MushroomObserver Data Demonstrates Effects of Weather Events on Fungal Diversity

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Context

What do we know?

01 Mycelium needs water + moisture[1, 2]

02 Fungi prone to evaporative water loss[3]

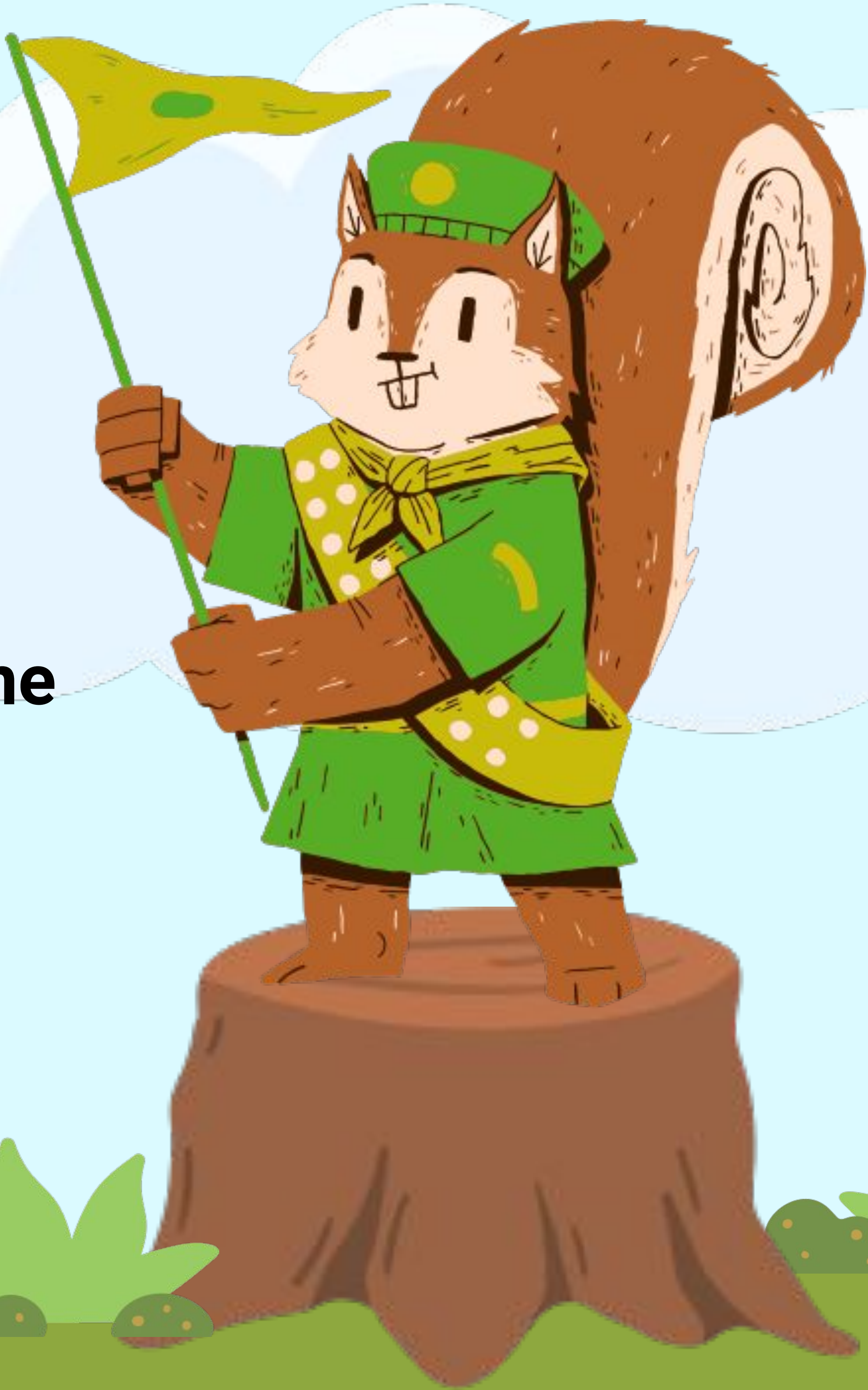
03 Sudden low temperatures kickstart fruiting body growth[4]

What do we know?

04 Fire alters soil composition and carbon availability[5]

05 Post-fire environments are suitable for some pioneer species[5]

06 Citizen science can be unreliable



Hypothesis

Precipitation, temperature, and fires will affect the abundance, richness, and diversity of various species of macrofungi

Predictions

Fire	Temperature	Precipitation
Decreases abundance	High temperatures decrease abundance and evenness	Wetter weather increases abundance and evenness

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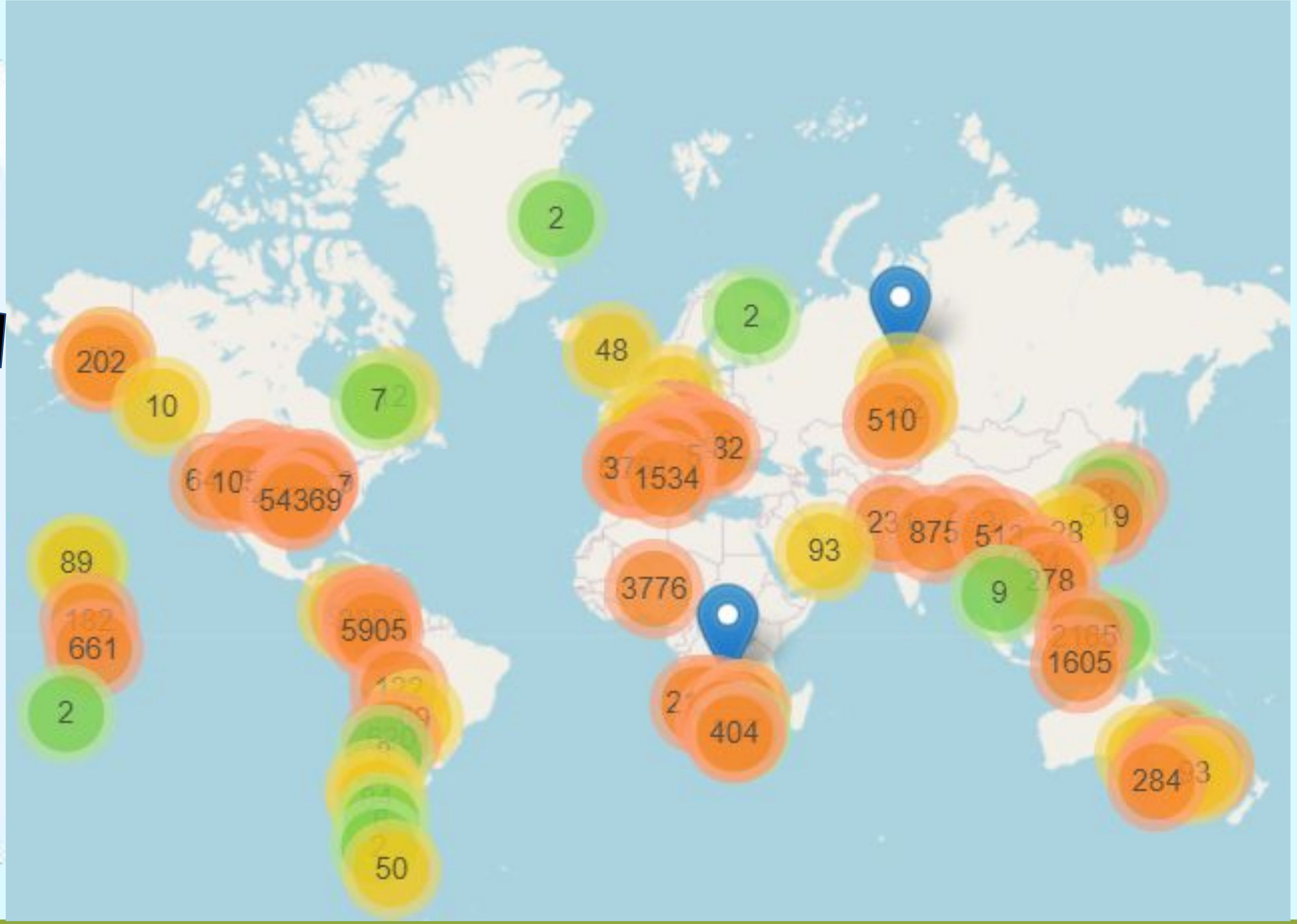
Methods

Data Sources: MushroomObserver

- ➢ Citizen science database
- ➢ Each entry includes date, ID, and location



Manipulations:

- ➢ Applied ID and location info
- ➢ Observation dates matched up to fire/weather data

Data Sources: Fire

Public opendatasoft

- Repository of datasets.
- Border data relating to counties.

CalFire Incident Data

- Fire data from California including inactive and active fires/wildfires recorded from local firelines.
- Does not include fires less than 10 acres in size.
- Subsetted to include relevant and interpretable data.

Manipulations:

- Related subsetting for readability
- Reformatting data types to a standard convention throughout
- Applied latitude and longitude values to locations to match another dataset that already included them.

