek, Ranch Creek, Brewster Creek, and Gilbert Creek (Figure 3).

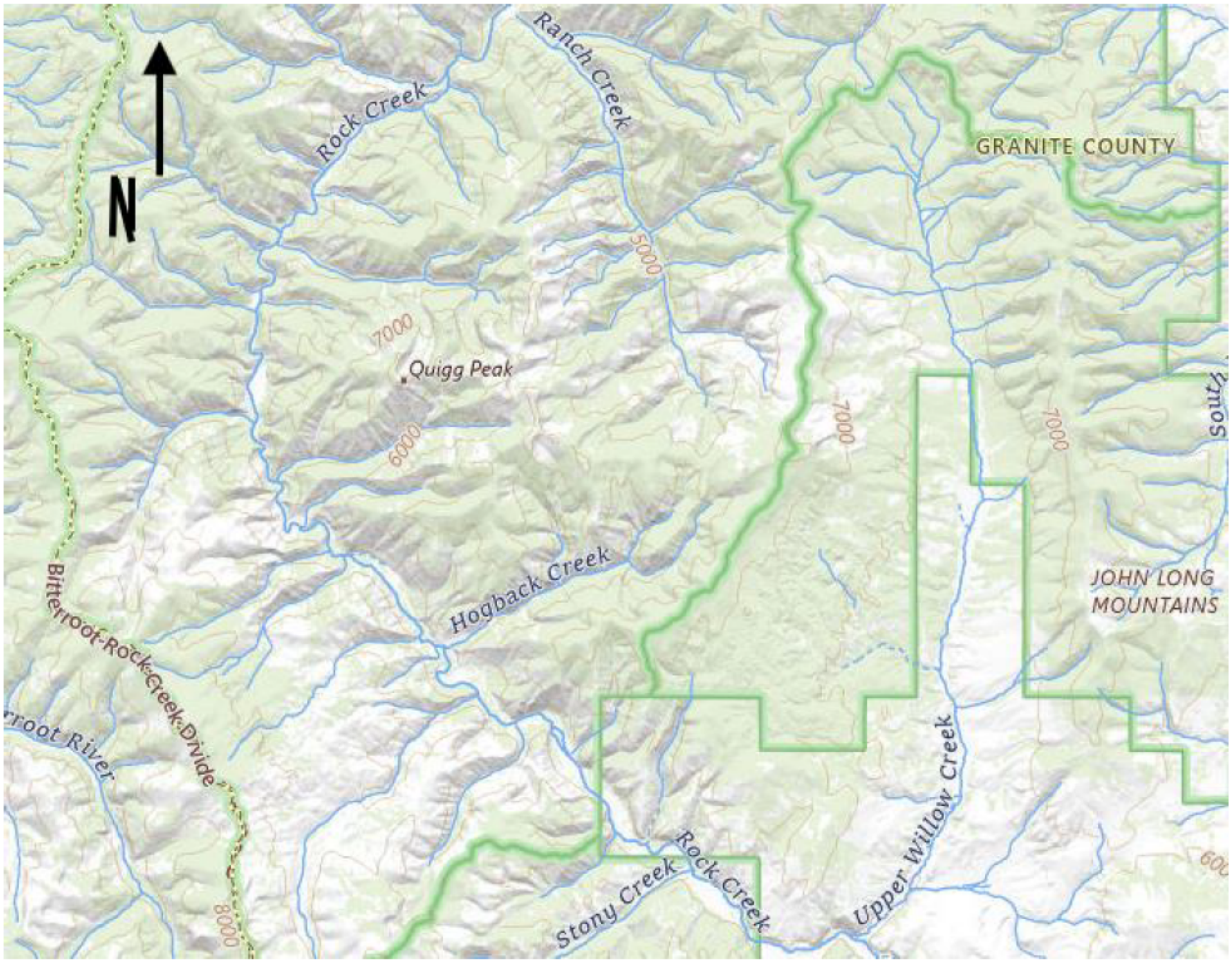


Figure 3: Lower Rock Creek with Stony Creek bottom center and Ranch Creek upper left center.

The upper Rock Creek watershed is comprised of multiple drainages flowing from different portions of the Anaconda range and Sapphire range (Figure 4). The upper Rock Creek watershed comprises of the East Fork, Middle Fork, West Fork, Ross' Fork, as well as Meyers Creek, Copper Creek, and Carpp Creek. These and other tributaries that have experienced different wildfires over the last few decades. Despite the fire in the surrounding drainages, the East Fork has experienced no fires, likely within a century or more except for a small 0.004 square kilometers fire (Figure 5). These Rock Creek tributaries have been established as good bull trout habitat, with historically strong populations. Therefore, this watershed would make a good model for this analysis. This analysis aims to examine if any relationship exists between wildfires and the spawning use within tributaries of burned.

Figure 4: Upper Rock Creek watershed.

The Meyers fire and the Wetstone fire began in the Sapphire Mountains in the summer of 2017. The fires merged, became known as the Meyers fire, and burned 251.04square kilometers in the summer and fall of 2017.

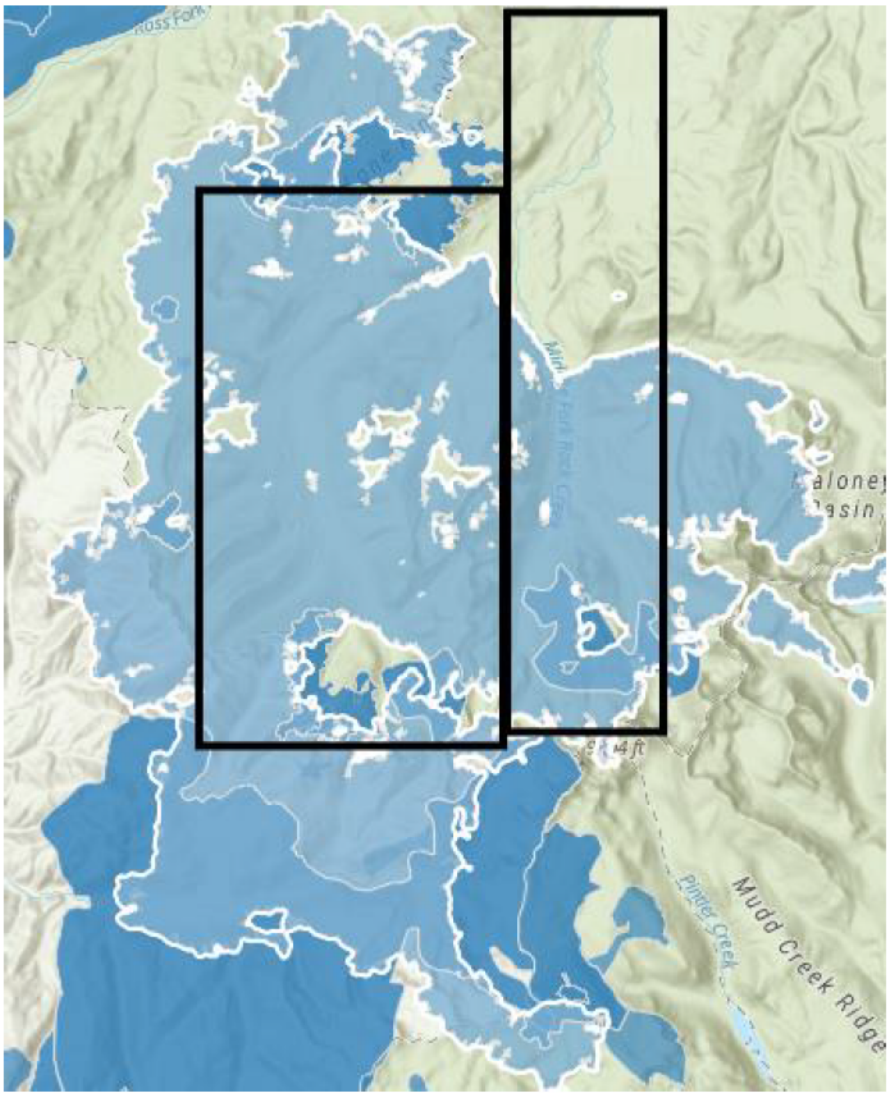


Figure 5: Meyers Fire boundary with box around Middle Fork drainage on the right, and Copper Creek drainage on the left. Ross Fork drainage is unmarked in top left.

