

The Impact of Wildfire Activity on Stream Temperature in Colorado

Jonathon Hirschi

April 27, 2021

Data 2 Policy Symposium 2021

Math 5387, Dr. Joshua French



Stream Temperature Background

- Stream water temperature is critically important to ecological systems
- Microbes, insects, fish, and other aquatic species have adapted to specific temperature ranges
- In Colorado, species like the threatened Greenback Cutthroat Trout depend on cold waters for spawning, ideally 2.7 – 12.8 °C (37 - 55 °F)



Wildfires and Stream Temperature

- Wildfires can directly heat waters and destroy vegetation that provides cooling shade (riparian zones)
- Climate change is projected to cause increased wildfire activity, so it is important to understand how this will affect water quality



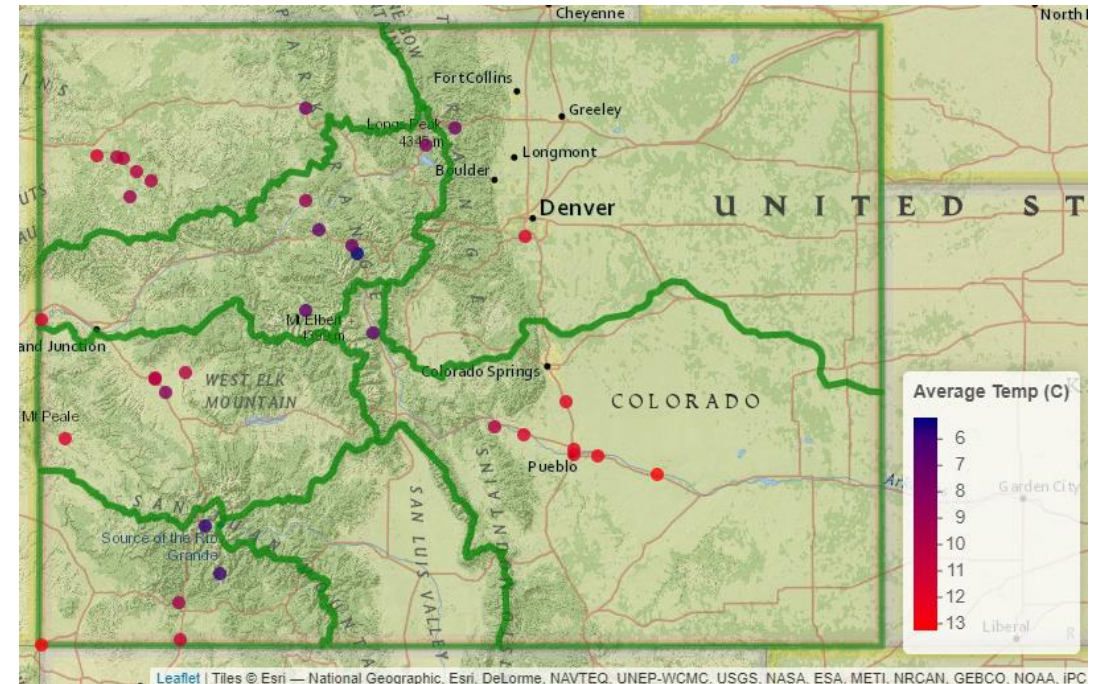
Analysis Goal

- Build a statistical model of stream temperature in Colorado
- Examine the relationship between wildfire activity and stream temperature



Water Quality Data - USGS

- The United States Geological Survey (USGS) has water monitoring sites all over the country
- USGS developed the R package *dataRetrieval* to allow researchers to easily access water quality data
- We collected water temperature and discharge (flow rate) data in addition to physical information on the sites, such as elevation above sea level and major river basin
- In total, we utilized data from 34 USGS monitoring sites
- We averaged the data over season