Wrangled Data: Fire

For 15 randomly selected counties from California:

1	2013	Riverside	53538	33	216.6653
2	2014	Riverside	57	12	0.230676
3	2015	Riverside	1570	24	6.353703
4	2016	Riverside	139	12	0.562525
⋮					
149	2020	Sonoma	248	397	1.003642
150	2021	Sonoma	22	204	0.089033
151	2022	Sonoma	84	135	0.339943

Year

County

Total area burned by fire (acres)

Total number of mushroom observations

Total area burned by fire (km^2)

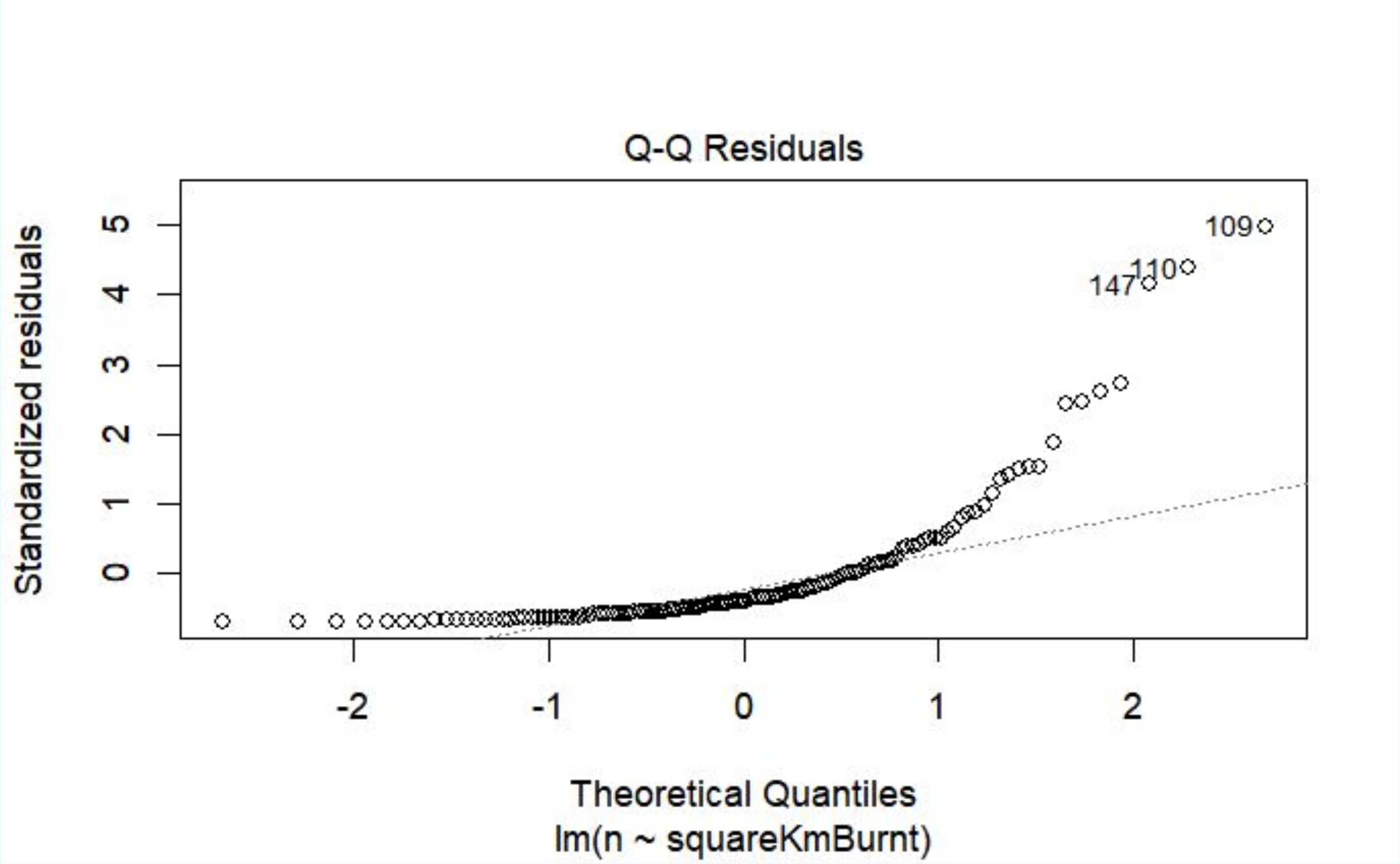
Does the total area burned by fire affect the total number of mushroom observations?

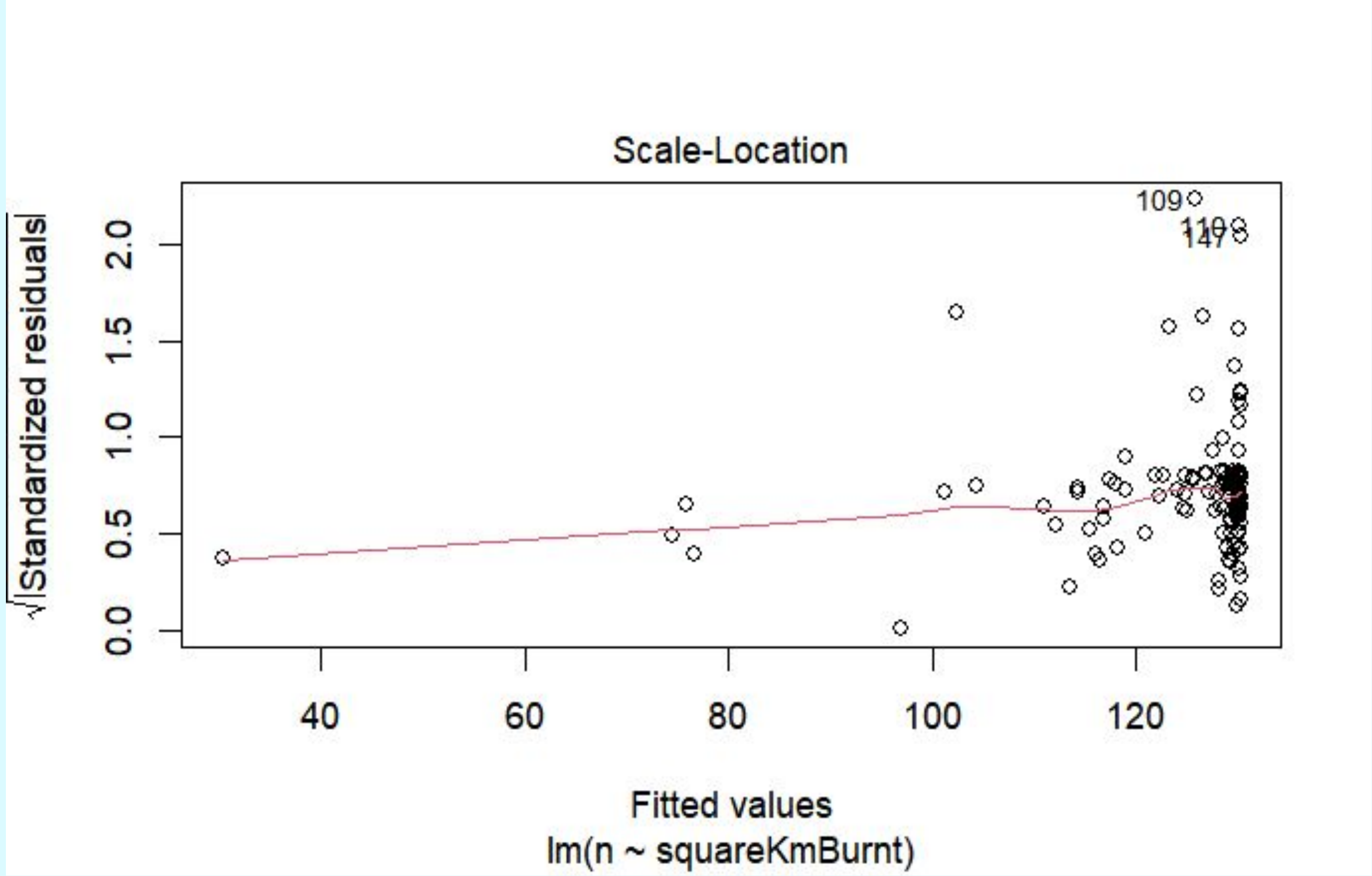
Tests: Fire

- **Linear mixed model**
  - ➢ Regressed number of mushroom observations on area burned by fire
  - ➢ Used county as a random effect