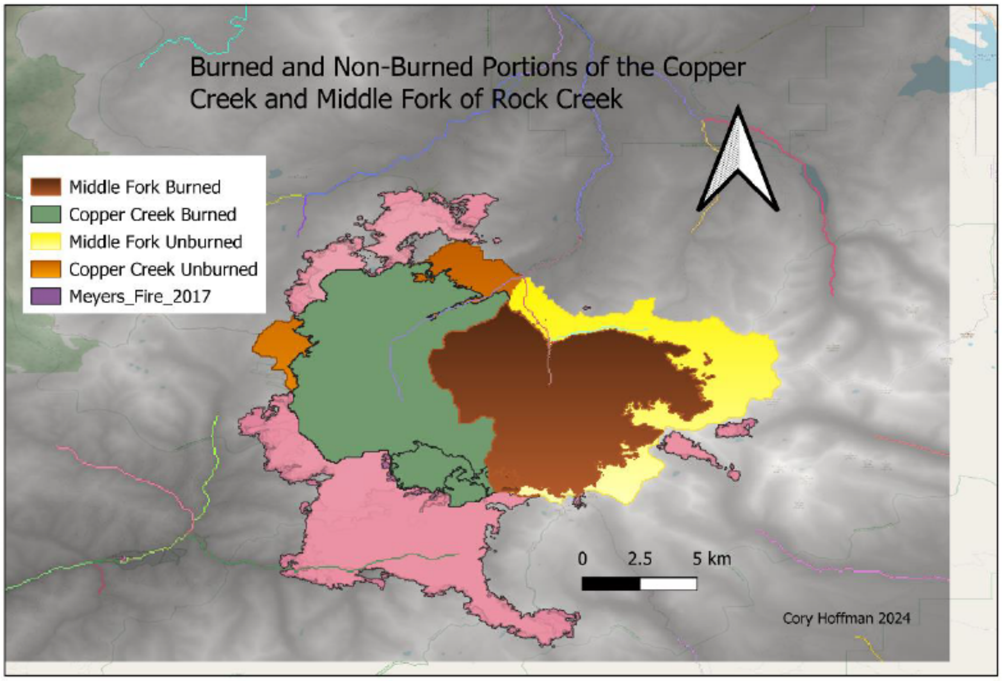


Figure 6: Map of watershed boundary for the Middle Fork of Rock Creek and Copper Creek with burned and unburned sections from the Meyers Fire.

Data Collection

I used Muck (2010) to determine threshold levels of suspended sediment in mg/L for bull trout. I used Muck (2010) because it is a thorough literature review on the impacts of suspended sediment on salmonids and gives a comprehensive outline on determining the levels for water bodies, based on the timing of suspended sediment, the duration it will remain in the stream, and the life history class of the bull trout (Muck, 2010).

Sediment data were gathered from the U.S Geological Survey (USGS) national water monitoring website. Streams that had sediment data were identified by their reference page, with all sites cataloging sediment data, specifically focusing on the page with Missouri and Montana streams (https://water.usgs.gov/osw/sediment/ms_mt_stations.html#mt). Streams were selected from the Montana Fish Wildlife & Parks bull trout restoration area/core area habitat streams. To supplement gaps in the sediment data, I used the available literature for responses of sediment after wildfires.

Bull trout redd data were taken from the Montana Fish Wildlife & Parks list of all core bull trout streams and restoration areas in Montana, from 1979 to 2012. I selected streams that were of roughly the same size as the Middle Fork of Rock Creek. Once a stream was selected, I acquired the "summary of all available data" from the local gauge stations site. I verified that the sediment data and the time of data collection fit with the time frame for the redd data and wildfires. I would then select suspended sediment concentration from the "discreet sample data" page between 09/01/1995 as the start date and 10/30/2005. If it made sense for the site to select outside of that range based on when the sediment data was collected, I would extend the scope for the sediment data. The data were then organized by watershed, redd count, and fire data also included. It also included sediment data for each year was the mean based on all available samples for each available year.

Fire data were taken from the U.S Forest Service fire history web page (https://www.fs.usda.gov/detailfull/flathead/maps-pubs/?cid=fseprd627869). I would select streams with available redd data that overlapped historic fire data. In most instances, the availability of the sediment data did not align with the redd count time frame; therefore, it was impossible to match for that watershed. I only used fires between 1979 and 2012 and >4 kilometers squared except for the Copper Creek fire which was 3.97 kilometers squared. In some instances, large fires only partially burned within the chosen watershed, and I used the measure area tool to trace the edge of the fire within the watershed to estimate the size of the impact on the stream.

I took a mean of the redd counts before and after the fire. To average the redd counts, I used as many years as possible in either direction which counts were available. The redd data for the Middle Fork of Rock Creek and Copper Creek were recorded every year from 1993-2012, and so seven years before and after the 2000 fire season were used to average the redd counts. Four years were used to average for the Ross Fork, seven were used for the Middle Fork and Copper Creek, six were used in Stony and Little Stony, and five for Ranch Creek, Gold Creek, and the North Fork of the Blackfoot River. I also used a linear regression for the redds before and after the fire. In addition, I used a single tail T-Test. All statistical analysis was done with Microsoft Excel for all streams.

RESULTS

Spawning Redds

Stony and Little Stony Creeks

Little Stony Creek had redd count data available from 1998 to 2012. The 145.9 square kilometer Wyman #2 (Figure 15) fire burned almost the entirety of the Little Stony Creek drainage in 2006, and most of the northwest side of the Stony Creek drainage, with roughly 56.66 square kilometers of the fire occurring in the Stony Creek drainage. Redd count averages on Stony Creek were 6.5 in the six years following the Wyman #2 fire from 2006-2012, in 2006, and 14.17 in the six years before the fire from 2000-2006 ($p=0.016$). The trend line before the fire was positive ($m=0.4286$), and negative after the fire ($m=-2.4286$). Little Stony Creek had only one redd in the following six years for an average of 0.17 after the fire, and 7.5 in the six years before the fire ($p=0.013$). The trend line before the fire was negative ($m=-2.0286$), and slightly positive after the fire ($m=-0.1429$).

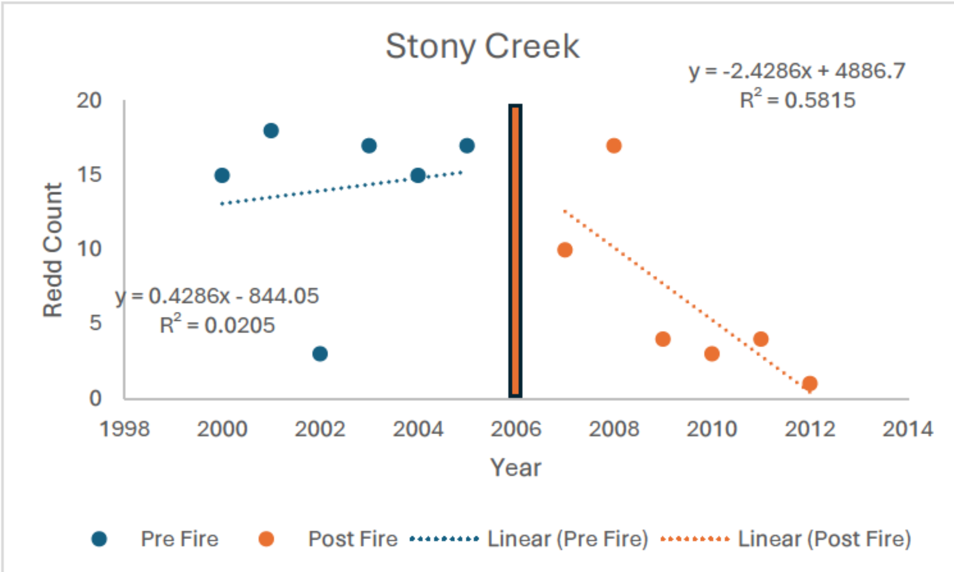


Figure 6: Number of redds per year and year of fire for Stony Creek.

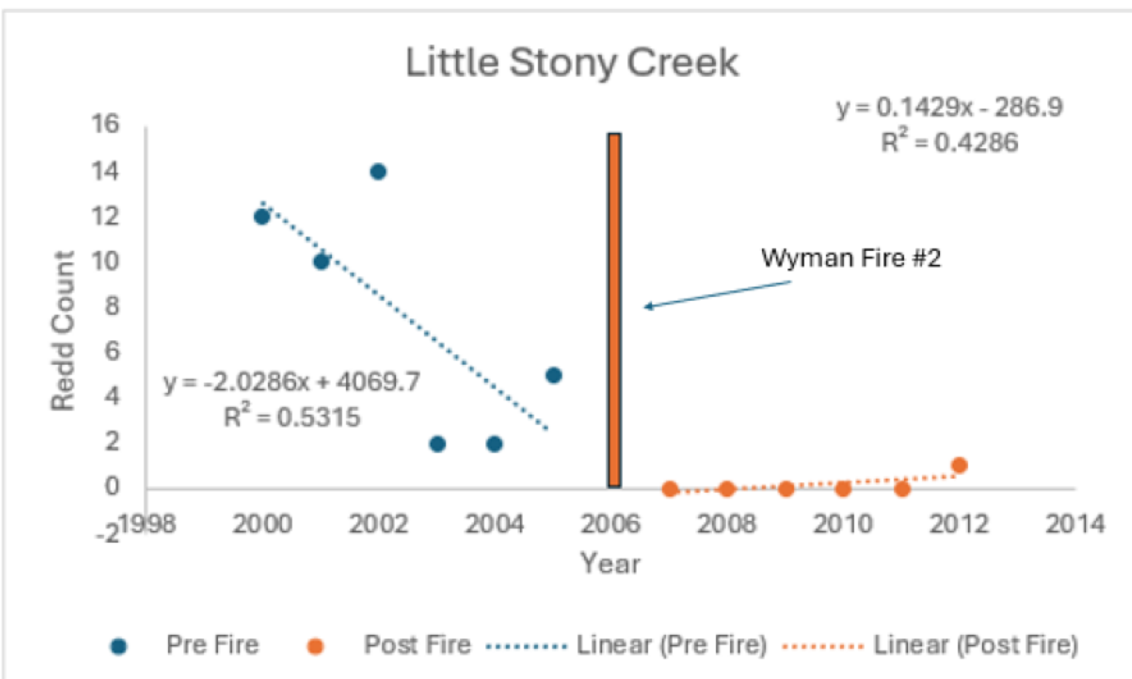


Figure 7: Number of redds per year and year of fire for Little Stony Creek.