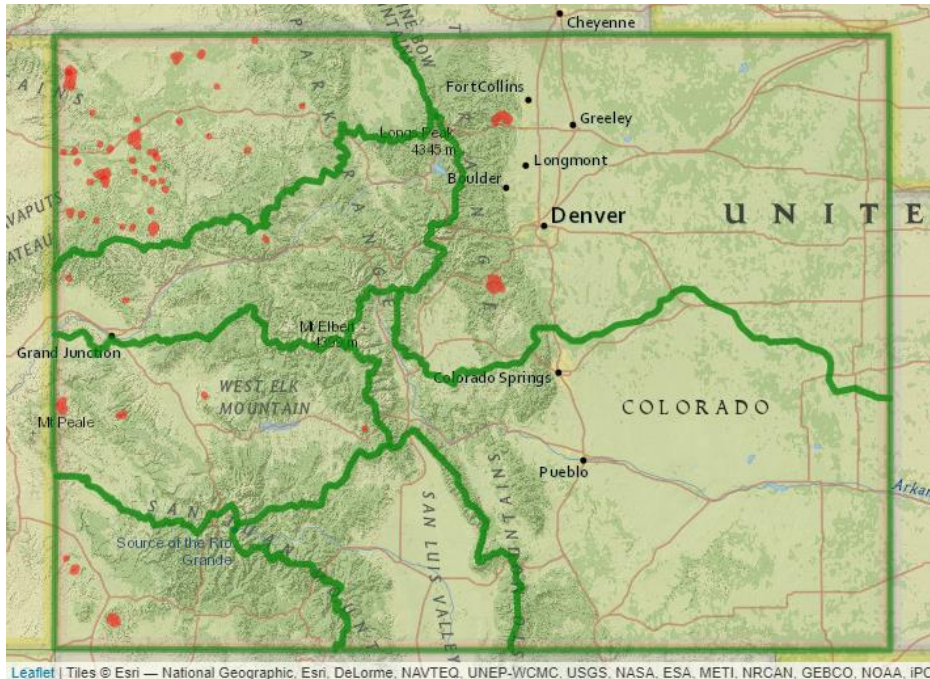


USGS Sites Utilized, with Major River Basin

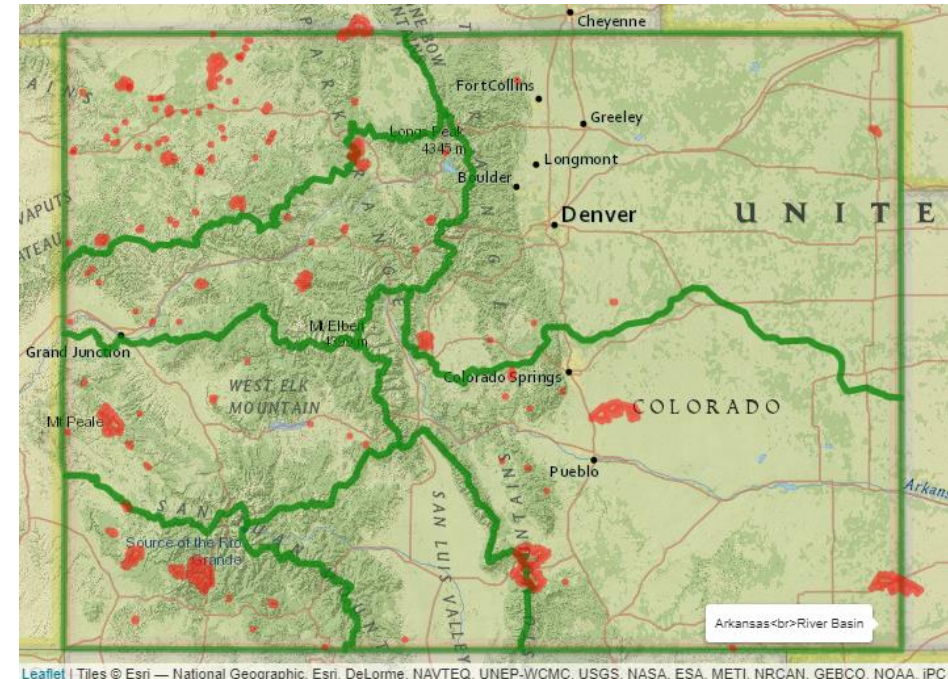


Wildfire Data – NIFC

- The National Interagency Fire Center (NIFC) provides spatial data for the locations, dates, and sizes for wildfires in America from 2000-2018
- Colorado had 953 wildfires over this period
- We calculated the number of fires per season and total acres burned, averaged over the major river basin