Data Manipulation for Analysis: Fire

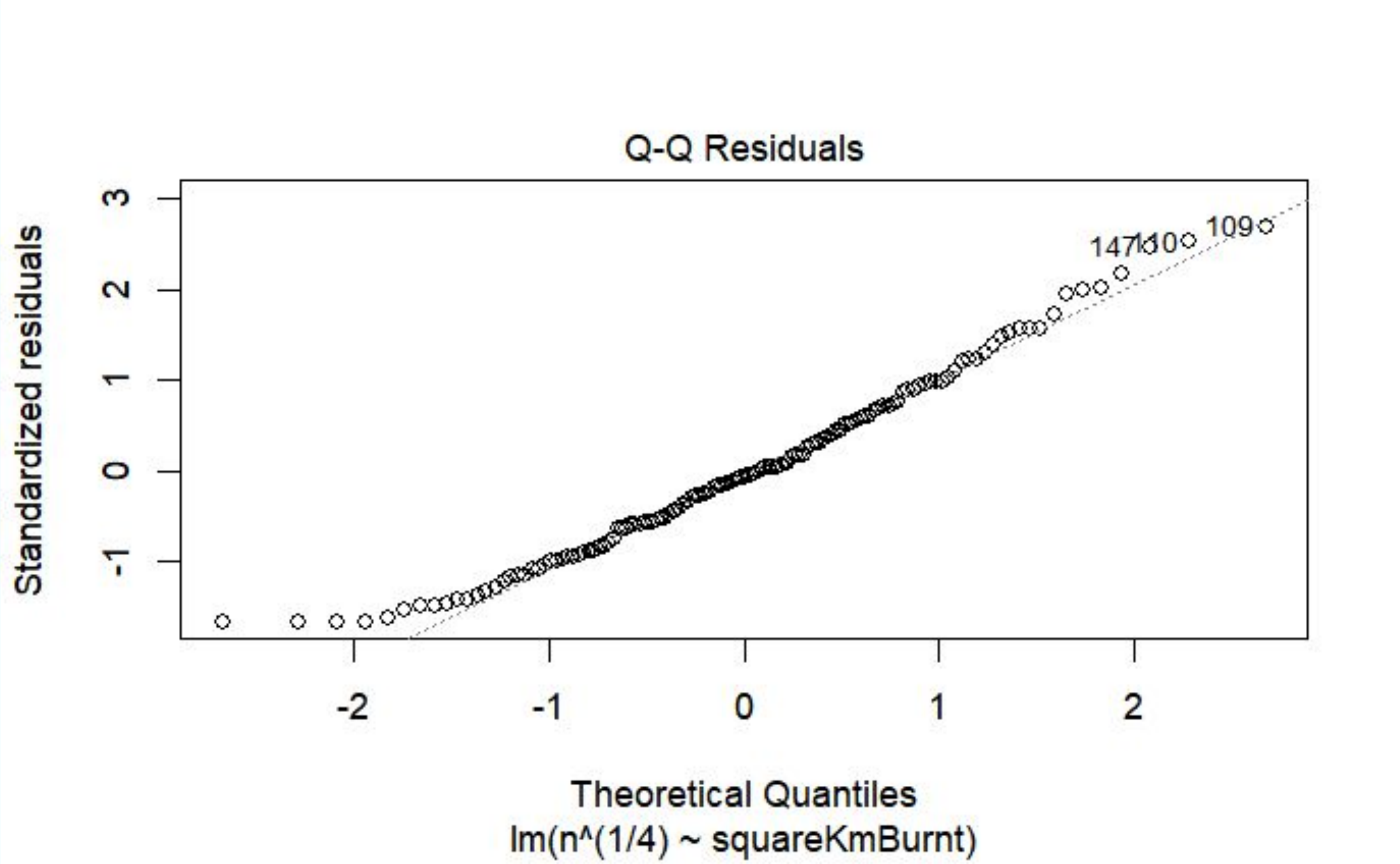
Before the transformation:

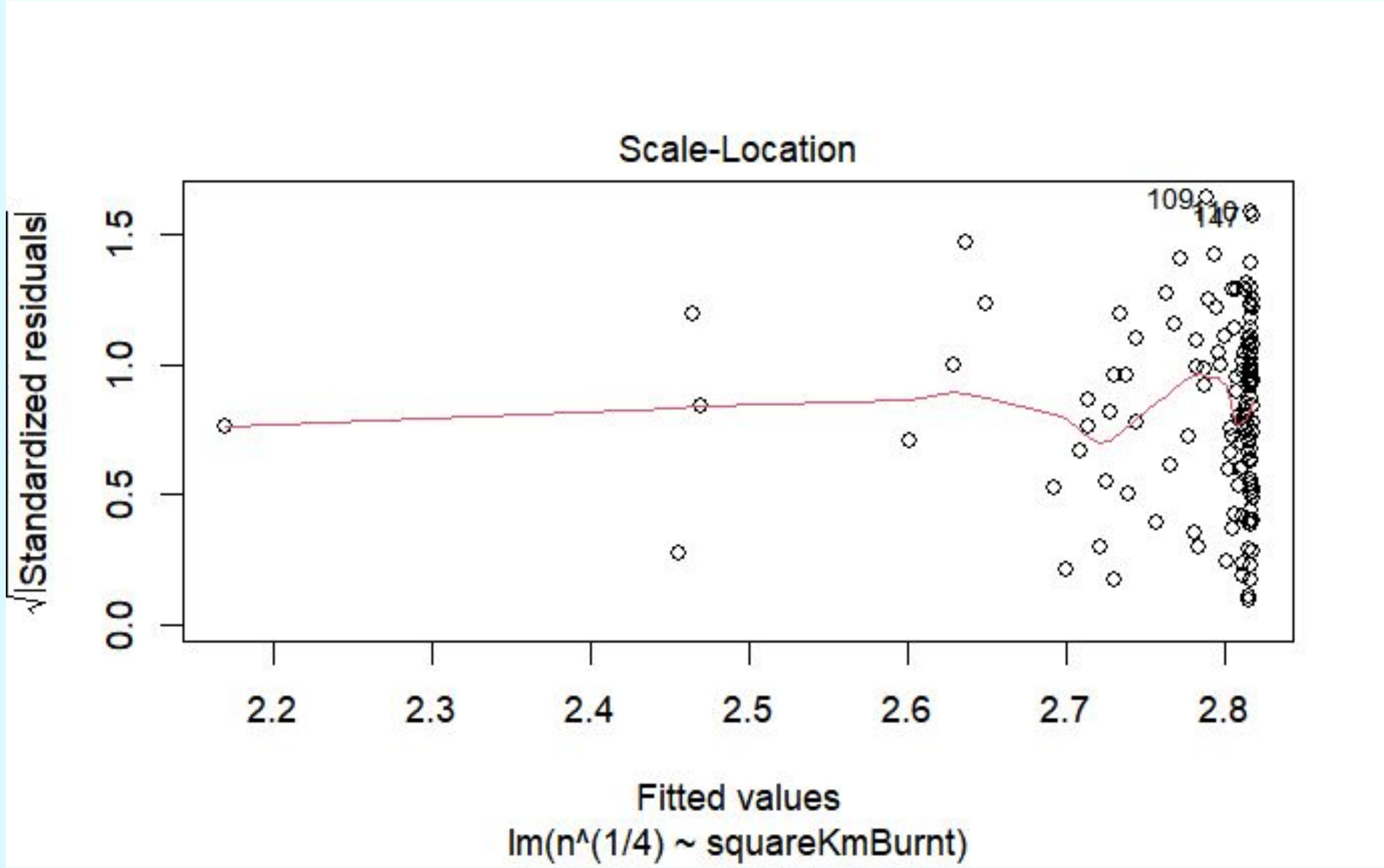




Data Manipulation for Analysis: Fire

After the transformation:





Fire search function; QOL feature

```
fireSearch <- function(dataset, search_value=NULL, lat=NULL, lon=NULL,
                       error_threshold=1){
  if (is.null(search_value) && (is.null(lat) || is.null(lon))) {
    stop("Provide either 'search_value' or 'lat' and 'lon'")
  }

  if (!is.null(search_value)) {
    search_value <- tolower(search_value)
    result <- dataset[tolower(dataset$incidentCounty) == search_value, ]
  }

  else {
    # Latitude and longitude search threshold to find close proximity fires.
    result <- dataset[
      abs(dataset$lat - lat) <= error_threshold &
      abs(dataset$lon - lon) <= error_threshold,
    ]
  }

  return(result)
```

Data Sources:
Temperature and Precipitation

RAWS USA Climate Archive

California

- 2007 - 2020

Ontario Climate Data Portal

Ontario

- 2010 - 2022

Climatic Research Unit gridded Time Series

Colombia

- 2010 - 2022

1. Monthly mean temperature, total precipitation
2. Grouped MushroomObserver data by month to match climate data
3. Shannon Diversity Index for each month (Family diversity)