Ranch Creek

Ranch Creek was also burned in 2006 by the Fisher Point fire, at 73.74 square kilometers. The redd count for Ranch Creek had a mean redd count of 12.7 for the six-year pre-fire and 8.7 for the six years following the post-fire (p=0.072). The trend line before the fire was slightly negative (m=-0.5155), and slightly positive after(m=0.0571). Sediment data could only be collected downstream at the Rock Creek gauge station near Clinton, Montana, and the data stopped being recorded in 2003. This was true of all the Rock Creek tributaries, including Copper, Ross Fork, Middle Fork, Stony, and Little Stony Creek.

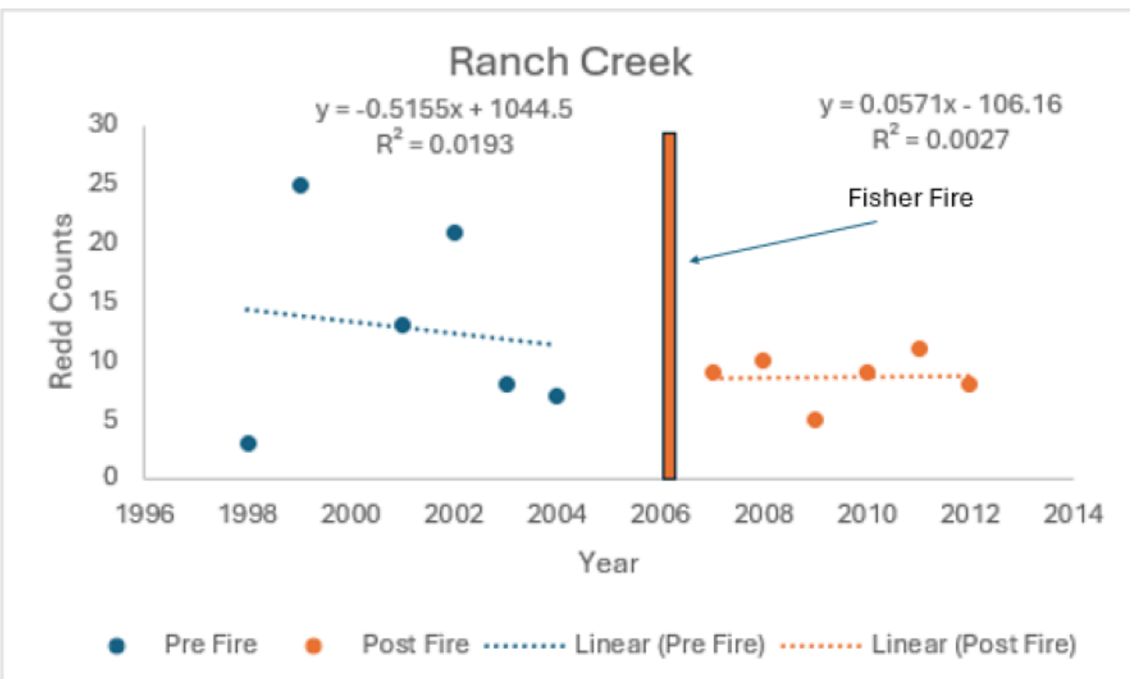


Figure 8: Number of redds per year and year of fire for Ranch Creek.

Middle Fork Rock Creek

The Middle Fork of Rock Creek experienced another wildfire in the 21st century before the Meyers fire. The Falls fire and Copper Creek fire burned roughly 3,000 acres, with about 8.5 square kilometers in the Falls Fork of Rock Creek in the Anaconda Pintler Wilderness area and another 3.56 square kilometers from the Copper Creek fire and a portion of the 0.47 square kilometer Clifford fire, which all burned in the year 2000. Redd counts fell from an average of 29.29 in the seven years pre-fire to 20 in the seven years post-fire (p=0.044). The trendline was positive before the fire (m=3.5714), and negative after the fire (m=-2.3929).

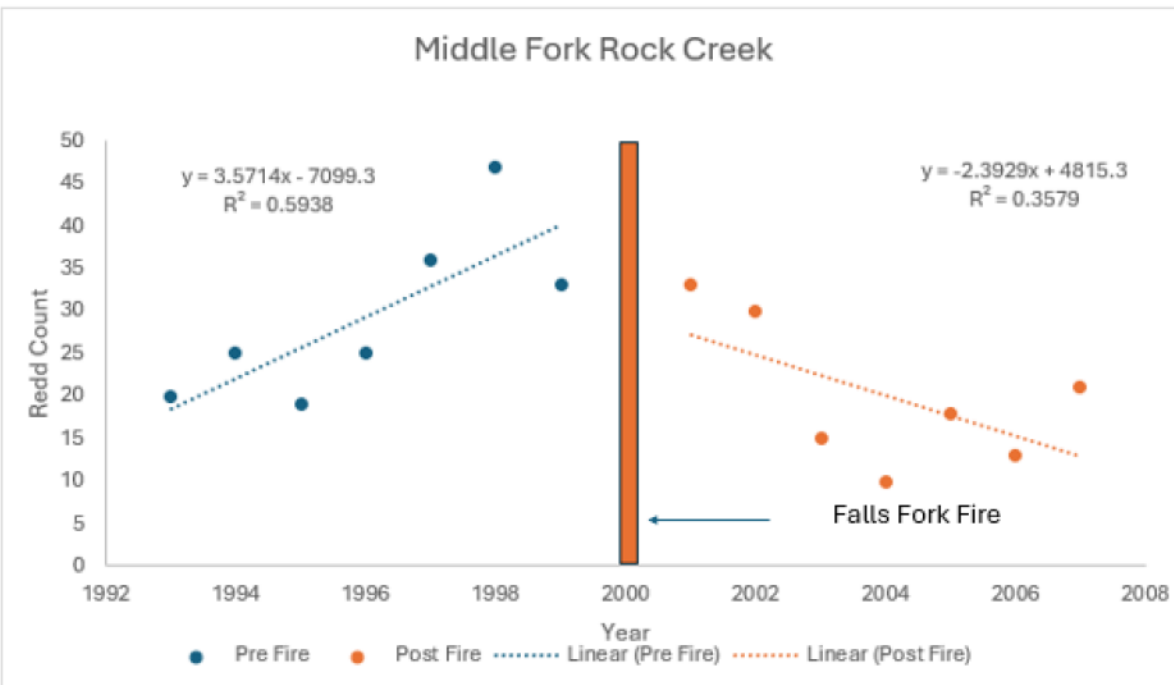


Figure 9: Number of redds per year and year of fire for Middle Fork of Rock Creek.

Copper Creek

Copper Creek experienced two smaller fires in 2000: the Copper Creek fire of 3.56 square kilometers and the Clifford fire of 0.49 square kilometer, which only partially burned in the Copper Creek drainage. The red counts dropped in this watershed from 13.86 in the seven years prior to the fire to 8.86 in the seven years following the fire (p=0.063). Trendlines before and after the fire were positive, but with a greater slope before the fire (m=1.2143 before the fire, m=0.619 after the fire).

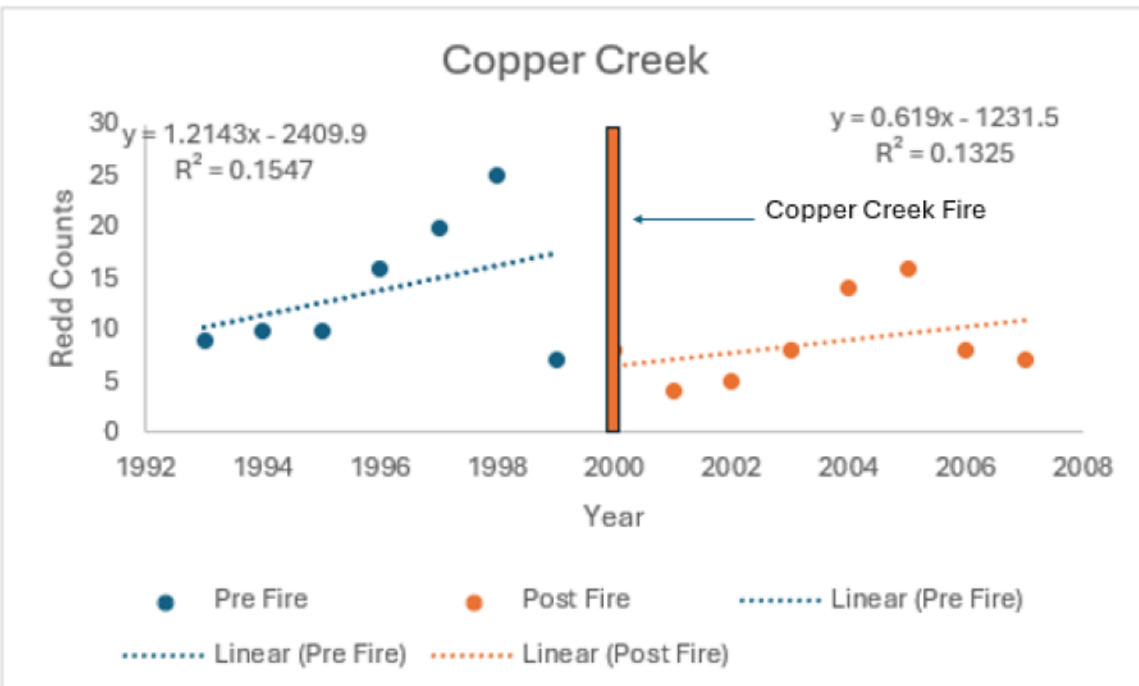


Figure 10: Number of redds per year and year of fire for Copper Creek.