Colorado Wildfires – 2000

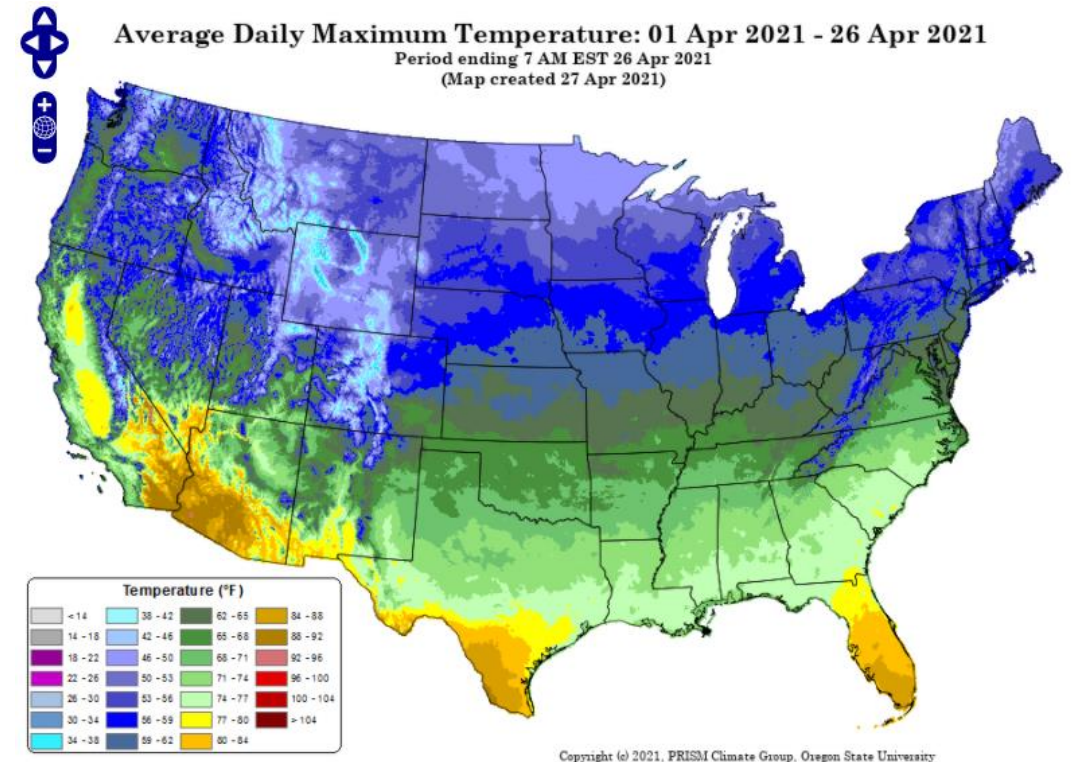


Colorado Wildfires – 2018



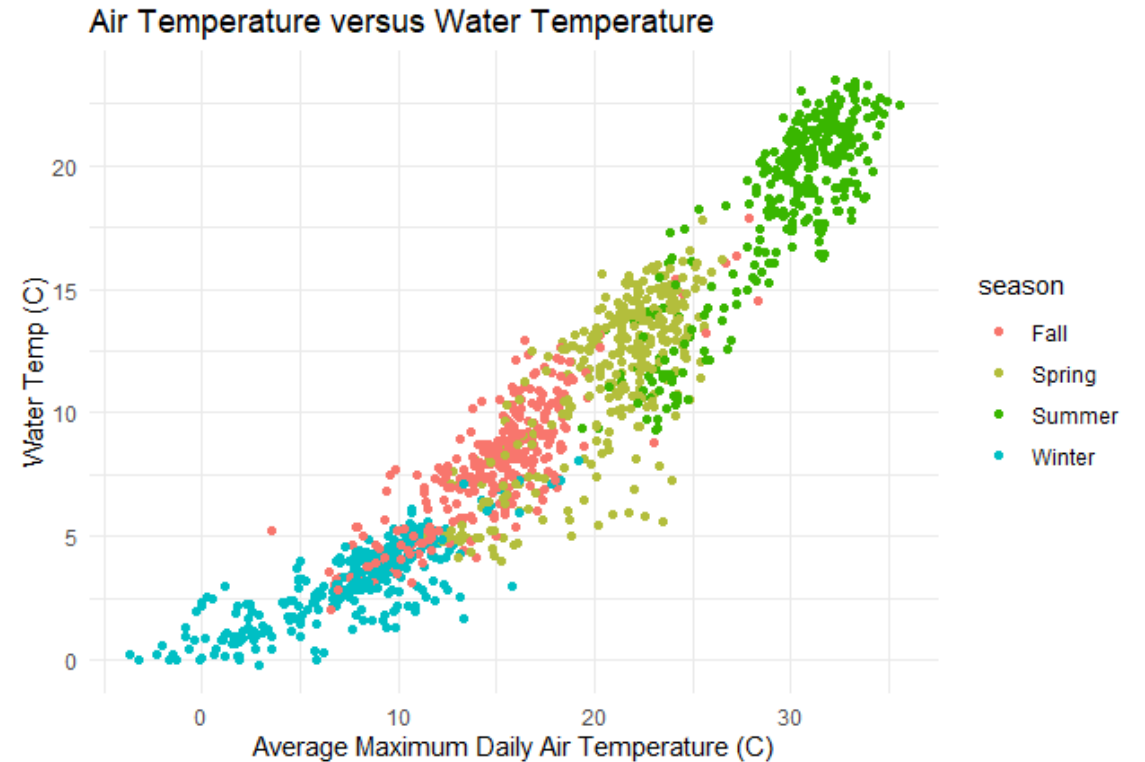
Climate Data – PRISM

- The PRISM Climate Group provides detailed spatial climate data for short and long term
- We accessed this data using the R package *climateR*, developed by Mike Johnson of NOAA