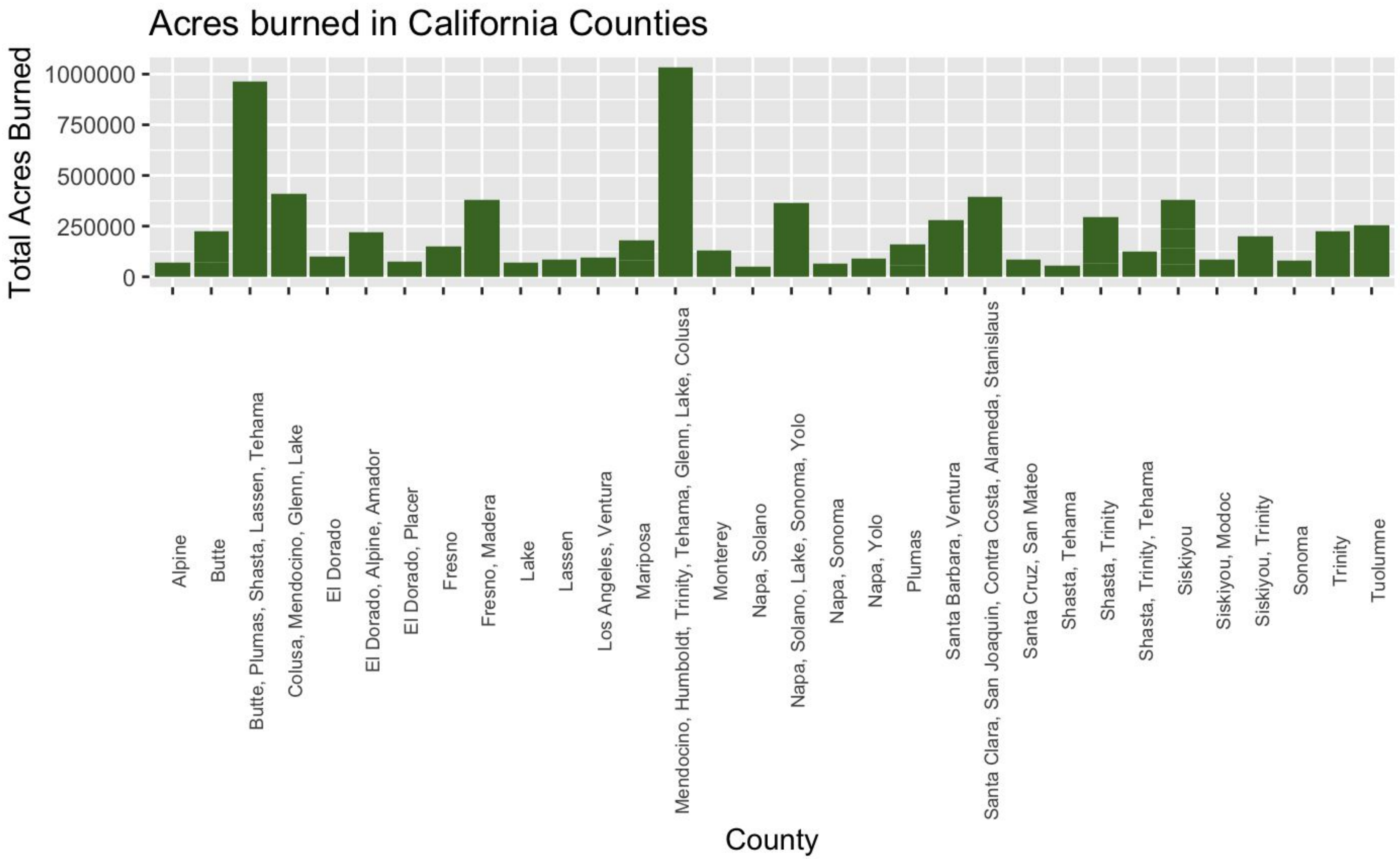
Tests: Temperature and Precipitation

- Generalized Linear Models to determine effect
  - Abundance data is Poisson distributed
  - Diversity index ?