Ross Fork of Rock Creek

The Ross Fork of Rock Creek was heavily burned in 2000 by the Coyote fire. This fire burned 89.03 square kilometers. The redd counts in the main fork of Ross Fork of Rock Creek had the smallest decline in average of those streams in the study. The average redd count went from 7.5 to 5.25 redds (p=0.309). The trend lines were positive before and after the fire for the South Fork of Ross Fork with a greater slope after the fire (m=0.9 before, m=1.4 after).

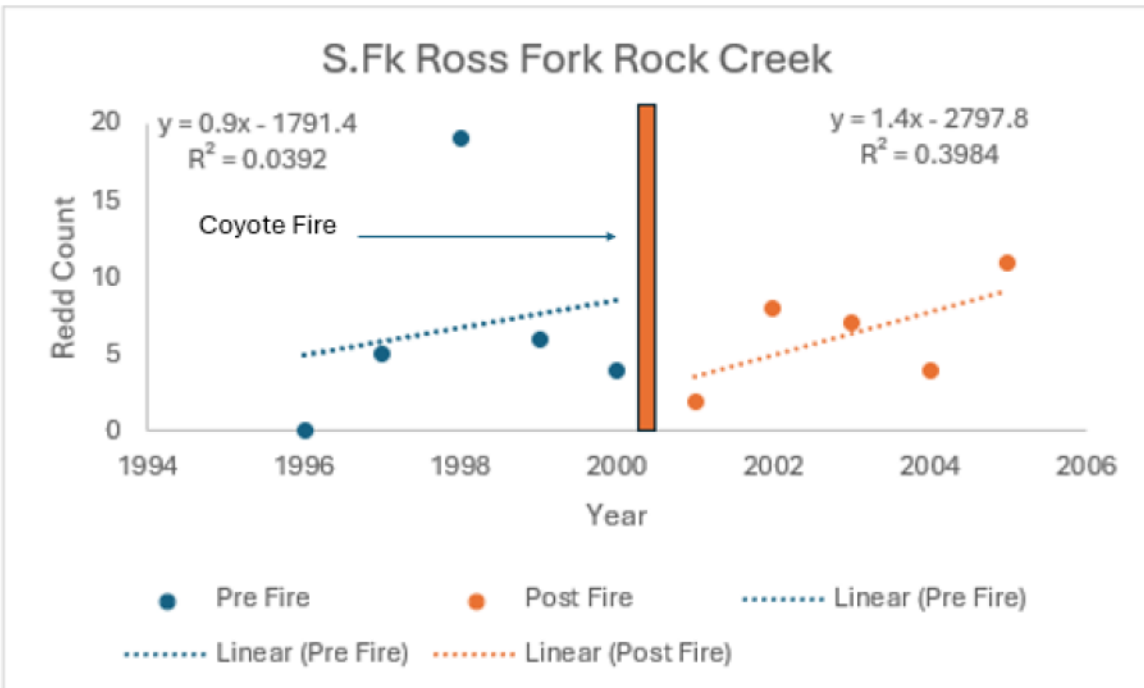


Figure 11: Number of redds per year and year of fire for Ross Fork of Rock Creek.

Gold Creek

The Gold Creek drainage experienced the 101.99 square kilometer Mineral/Primm fire in 2003. The redd counts in this drainage fell from 15.6 following the fire to 2.4 after the fire (p=0.008). The trend lines were negative before and after the fire, but greater before the fire (m=-3.3 before, m=-1.1216 after).

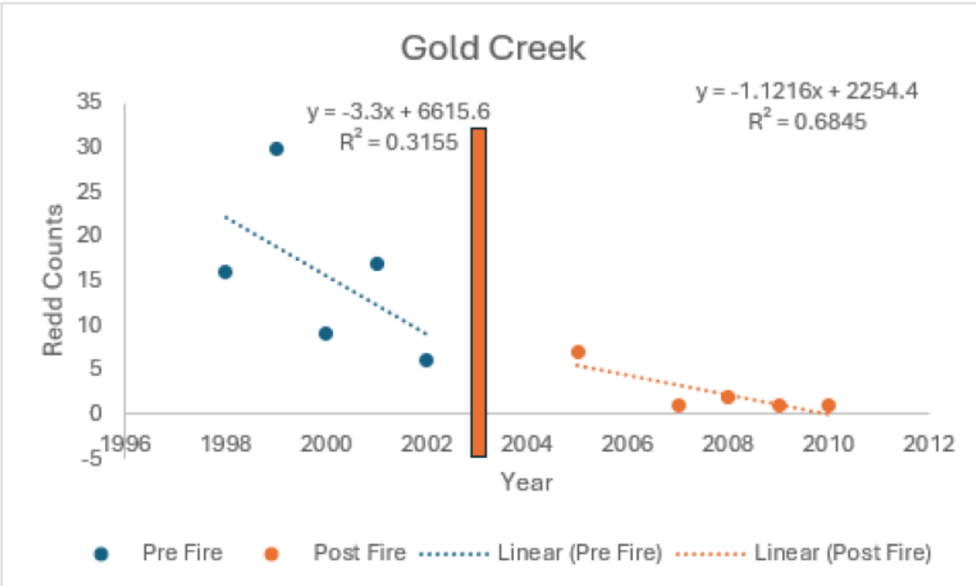


Figure 12: Number of redds per year and year of fire for Gold Creek.

North Fork of the Blackfoot River

Redd Counts for the North Fork of the Blackfoot River were the only stream that increased post-fire. They not only increased, but the mean more than doubled in the five years post-fire, changing from 51.6 redds before the fire to 113.4 after (p=0.002). The slope of the trend line was slightly negative before the fire (m=-1.6), and strongly positive after the fire (m=13.3). The 101.78 square kilometers Conger fire in 2007 was the largest during the period of data collection, however, there was a large fire in 1988 that had burned much of the watershed before, as well as a few smaller fires after.

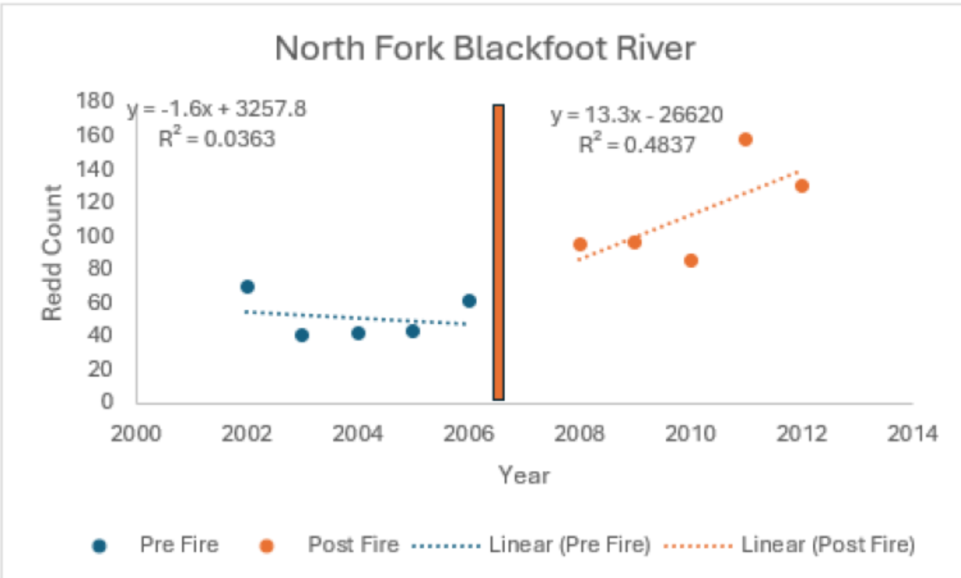


Figure 13: Number of redds per year and year of fires for the North Fork of the Blackfoot River.