- We extracted the daily maximum temperature and precipitation in millimeters at the locations of the USGS monitoring sites from 2000-2018



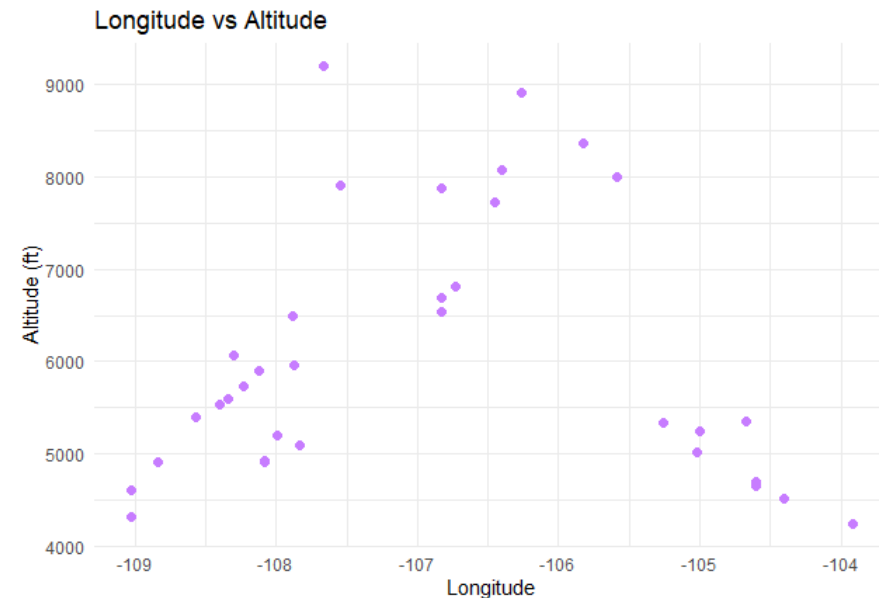
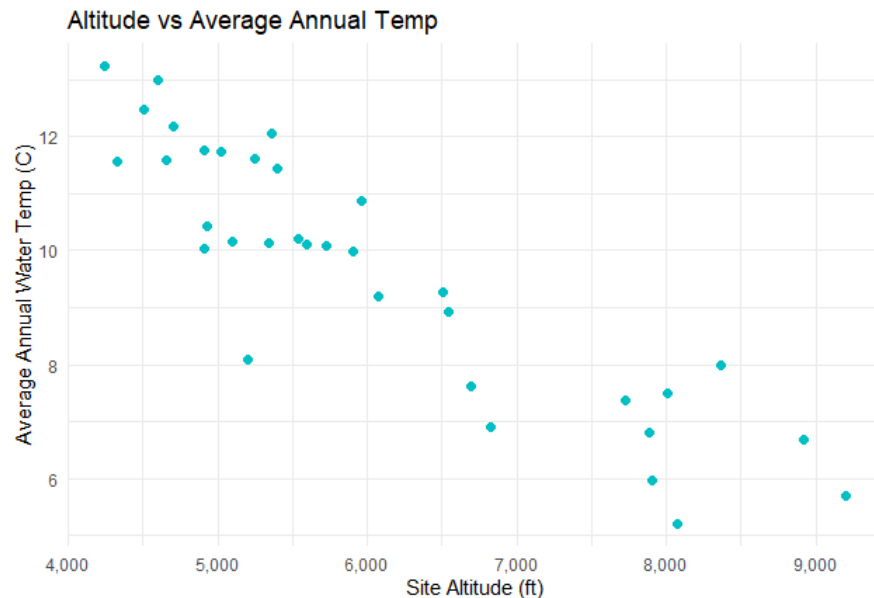
Data Exploration – Air Temperature