03

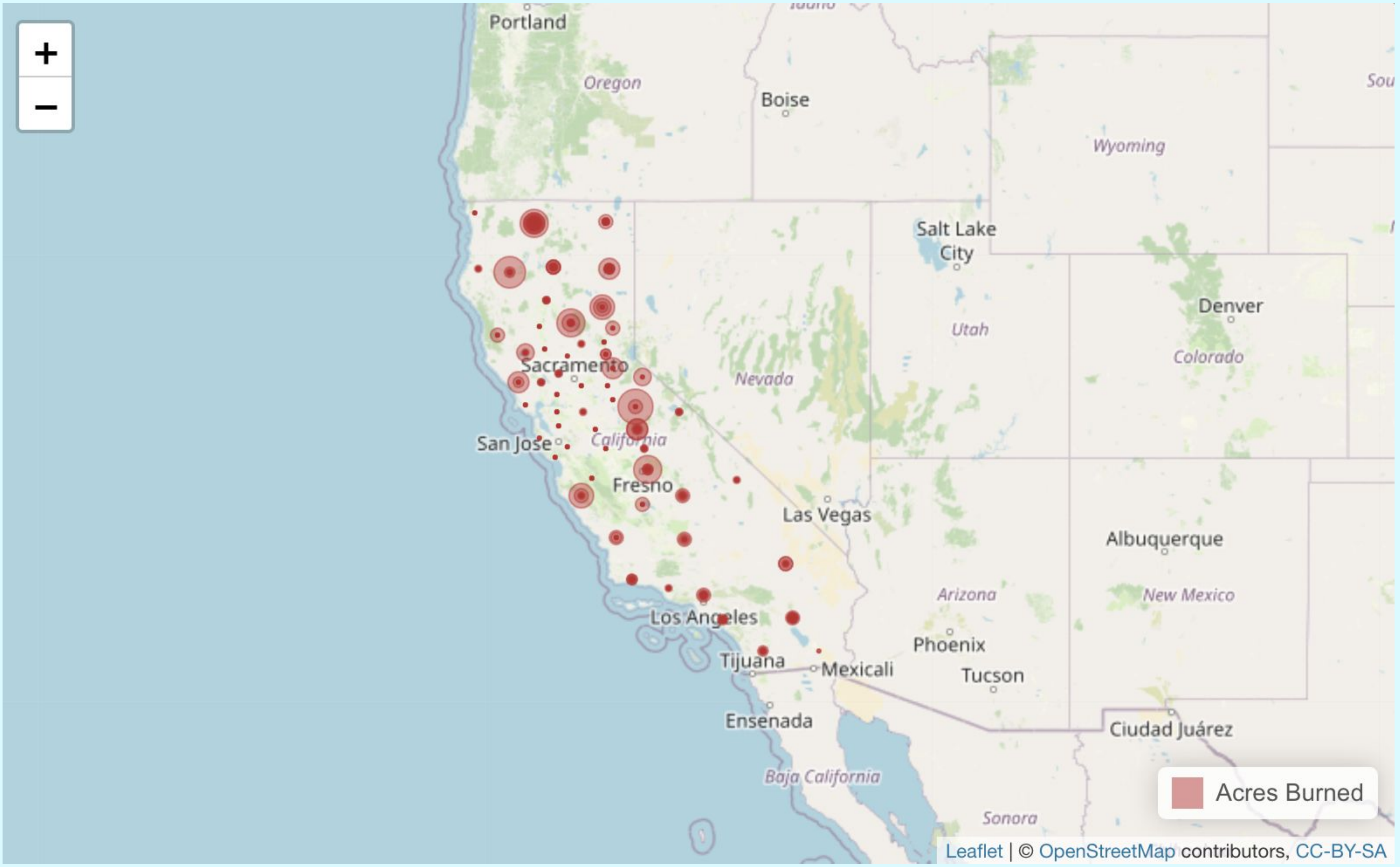
Results

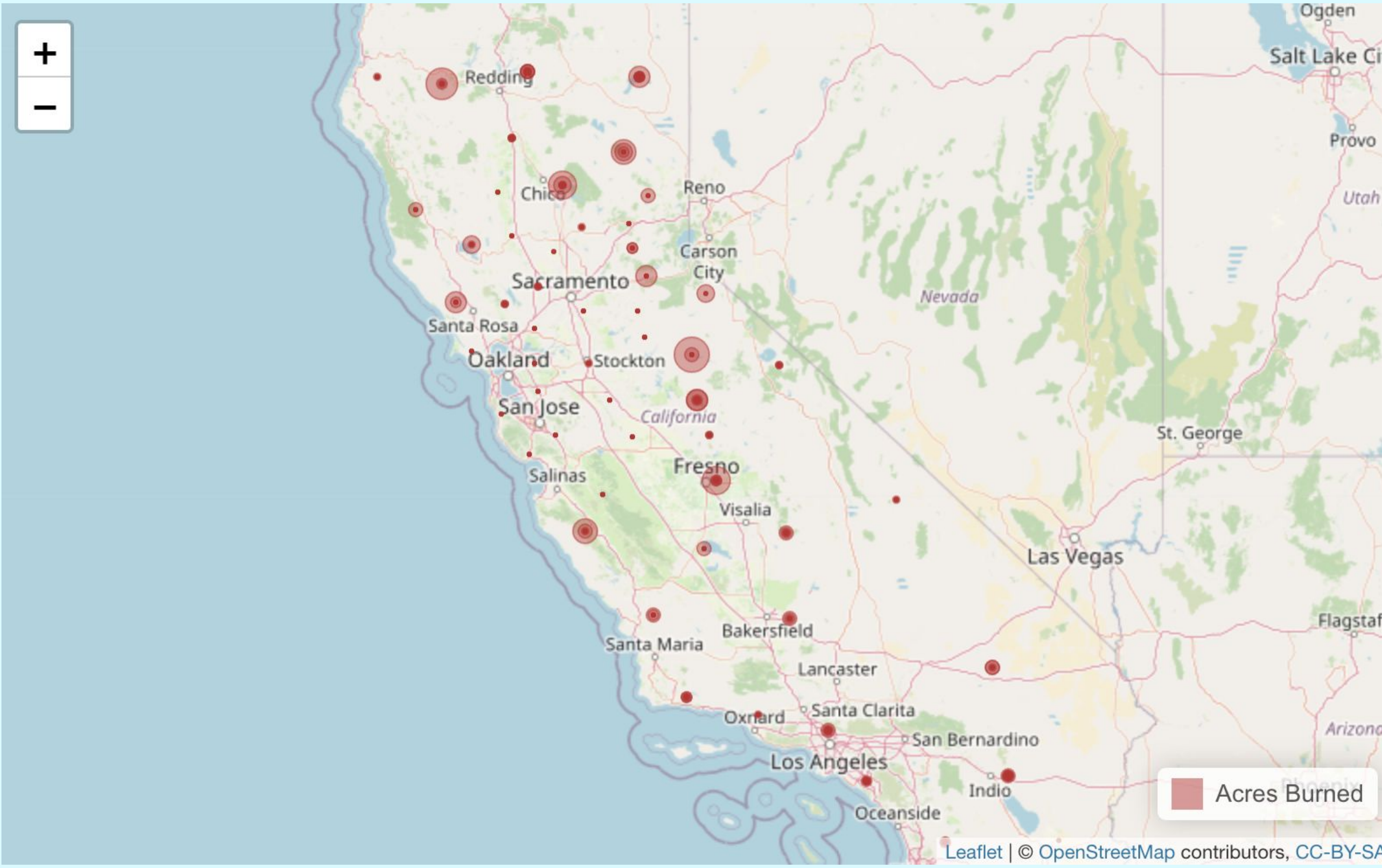
Results: Fire



Acres burned in California Counties
Total Acres Burned
1000000
750000
500000
250000
0
Alpine
Butte
Butte, Plumas, Shasta, Lassen, Tehama
Colusa, Mendocino, Glenn, Lake
El Dorado
El Dorado, Alpine, Amador
El Dorado, Placer
Fresno
Fresno, Madera
Lake
Lassen
Los Angeles, Ventura
Mariposa
Mendocino, Humboldt, Trinity, Tehama, Glenn, Lake, Colusa
Monterey
Napa, Solano
Napa, Solano, Lake, Sonoma, Yolo
Napa, Sonoma
Napa, Yolo
Plumas
Santa Barbara, Ventura
Santa Clara, San Joaquin, Contra Costa, Alameda, Stanislaus
Santa Cruz, San Mateo
Shasta, Tehama
Shasta, Trinity
Shasta, Trinity, Tehama
Siskiyou
Siskiyou, Modoc
Siskiyou, Trinity
Sonoma
Trinity
Tuolumne
County

Visual map using Leaflet





Results of the Regression Test: Fire

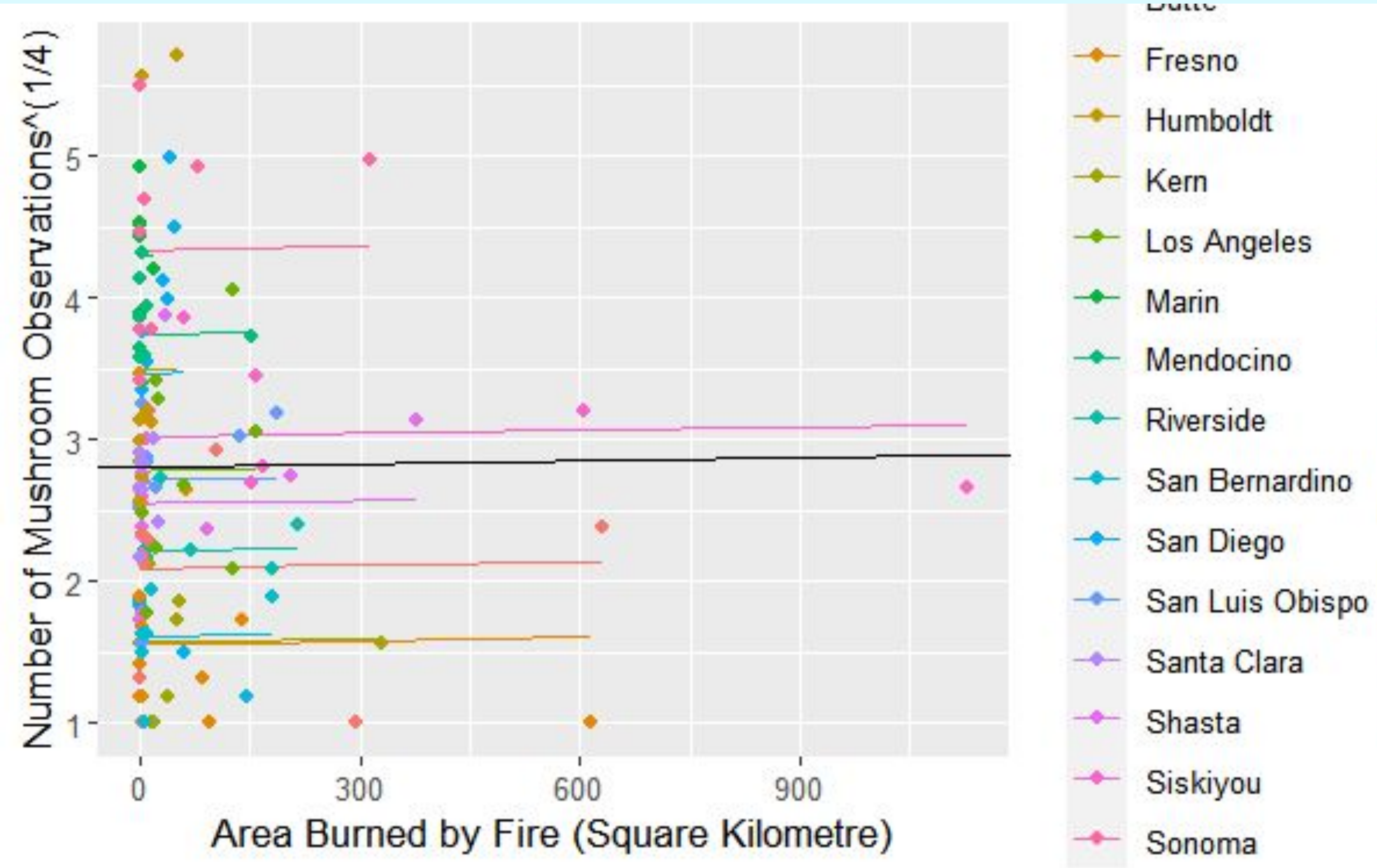
If without random effects:

With counties as a random effect

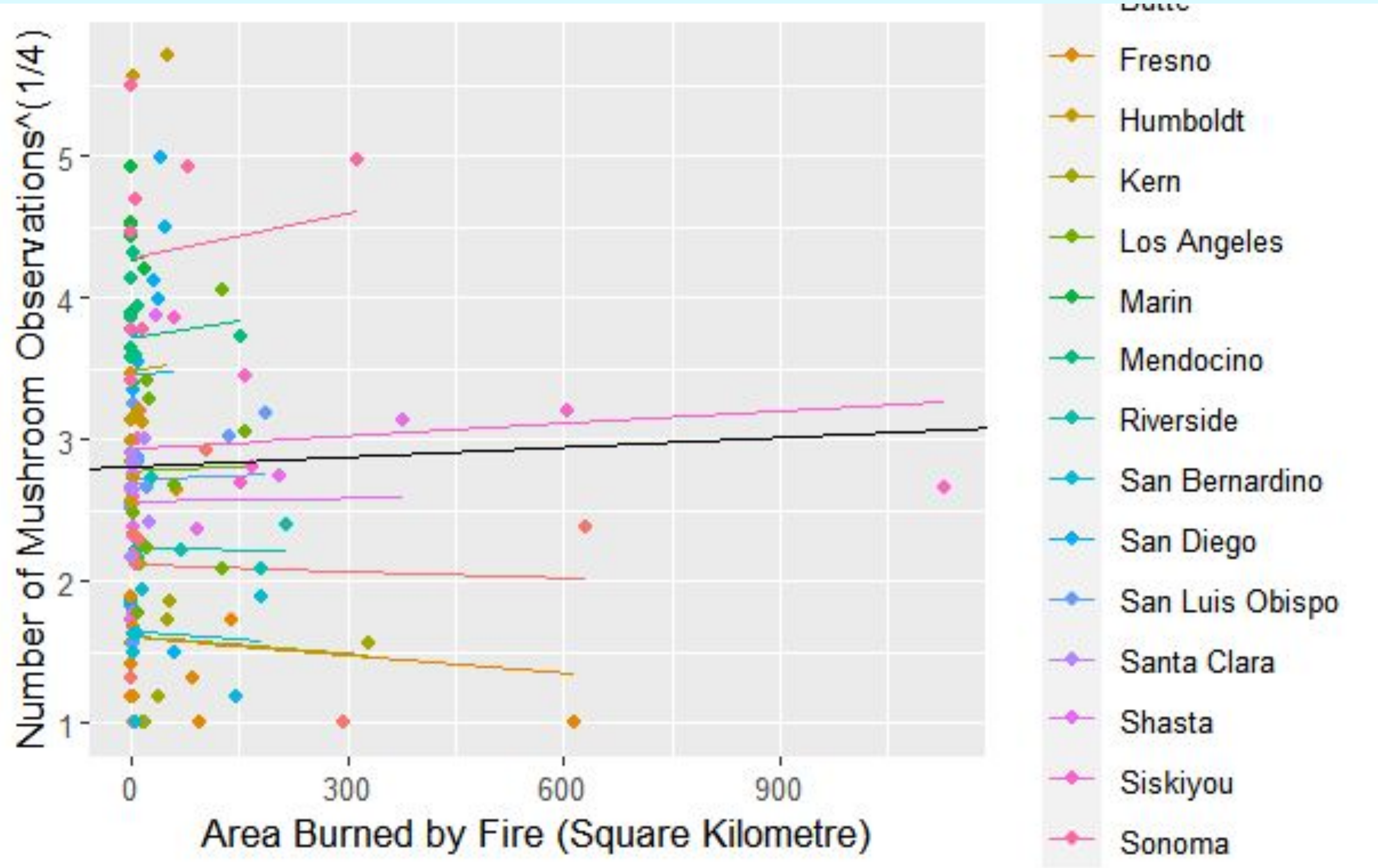
```
Linear mixed model fit by maximum likelihood . t-tests use Satterthwaite's method ['lmerModLmerTest']
Formula: n^(1/4) ~ squareKmBurnt + (1 | incidentCounty)
   Data: regressionData

     AIC      BIC   logLik deviance df.resid 
   311.1    322.7   -151.6    303.1      129 

Scaled residuals: 
    Min      1Q  Median      3Q     Max 
-3.0888 -0.5627 -0.0181  0.4409  3.4440 

Random effects:
 Groups         Name        Variance Std.Dev.
 incidentCounty (Intercept) 0.8345   0.9135  
 Residual                   0.4107   0.6409  
Number of obs: 133, groups:  incidentCounty, 15

Fixed effects:
               Estimate Std. Error        df t value Pr(>|t|)    
(Intercept)   2.812e+00  2.438e-01 1.514e+01  11.536 6.68e-09 ***
squareKmBurnt 7.655e-05  4.168e-04 1.202e+02   0.184    0.855    
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Correlation of Fixed Effects:
            (Intr)
squarKmBrnt -0.104
```