Skalkaho Creek

Skalkaho Creek had some of the highest numbers of redd counts annually. Although it experienced a large fire in 2000, the number of redds still remained relatively high, though not with as high counts as before. It appears the population was trending upward until the fire, and has remained more stable until 2012, at the end of the counts. The mean for redd counts before the fire was 34.7 and 44 after the fire (p=0.118). The trend line was strongly positive before the fire (m=7.886) and strongly negative after the fire (m=-6.491)

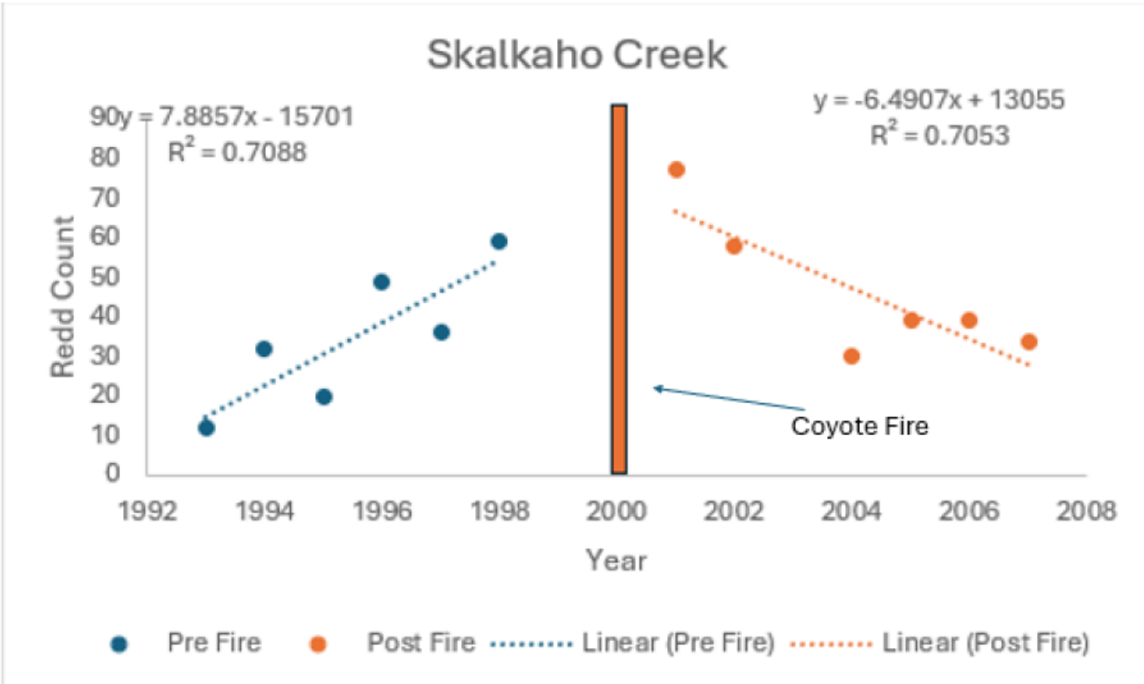


Figure 14: Annual redd counts and year of fire for Skalkaho Creek.

Table 1: Fire and Redd Data for Lower Rock Creek and Blackfoot Streams .

Stream	**Stony Ck.**	**Little Stony Ck.**	**Ranch Ck.**
x̄ ReddsPost Fire	6.5	0.2	8.7
x̄ Redds Pre Fire	14.2	7.5	12.8
P	0.016	0.013	0.072
Fire km²	145.87	145.87	73.74
Fire year	2006	2006	2006
Fire Name	Wyman #2	Wyman #2	Fisher Point

Table 2: Fire and Redd Data for Middle Fork of Rock Creek, Copper Creek and South Fork Ross Fork Rock Creek.

Stream	**M.Fk.Rock Ceek**	**Copper Creek**	**S.Fk.Ross Fork Rock Creek**
x̄ ReddsPost Fire	20	8.9	5.3
x̄ Redds Pre Fire	29.3	13.9	7.5
P	0.044	0.063	0.309
Fire km²	12.14	4.0	89.03
Fire year	2000	2000	2000
Fire Name	Falls Fork	Copper Creek	Coyote

Table 3: Fire and Redd Data for Blackfoot, Clark Fork River and Bitterroot River tributaries

Stream	**Skalkaho Creek**	**Gold Creek**	**N.Fk.Blackfoot River**
x̄ ReddsPost Fire	44	2.4	113.4
x̄ Redds Pre Fire	34.7	15.6	51.4
P	0.118	0.008	0.002
Fire km²	73.74	101.99	101.78
Fire year	2000	2003	2007
Fire Name	Coyote	Mineral/Primm	Conger Creek

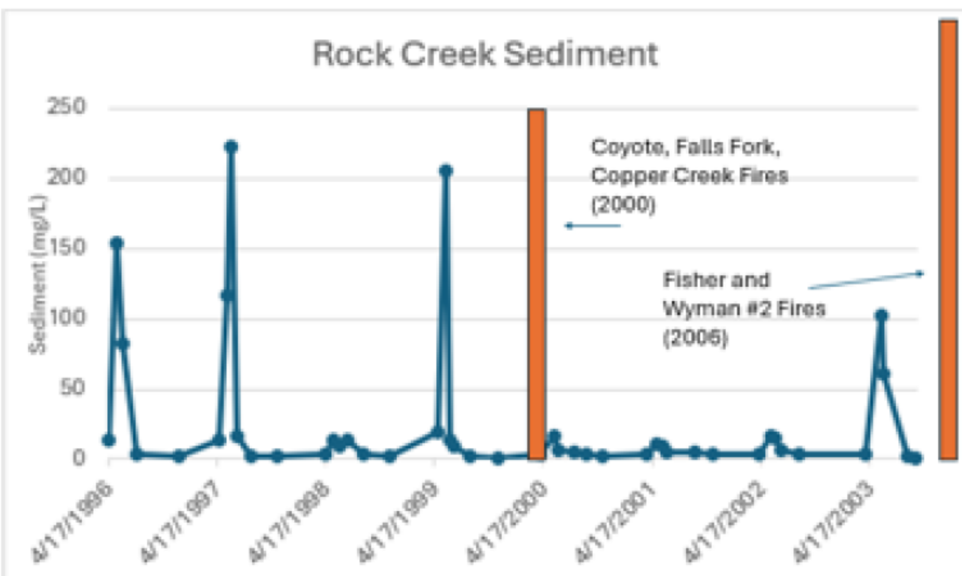
Sediment

Sediment data from gauging stations were difficult to obtain. Of sites where sediment data were available, the years typically did not align before or after a significant fire. Often the sediment data would no longer be recorded right before the fire, or start being recorded right after a fire. Some streams were large enough to have records expanding for multiple decades, coinciding with fires, however, this often meant the drainage area was so large that it became difficult to point to one event as a single cause for an increase in sediment.

Rock Creek

Rock Creek had sediment collected from the years 1985 to 2004. Wildfires in this watershed were mostly absent during this period.