- Air temperature is strongly related to stream water temperature
- We examined a simple quadratic trend (temperature plus temperature squared)



Data Exploration – Altitude

- Water temperatures are colder at higher altitudes (feet above sea level)
- In Colorado, altitude is strongly related to longitude due to the North-South orientation of the Rocky Mountains

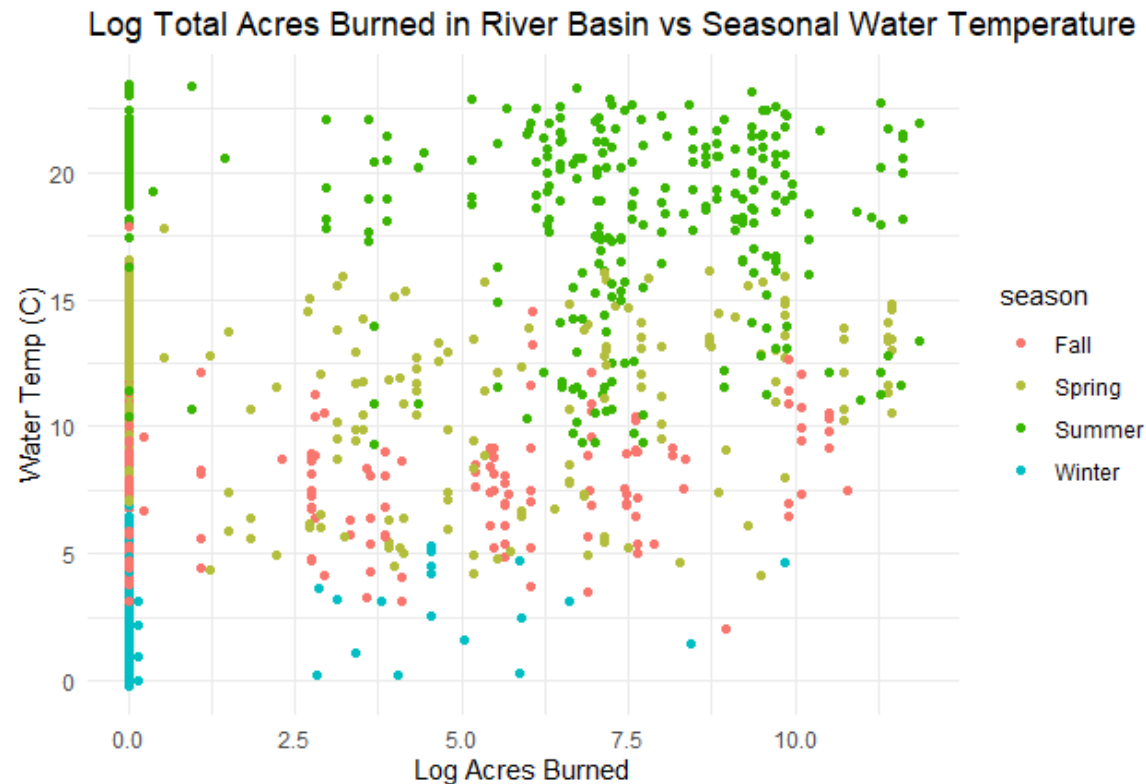


Each plot point represents averages over USGS Site



Data Exploration – Wildfires

- The natural log of acres burned in a River Basin is slightly related to water temperature