p-value larger than $\alpha = 0.05$

AIC: 311.1



AIC: 314.8




```
             R2m       R2c
[1,] 0.0001001574 0.6701767
```

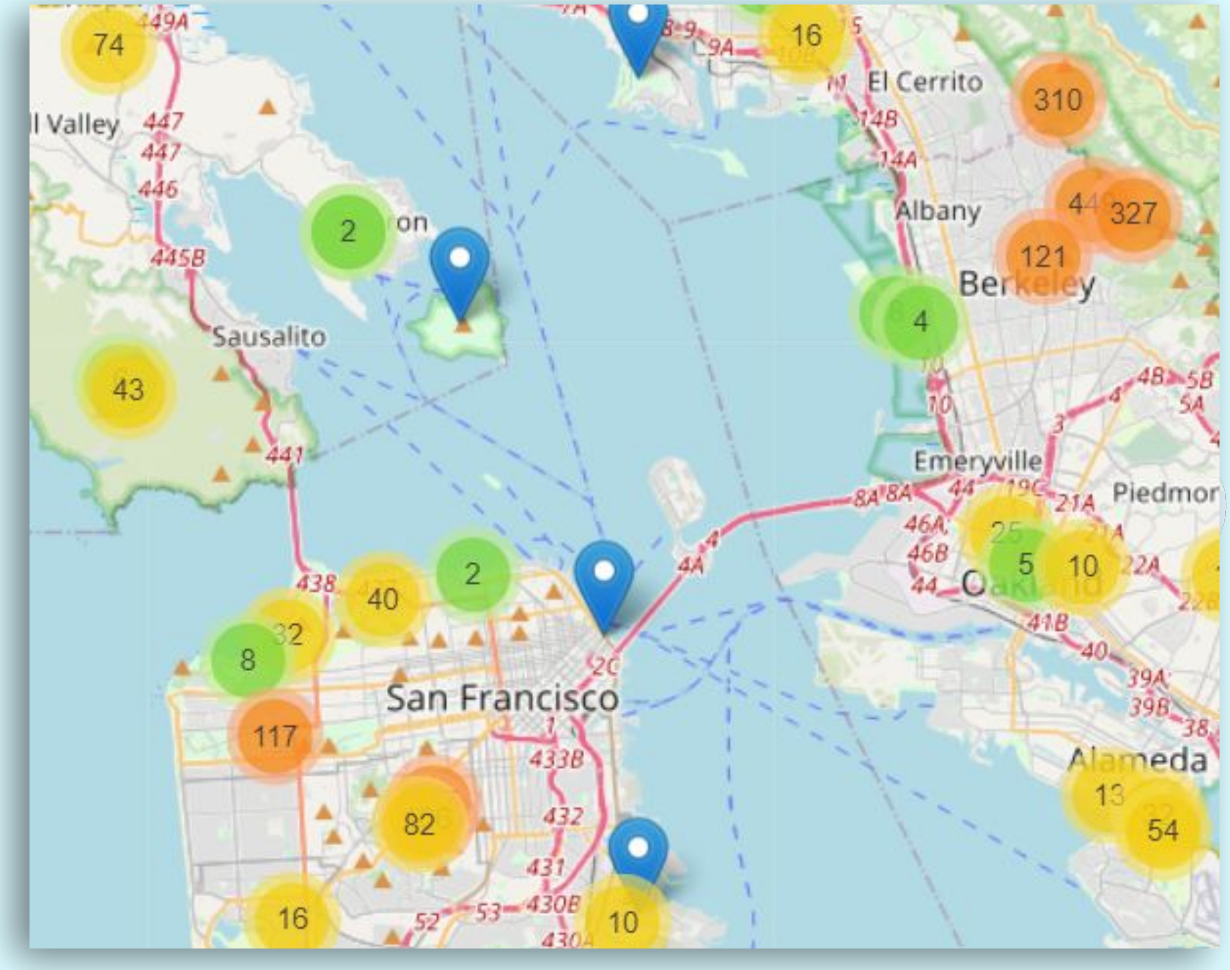
Possible Reasons for a Lack of Significant Relationship: Fires

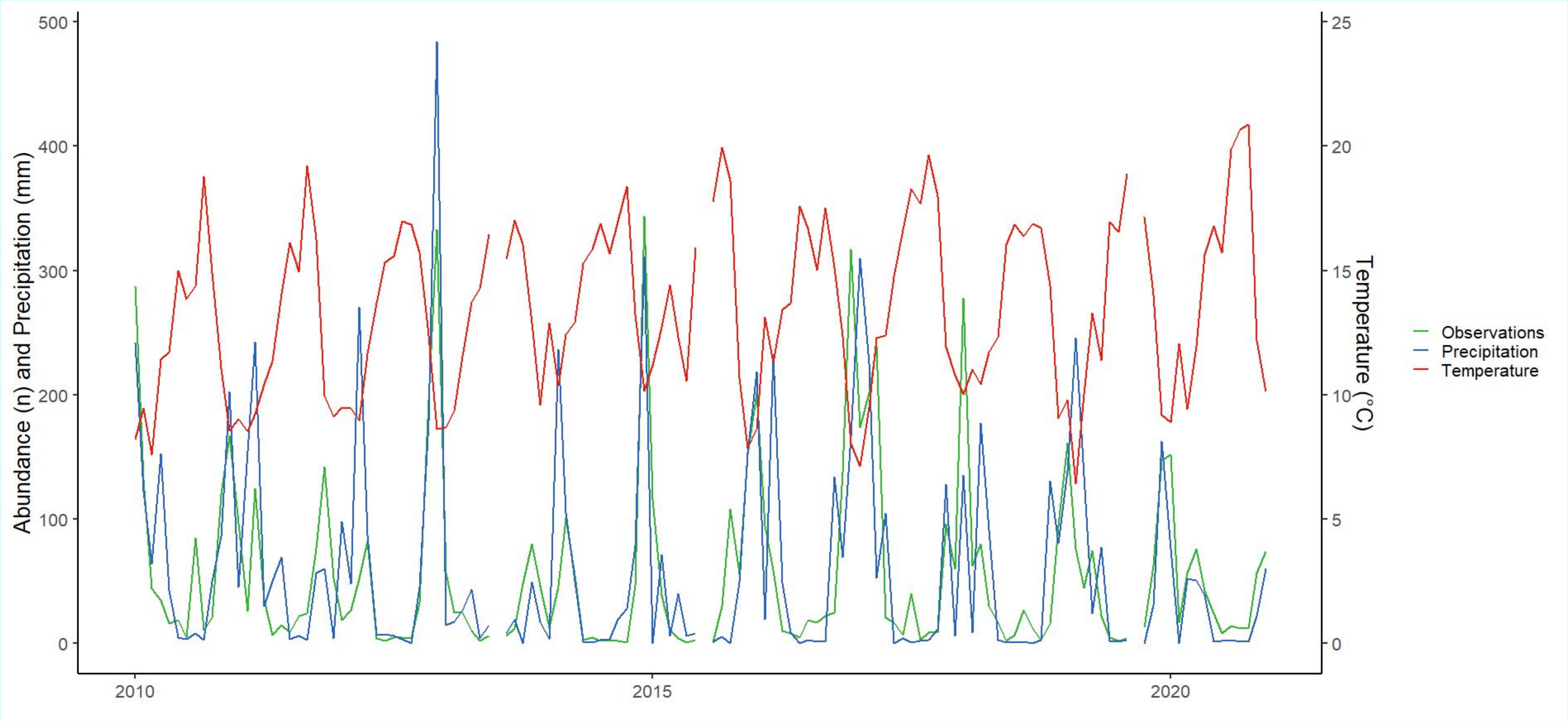
- Other variables masking the effect of fire
- Some species of mushroom may be more tolerant than the others[6]
- Mushrooms may be more tolerant than expected[7]