Figure 15: Sediment for Rock Creek 1996-2003



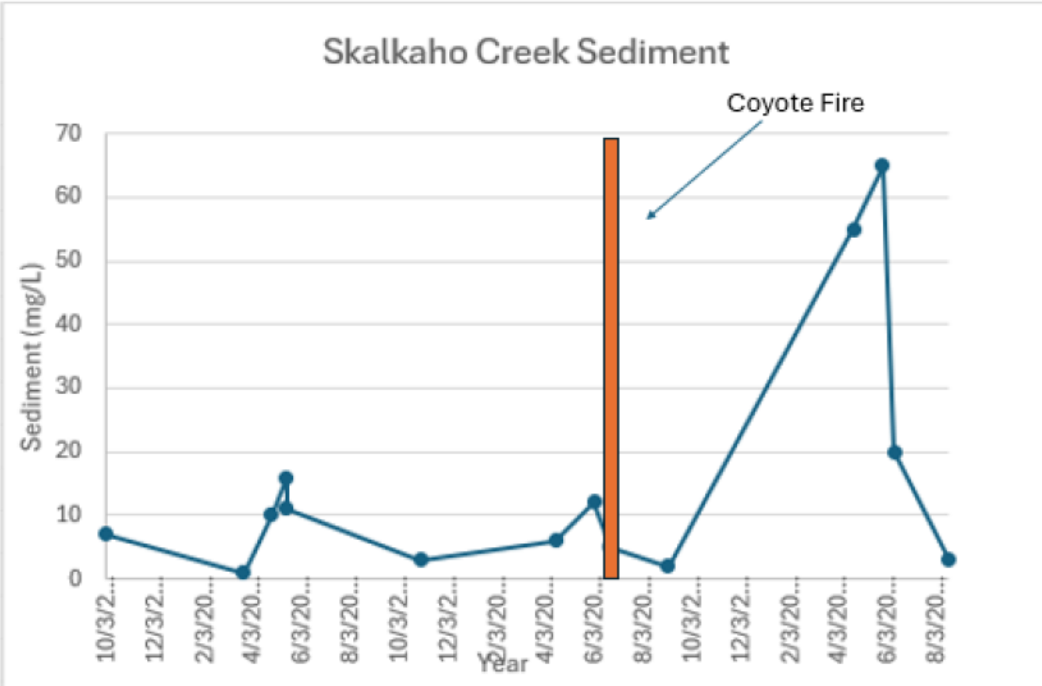


Figure 16: Sediment for Skalkaho Creek 2000-2003

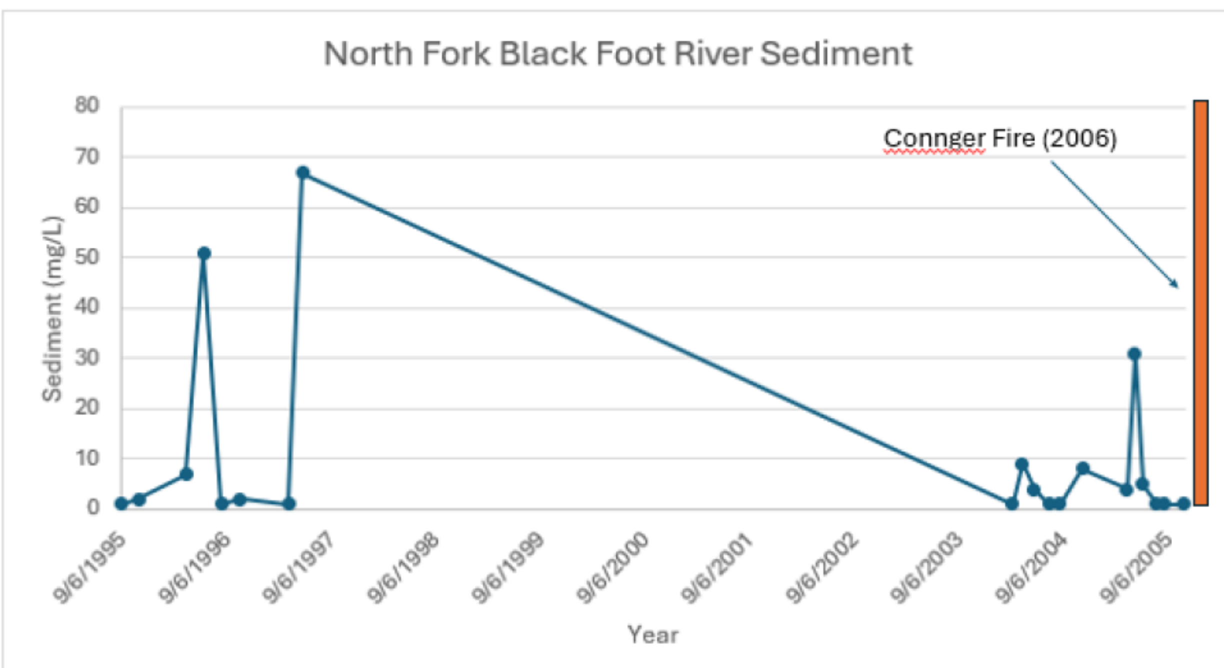


Figure 17: Sediment for North Fork of the Blackfoot River 1995-2005

DISCUSSION

The influence of fires over the behavior of bull trout seems to exist, but the response to fire is not always what I would have predicted. It seems that the extent of the fire in the watershed, as well as recent bull trout spawning densities and wildfires may play a role in shaping how bull trout respond to wildfires. The original impacts of suspended sediment to streams following wildfires could not be fully explored with the existing data. However, the redd count data were able to show that wildfires in these watersheds can influence the presences of bull trout spawning. These data do not cover trout survey data for number of individuals in each stream, only on the presence of spawning redds indicating spawning use. It may be that reduced overhead vegetative cover from fires, could increase stress on bull trout combined with more competition from non-native trout like brown trout that are more tolerant of warmer temperatures (Eby et al., 2014). Furthermore, the redd data for this paper only extended to 2012, and many wildfires have occurred in the Rock Creek and Western Montana region since.

Let us return to the questions that were introduced earlier. *Has the number of spawning redds changed after the occurrence of wildfire?*

The general trend of redd numbers has been declining over the last few decades in almost all the tributaries examined here despite the fires. Comparing with redd counts in unburned streams (Figures 18,19 and 20), it appears some streams have decreased or increased redd counts regardless of fires. However, fire seems to have an influence over bull trout using a stream for spawning. Five of the nine tributaries had some statistical significance for the fires influence on spawning site selection. However, it seems that fires cause a shift in the trend of bull trout spawning in these tributaries. About 88% of the streams examined here had a negative trendline after the fire. However, two streams here appeared to have a strong positive response in spawning rates after the fire. While the direct cause may be uncertain, we can look at the response of bull trout to use these tributaries after fires have occurred. The number of bull trout redds in each of the examined streams showed a decline after wildfire disturbance, with the exceptions of the North Fork of the Blackfoot River and Skalkaho Creek.

The North Fork of the Blackfoot River had the smallest p-value and the greatest increase in redds following a fire of any stream in this study, with a p=0.002. The mean more than doubled in the five years post-fire, changing from 51.6 redds before the fire to 113.4 The increase of redds gives the appearance that the North Fork of the Blackfoot River became more favorable after the fire. The reasoning behind this is unclear, but I would like to propose possible explanations.

The North Fork of the Blackfoot watershed has undergone multiple fires over the last few decades. Skalkaho Creek the North Fork of the Blackfoot River had a high number of redds (34.7 before and 44 after, and 51.4 before 113.4 respectively) comparatively before the fires, and had undergone multiple fires in the last few decades differing from the other watersheds. It is possible that fire in relatively undisturbed forests may temporarily disrupt bull trout spawning, more frequent fires may provide better habitat in the long term. Without any further data, or other variables measured like water temperature, it may be difficult to draw further conclusions on this. Further examination of this in the future could help shed light to see more watersheds have similar trends.

The reduction of trees could increase groundwater, potentially flushing out some existing sediment (Rey et al., 2023). Fires have been thought to increase competition with non-natives like brook and brown trout, that have a greater tolerance of warmer weather (Young, et al., 2013). Another potential explanation for the rise in bull trout redds after this fire could be that the Conger Fire eliminated potential barriers downstream that impeded bull trout passage. The relatively high number of redds before the fire suggest that conditions were still favorable, and that barriers being removed by the fire is likely not the reasoning (Kukula and Bylak, 2022).

The response to wildfire appeared to be related to whether the stream has more or fewer redds on average throughout time. Both Skalkaho Creek and the North Fork of the Blackfoot River had high annual redd counts compared to most of the other streams, 34.7 before and 44 after, and 51.4 before 113.4, respectively. While not included in the study, both sites experienced more frequent fires than the other watersheds of the study sites.

Copper Creek, Ranch Creek, and the Ross' Fork of Rock Creek showed a decline in redds, with the mean lower after the fire. However, the response was not as severe as other streams. Copper Creek showed a decline of mean redds from 13.9 to 8.9 redds per year after the Copper Creek Fire. The Copper Creek drainage also had the smallest fire in this study and burned primarily in the highest elevation part of the drainage, sparing much of the lower elevation forest. The South Fork of Ross Fork drainage did not have a great amount of area burned by the fire. The Ross Fork mean was 7.5 pre-fire, and 5.3 post-fire. This could partly explain the lack of response to this watershed by the fire. Ranch Creek, however experienced fire over a greater proportion of the total watershed area, so it does not fit as well with the South Fork of Ross Fork and Copper Creek.

Gold Creek declined from 15.6 to 2.2, however, a few outlier years in the late 90s and early 2000s could cause a higher mean pre-fire. Ranch Creek had a mean redd count of 12.8 pre-fire to 8.7 post-fire. While the trend has been declining here like the other streams, the fluctuations in redd counts seem to bounce steadily up and down, and with higher number counts in the most recent years collected. Little Stony Creek had a dramatic response after the fire, but this stream is a smaller tributary that typically had counts not exceeding fifteen. The entirety of the stream was burned, likely eliminating any reaches with buffer vegetation, and likely causing a great influx of sediment and increasing temperatures, although this information is unavailable. Redds almost disappeared entirely, except for one year that there was one in 2012. Redd counts declined from 7.5 to 0.2 per year after the fire. Stony Creek is a larger tributary that Little Stony empties into. Additionally, while some of this drainage was heavily impacted by the Wyman #2 fire, half of the drainage was unburned, retaining its vegetation. Here, the mean redd number declined from 14.2 to 6.5 after the fire of 2006. Little Stony Creek had almost no area that did not get burned over, save for a small portion in the headwaters. The intensity of this fire was not measured in this, or any other drainage in this study, however, so variation of intensity within the drainage is lacking. There is an obvious discrepancy in the total proportion of burned area between Stony and Little Stony Creeks. Little Stony Creek is a tributary of Stony Creek and is by nature a smaller area with less discharge than Stony Creek.

Bull trout populations have been declining over much of their range, and the streams in this study seem to align with that. While there does seem to be a difference in counts before and after fires, there are likely other variables also interacting with bull trout in these waters. Hogback Creek is another stream in the Rock Creek watershed that burned in 2017. Using the redd count data up to 2012, before the fire, there is still a negative regression on the redd counts for this stream. Most of the fires that occurred during the period of the redd count data were from 2000-2007. It may be that redd counts were especially high in the late 90's, and hotter and drier years during that time could alter the temperature or oxygen saturation of the water.