Variables Utilized in Model

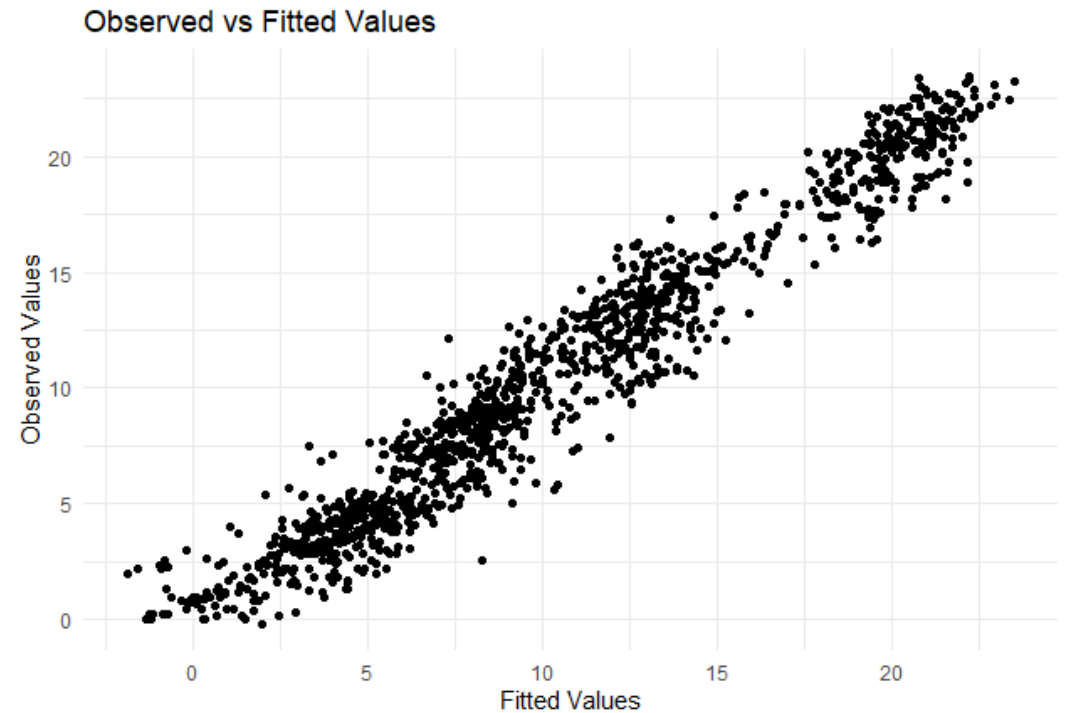
- After variable selection and diagnostic checks, we arrived at the following set of regressors
- We are ignoring the effect of repeated observations from the sites (for now)

Variable	Units	Explanation
Year	years	This could account for long term changes
Log Discharge	ft^3/sec	All things equal, a larger volume of water takes more energy to heat up
Log Precipitation	mm	Rainfall can have a warming effect on streams
Max Daily Temperature + Squared Value	$^{\circ}C$	The literature shows that air temperature is one of the main determining factors for stream temperature
Altitude	feet	Streams at higher elevations have cooler waters
Drainage Area	acres	This variable roughly measures the land area that feeds a stream water through precipitation draining into the stream
River Basin	Indicator	There are 7 major river basins in Colorado. This identifier could act as a proxy for important geographical information
Total Acres Burned in Basin	acres	Fires can directly heat waters and destroy riparian vegetation



Model Fit

- The model closely fit the data with no obvious structural deficiencies
- The adjusted R^2 value was 0.947



Model Results

Variable	Direction and Relative Magnitude of Relationship	Statistical Significance
Year	Slightly negative	Not significant
Log Discharge	Negative	***
Log Precipitation	Positive	***
Max Daily Temperature + Squared Value	°C	***
Altitude	Negative	***
Drainage Area	Slightly positive	***
River Basin		Mixed, some basins were significantly different. Arkansas River basin had warmest waters, and San Juan River basin had coolest
Total Acres Burned in Basin	Positive	Not significant



Effect of Wildfire Findings

- Total acres burned in the river basin had a slight positive relationship with water temperature, but the results were not statistically significant
- In other words, the data was consistent with there being no relationship between acres burned by wildfire and stream temperature



Additional Thoughts

- The treatment of wildfire data was broad, and merits further investigation
- There are many other important variables that could be included in a full model of stream temperature
- Researchers have developed accurate climate forecasting models, so stream temperature could be accurately forecasted into the future to see how climate change would affect ecosystems



Policy Suggestions

- Riparian zone restoration and management
 - Healthy riparian zones are high in moisture and can slow the spread of wildfires
 - This would have multiple benefits, such as habitat restoration, temperature regulation, and wildfire management
- Consider effects of wildfires holistically
 - Climate change, wildfires, and water quality are all linked
 - This is also linked to things like fishing and drinking water quality



Gunnison River, Colorado



References

- Stream temperature background, USGS:

https://www.usgs.gov/special-topic/water-science-school/science/temperature-and-water?qt-science_center_objects=0#qt-science_center_objects

- Fish Habitat Background, NRCS:

<https://efotg.sc.egov.usda.gov/references/public/CO/coldwaterfish.pdf>

- USGS *dataRetrieval* R Package:

<https://cran.r-project.org/web/packages/dataRetrieval/vignettes/dataRetrieval.html>

- Wildfire and Riparian Zones, USFS:

https://www.fs.fed.us/psw/topics/fire_science/ecosystems/riparian.shtml