Results: Temperature and Precipitation

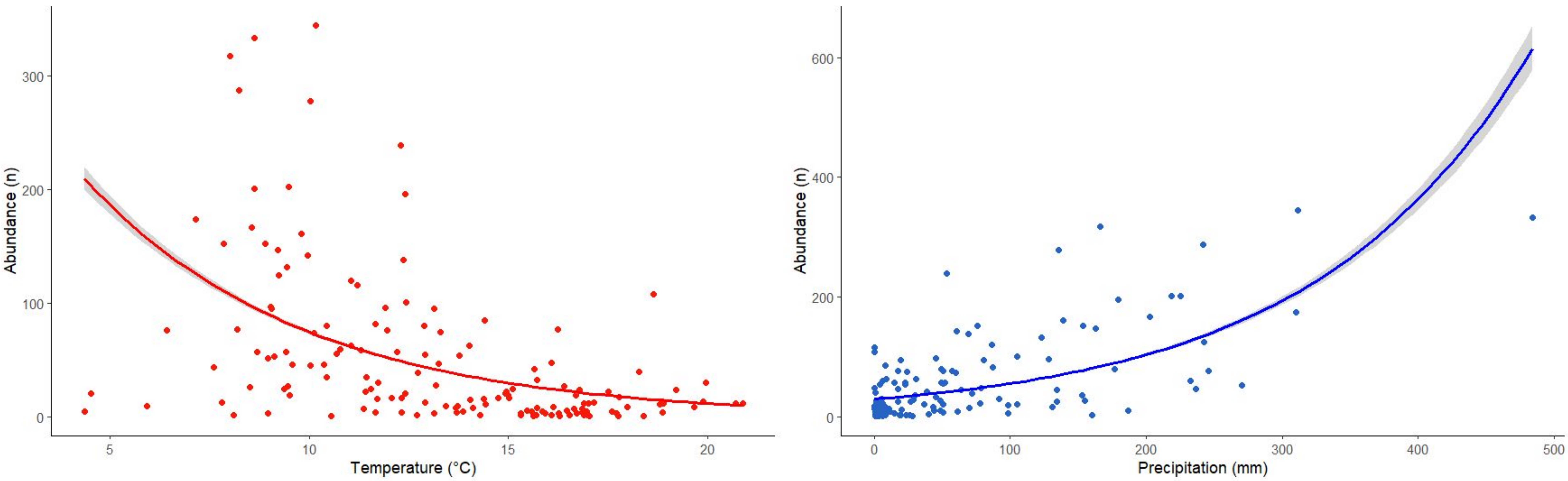
San Francisco

- ➢ **n = 9364 (149 months)**
- ➢ **Mediterranean Climate**
  - ○ *4 °C - 21 °C*
  - ○ *0 mm - 500 mm*

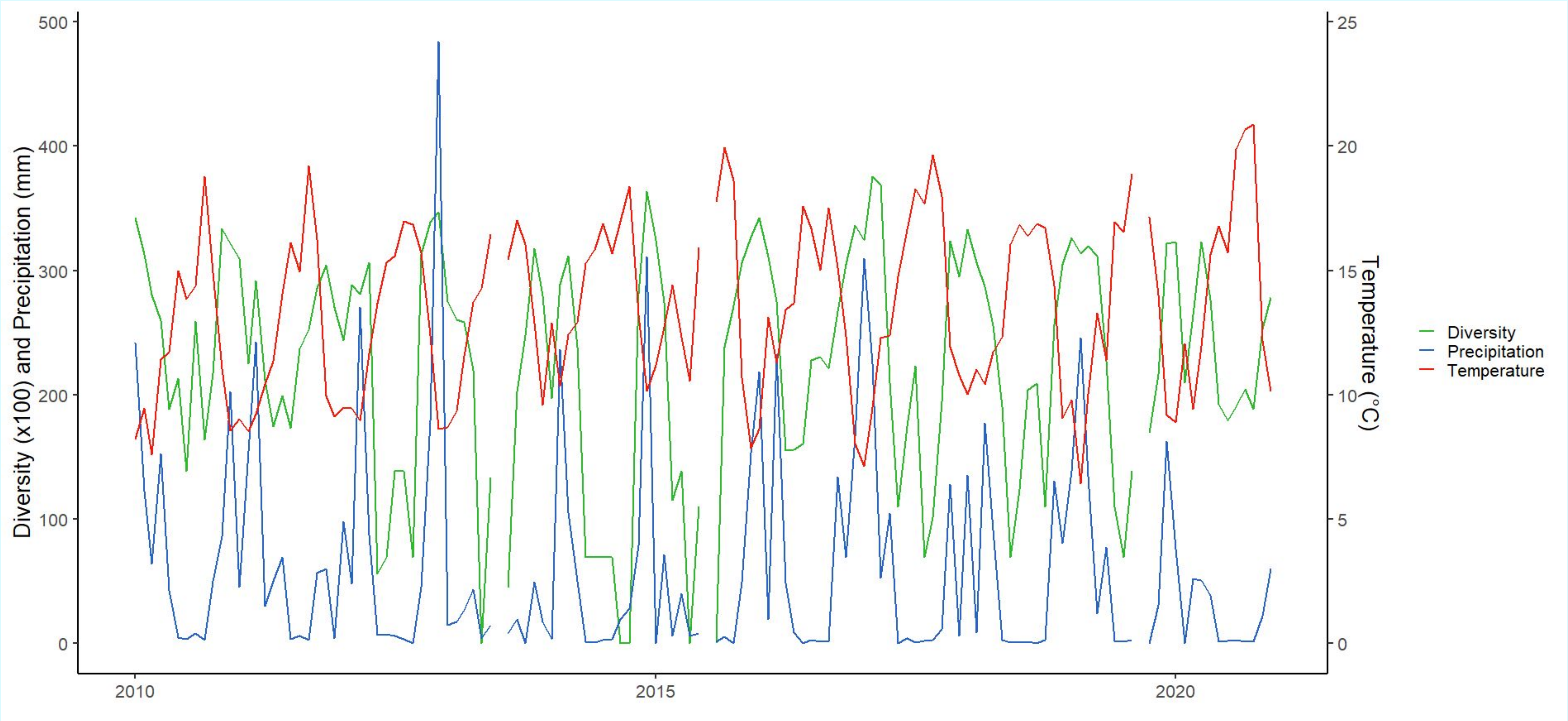




Abundance of MushroomObserver observations (green), precipitation (blue), and temperature (red) in San Francisco, California (2010-2020)



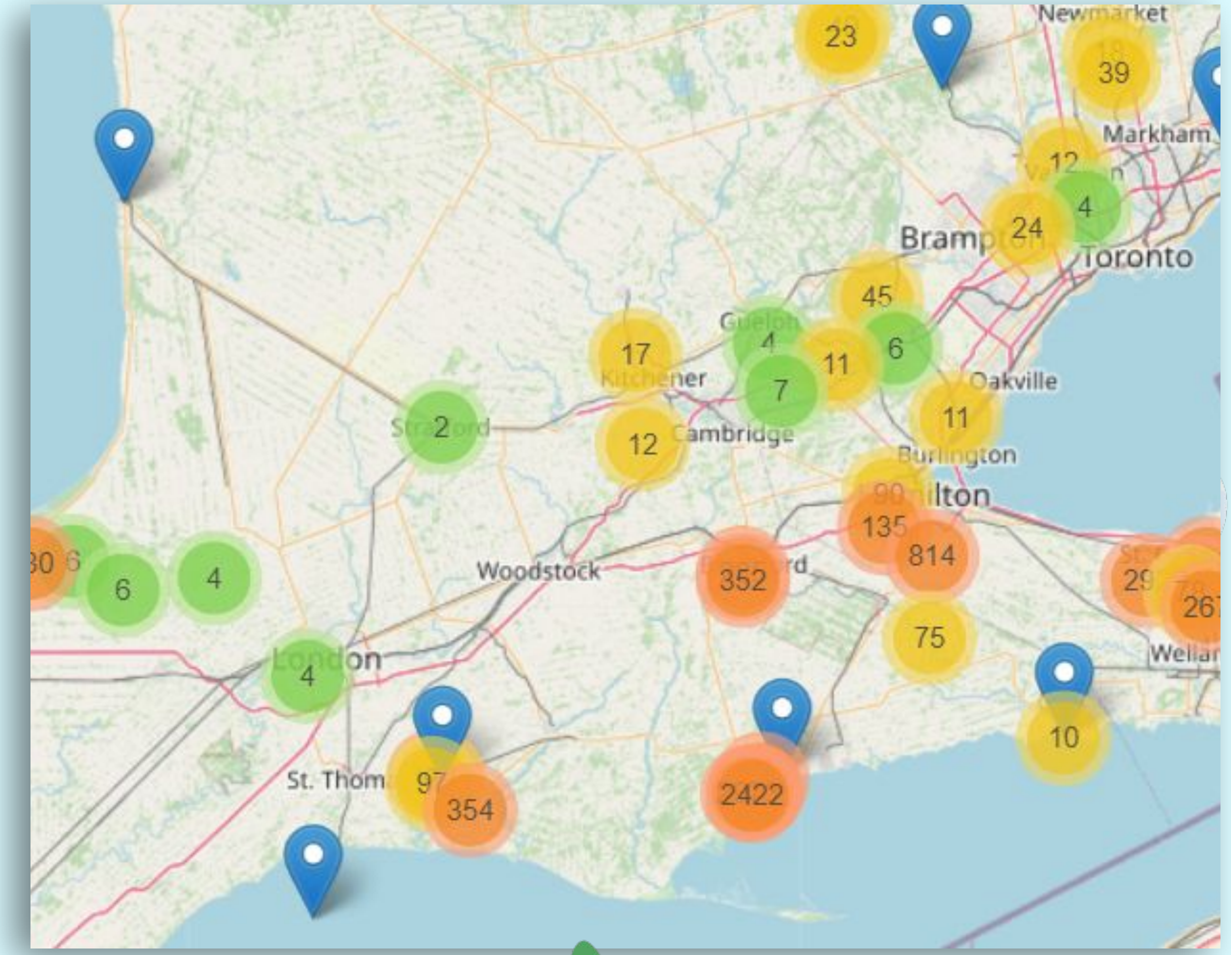
Correlations between observed fungal abundance, temperature (red) and precipitation (blue) in San Francisco, California