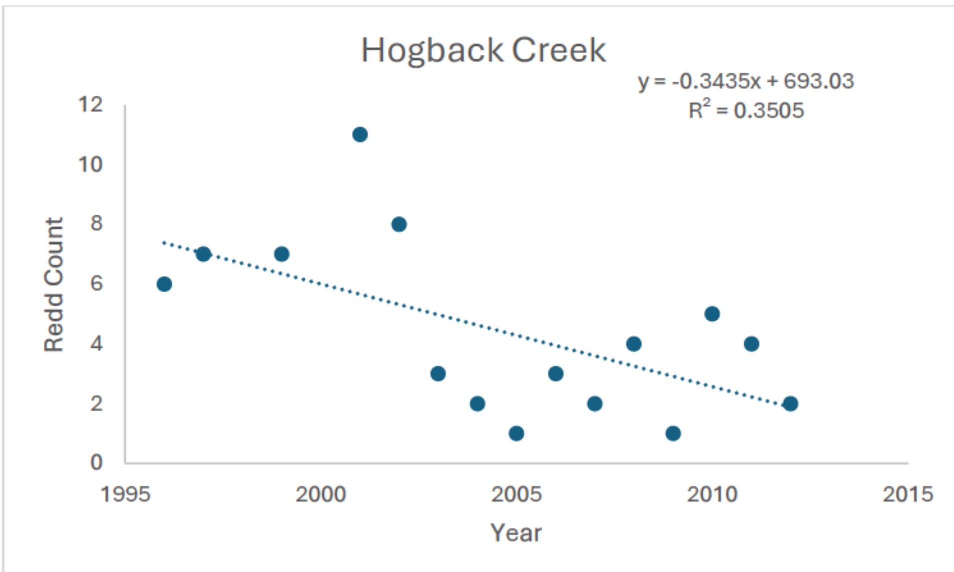


Figure 18: Redd counts for Hogback Creek with no fire during this period.

Rattlesnake Creek, a tributary of the middle Clark Fork River that is primarily unburned, except for a small section of the Primm/Mineral fire in 2003, has also undergone a strong negative regression. This was a case where there were high redd counts in the upper 20s and 30s followed by a sharp decline in 2008.

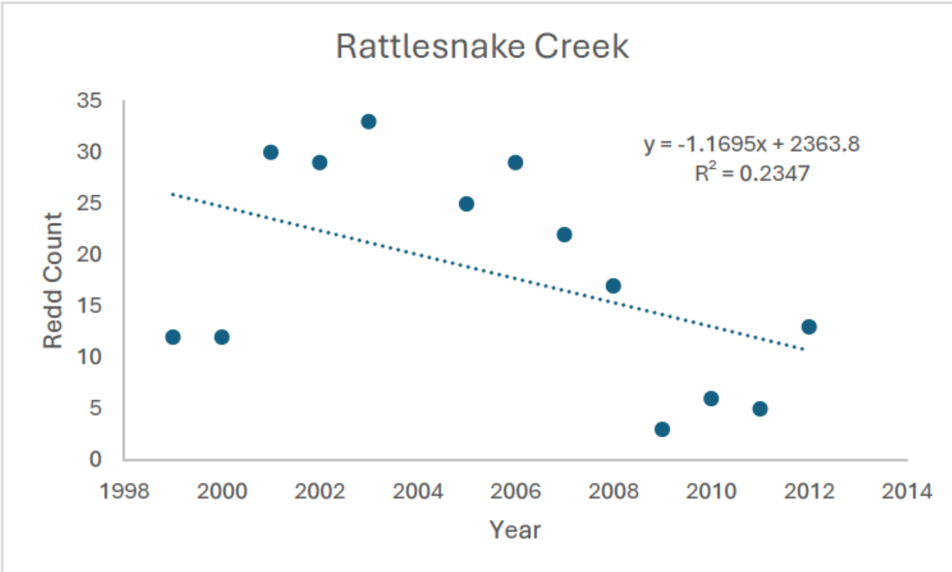


Figure 19: Rattlesnake Creek redd counts.

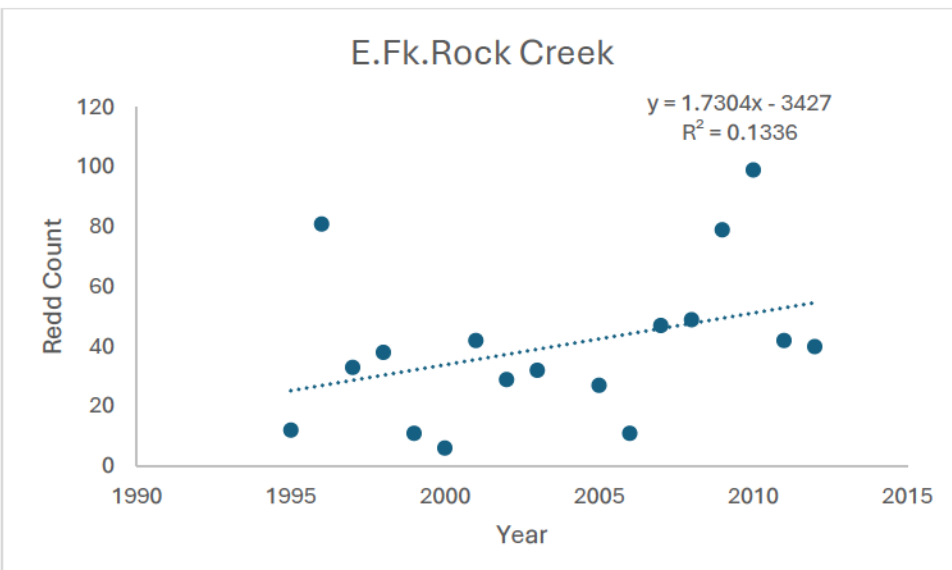


Figure 20: East Fork of Rock Creek

Has there been a change in water quality to the Middle Fork of Rock Creek following the Meyers Fire?

While sediment data were not complete enough for the study site, many papers have been published indicating how suspended sediment in streams typically increases following large fires. Malmon et al. (2007) found suspended sediment loads increase by two orders of magnitude, and silt and clay increase by 50-80% following a stand-clearing New Mexico wildfire. Site conditions and climate likely play a large role in sediment inputs following a fire. Lane, Sheridan, and Noske found that sediment increased by 8-9-fold in the year following a fire and remained two-fold greater two years after the fire.

When comparing the precipitation between the years of 1995 and 2005, 2000 was very dry, likely resulting in an increase in fire activity. This could also reduce the amount of sediment load washed into streams following fires as well. Dry years that may be more prone to wildfire, followed by particularly wet years, could be especially bad for bull trout habitat loss. Petticrew, Owens, and Giles (2006) found an increase of suspended sediment by 66% in the following year after a large fire. They also found that despite this increase in sediment, it was low compared to other fire-disturbed systems, likely due to a lack of hydraulic drivers. Similar findings from a study in California showed that while suspended sediment concentrations increased over 200 times from pre-fire conditions, the fluxes were lower than average due to drier conditions (Jumps et al., 2022). Ryan et al. (2011) found suspended sediment spiked significantly following rain but quickly returned to base levels during drought years. Course sediment carried to streams following a fire was a direct function of snowpack during the following year (Reneau et al., 2007).

Table 4: Average precipitation in Montana by month for 1990-2012 (Northwestern Agricultural Research Center. 2025)

DATE	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.	TOTAL
1990	0.96	1	1.76	1.63	3.74	2.68	2.34	2.44	T	2.32	1.37	2.6	22.84
1991	1.41	0.41	0.72	1.21	2.72	5.36	0.77	1.15	0.8	0.75	2.26	0.58	18.14
1992	1.17	0.61	0.83	1.18	1.65	5.34	2.24	0.94	1.21	1.07	2.37	1.53	20.14
1993	1.68	0.6	0.73	3.77	2.22	4	7	1.19	1.54	0.83	1.23	1.27	26.06
1994	1.43	1.49	0.11	2.01	1.79	2.59	0.1	0.23	0.46	2.12	1.89	1.07	15.29
1995	1.17	0.9	2.33	2.25	1.44	5.63	1.91	1.47	1.21	2.75	2.33	1.91	25.3
1996	2.22	1.18	1.19	3.32	4.58	2.05	0.95	0.8	2.67	1.58	3.99	3.52	28.05
1997	1.5	1.62	1.18	1.69	2.62	3.41	0.99	1.94	2.36	0.94	0.33	0.42	19
1998	0.77	0.33	2.64	1.8	5.14	4.64	1.18	0.72	1.48	0.71	1.11	1.47	21.99
1999	1.05	1.18	0.9	0.55	1.32	2.74	1.63	1.93	0.36	1.72	2.33	1.08	16.79
2000	1.46	1.81	1.3	2.21	0.89	1.8	0.84	0.35	1.4	0.62	0.46	1.23	14.37
2001	0.75	1.54	1.03	2.62	0.57	3.29	0.91	0.54	0.32	1.8	1.44	0.59	15.4
2002	1.21	1.66	1.48	0.91	2.72	2.39	1.45	1.44	1.18	0.25	0.87	1.67	17.23
2003	1.63	1.01	2.32	2.23	1.78	1.57	0.05	0.35	2.56	1.29	0.59	1.04	16.42
2004	2.02	0.42	0.57	2.23	1.97	1.31	1.24	3.6	1.89	1.62	0.84	1.49	19.2
2005	1.38	0.01	1.41	2.21	1.73	8.44	0.26	0.6	2.28	2.2	1.45	1.42	23.39
2006	3.04	1.1	0.55	2.12	2.89	5.5	0.51	0.71	1.95	1.1	2.28	0.24	21.99
2007	0.39	2.26	0.54	1.62	3.29	1.35	0.75	0.23	1.28	1.11	1.02	1.13	14.97
2008	1.31	0.76	0.61	0.9	2.33	3.65	3.8	1.15	1.57	0.61	1.71	2.37	20.77
2009	1.72	1.59	1.43	0.98	1.62	1.98	2.44	0.99	0.04	1.72	0.37	2.66	17.54
2010	1.42	0.66	0.72	3.47	2.45	5.03	1.25	1.35	1.71	0.74	2.77	1.69	23.26
2011	2.43	1.61	0.87	2.25	3.2	4.48	0.99	0.24	0.91	2.46	0.46	0.4	20.3
2012	1.08	1.15	1.16	1.35	2.11	7.11	1.41	0.56	0.75	2.46	1.66	1.84	22.64

Fire intensity was not included in this study and would add more useful information to understanding the dynamics between these fires and the use of these streams by bull trout. Presumably, more severe fires that leave less vegetation on the landscape, and burn hotter will take longer to recover, be more susceptible to erosion, and thus provide less habitat for bull trout. Temperature increases from radiant heat and less shade from riparian vegetation will also decrease the value of habitat in burned watersheds. The lack of data for water quality parameters leaves this question inconclusive.

If water quality has changed, have any parameters exceeded the threshold of bull trout habitat requirements?

The relationship between wildfire and erosion is well established (López et al., 2020). Watson and Hillman (1997) found an inverse relationship between fine sediment and bull trout at all scales. One of the most complete works regarding the relationship between suspended sediment and bull trout was put together by Muck (2010). This paper is in two parts, with a literature review of salmonid and bull trout response to sediment, with the second part being a management document for likely impacts of sediment on bull trout for different age groups and watersheds, based on duration of exposure. Severity is based on background levels of sediment combined with duration of exposure, and can be measured on impacts to individuals, populations or habitat.

I have selected a few points from that paper to determine the likelihood of impacts from sediment on bull trout. The following statements are from that document and used in my determination of likely impacts to bull trout from these fires. For simplicity, I will only use some of the thresholds at the lower and higher ends given here. "For impacts to individual bull trout, adverse effects would be anticipated in the following situations: A) Any time sediment concentrations exceed 148 mg/L over background. B) When sediment concentrations exceed 99 mg/L over background for more than one hour continuously. C) When sediment concentrations exceed 40 mg/L over background for more than three hours cumulatively. D) When sediment concentrations exceeded 20 mg/L over background for over seven hours cumulatively." (Muck, 2010)

Skalkaho Creek had multiple measurements of suspended sediment after 2000 that exceeded 20 mg/L, including 55 mg/L and 65 mg/L. Rock Creek had five suspended sediment measurements greater than 100 mg/L, two over 200, and the highest being 223 mg/L. The North

Fork of the Blackfoot only had three measurements of suspended sediment exceeding 30 mg/L, with the highest being 50 mg/L. Making some assumptions comparing the Middle Fork of Rock Creek with other streams in the literature, as well as other Western Montana watersheds, it seems that given the impact the Meyers Fire had on the Middle Fork Watershed, as well as the typical snowpack of the mountains there that sediment values likely exceed the minimum threshold for bull trout of 20 mg/L for cumulative seven hours, or may have even reached higher levels for shorter durations. Without direct measurements of suspended sediment before and after each fire it is difficult to draw conclusions about the direct water quality parameters. Therefore, this question is left mostly speculative from what data there is available combined with the literature.

What were the likely impacts on bull trout in the Middle Fork of Rock Creek following the Meyers Fire?

The Middle Fork of Rock Creek had a robust bull trout population compared to other nearby streams-, as indicated by the number of spawning redds. In the Middle Fork of Rock Creek, redds averaged 22 per year between 1993 and 2012. Comparing this with other streams in the study with higher redd counts, such as Skalkaho Creek, 40.4, or the North Fork of the Blackfoot River, 66.5, from 1988 to 2012, it is still near 50-33% of the redds of those streams. I would expect the total impact on bull trout to be great but given the ability of bull trout to migrate temporarily out of this tributary to other waters, the temporary impact may not be too harmful. Settled fine sediment likely impacted bull trout redds. However, their ability to clear redds for spawning may have been compromised, resulting in by the suffocation of eggs in the fines.

Another possible explanation for this stream being good for spawning compared to some of the others in the study is likely due to the size of the stream compared to other nearby waters, such as Copper Creek, which runs into the Middle Fork. The upper watershed is also protected by the Anaconda Pintler Wilderness which has historically maintained cooler water, with no roads or logging to add sediment (Zellmer, 2012). Fire is a natural component in mountain watersheds, and although short term conditions may be uninhabitable for salmonids, they can provide better habitat long term by adding more large woody debris and cycling nutrients (Robinson, UehlinIger and Minshall, 2005).

The Meyers fire and Middle Fork of Rock Creek watershed differed from a couple of the other streams here watersheds with a more mosaic burn pattern, with fires that have occurred more frequently over the last few decades. Of the streams used here, the North Fork of the Blackfoot River had the longest history of the last few decades, going back to 1988 with the Canyon Creek fire that burned 38,642 acres. While other small fires in the study sites did occur in the 1980s and 90s, most were less than a few hundred acres and likely didn't play a large role in stream conditions. The bull trout of the North Fork of the Blackfoot River have been living in a landscape impacted by larger fires and could possibly be an explanation for why the trend of redds here has been increasing.

Of the nine different streams that were used for this study, only two had an increase in redd counts from the fire in question. However, I was selective in choosing the fire with the most acres burned that coincided with the available redd count data. Doing more extensive studies with more watersheds, a wider range of fire sizes with included intensity, as well as how fire mosaics overlap, could give a clearer picture of how fires impact bull trout spawning habitat. Additional climate and topography, soil type, vegetation type, parent rock material, and other information could also help elucidate the connection between fire and bull trout spawning use of mountain streams. Stream temperature was not examined in this paper but has been addressed in previous studies by other authors. The Meyers Fire of 2017 had a substantial impact on the landscape of the upper Middle Fork, Copper Creek and Ross Fork drainages. It is likely that this fires role on the landscape influenced bull trout spawning behavior.

Implications for management

Understanding bull trout populations and conservation areas is important for knowing where to target restoration and conservation efforts. The results of this study highlight the fact that wildfires play a role in bull trout selecting tributaries in which they live and spawn. Under the right circumstances, focusing restoration efforts and riparian vegetation planting on priority areas after fires may help improve bull trout habitat. Maintaining travel corridors between headwater refugia is equally important. For instance, Isaak et al., (2022) state the importance of headwater streams for the conservation of bull trout and identifying refugia for conservation and restoration efforts. However, this can potentially lead to the isolation and fragmentation of populations (Isaak, et al., 2022).

Further research incorporating fire severity and soil type could greatly expand the understanding of wildfire and bull trout habitat relationships. Wells et al. (2024) found that burn severety, followed by topography, physical ecosystem features and weather, were the greatest determining factors influencing fire impacts on Colorado River Cutthroat Trout (Oncorhynchus clarkii pleuriticus). It may be that fire caused debris flows may benefit species in some instances by providing in stream large woody debris (Wells et al., 2024; Rieman et al., 1997).

One of the limitations in this study was in the gathering of sediment data from the USGS gauging stations. Sites vary by time frame during which sediment data is available, with many sites having limited to no data in the 21st century, when fires became more frequent and larger throughout much of the west. Furthermore, many streams where sediment records were more recent were typically higher order streams, with large drainage areas that made it more challenging to track sediment responses from events upstream. Sediment samples were collected throughout the year, causing more difficulty tracking trends. Having a standardized sediment sampling spanning decades for each of these streams would greatly increase our ability to see the influence fire has on these watersheds with suspended sediment.

Conclusion

The results of my study indicate that wildfires play a role in spawning site selection by bull trout, with influence that may persist for several years. Furthermore, without having sediment data or redd count data for the Middle Fork of Rock Creek after the Meyers Fire, we could assume that it is likely that bull trout redd numbers may have declined from this watershed following the fire, given trends of similar streams with comparable fire size and previous redd counts. We need to consider the assumption that the redd counts are reliable, with the same protocols followed by researchers who are as likely to spot them in the water from year to year.

With an increase in fires worldwide due to a changing climate, understanding the role fire plays in ecosystems is crucial for species management. This is especially true with species such as bull trout with declining populations, without a clear explanation. Wildfires influence change on the landscape scale and understanding the role fires have played in the evolution of bull trout combined with habitat needs and the change of fire regimes may help us better understand management priorities.

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