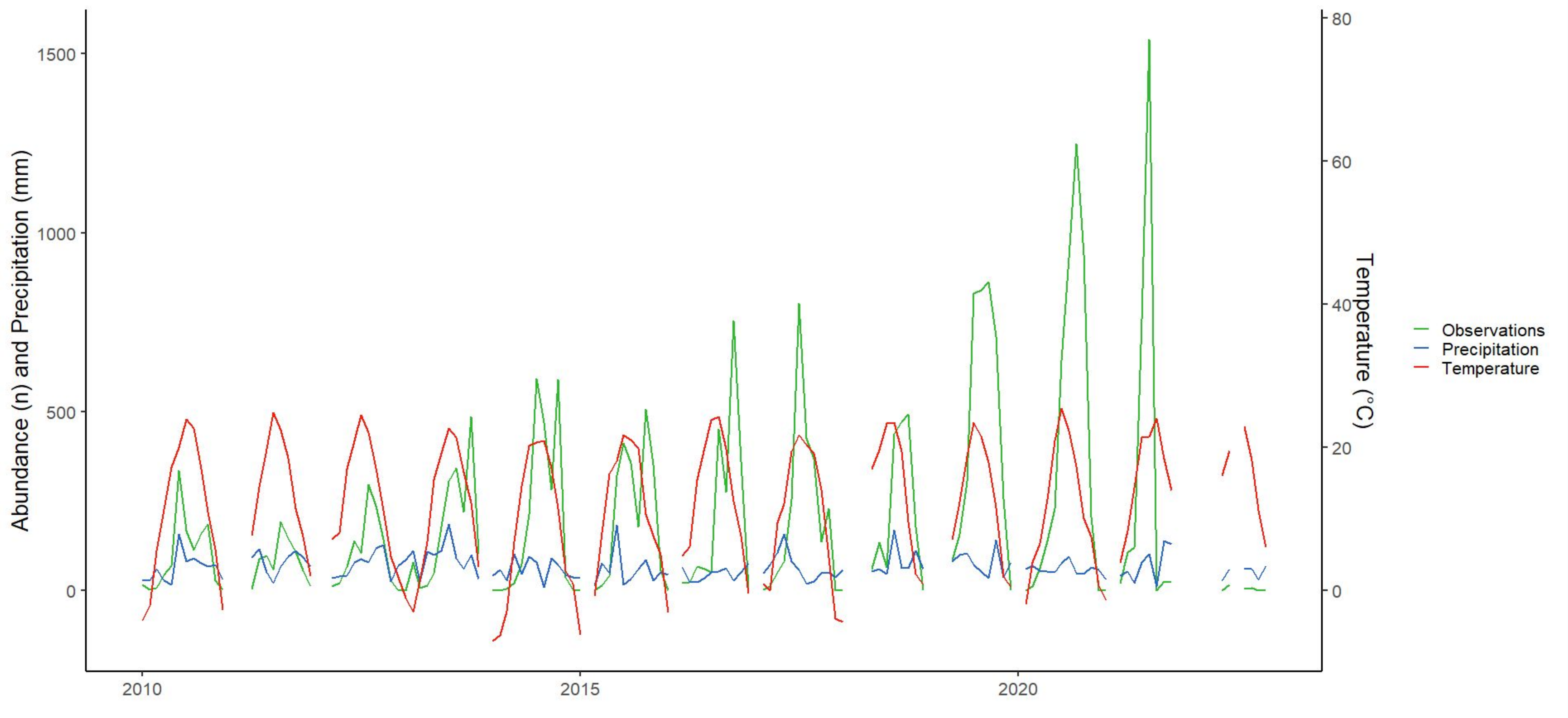


Fungal diversity (green), precipitation (blue), and temperature (red) in San Francisco, California (2010-2020)

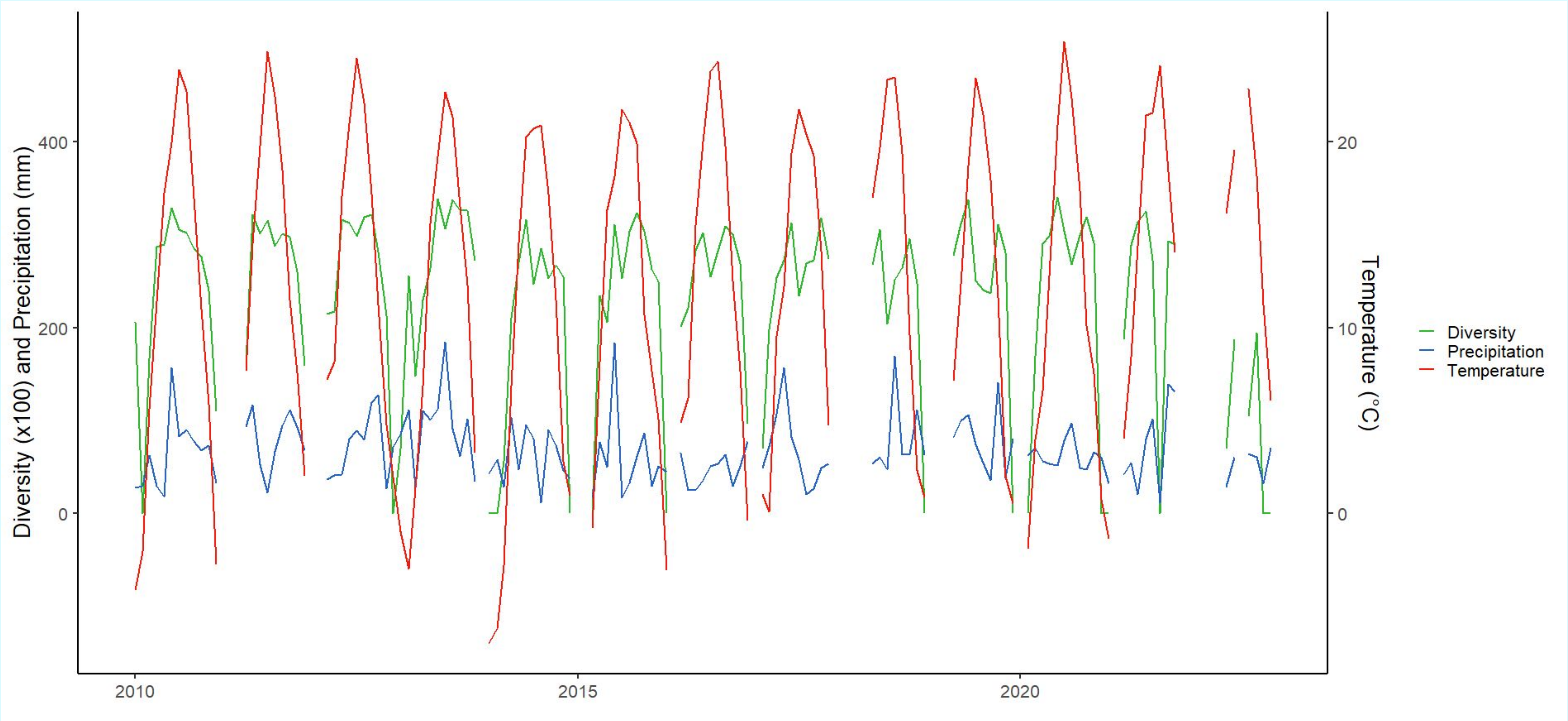
Ontario

- n = 26692 (132 months)
- Humid Continental
  - *-11 °C - 25 °C*
  - *7 mm - 200 mm*

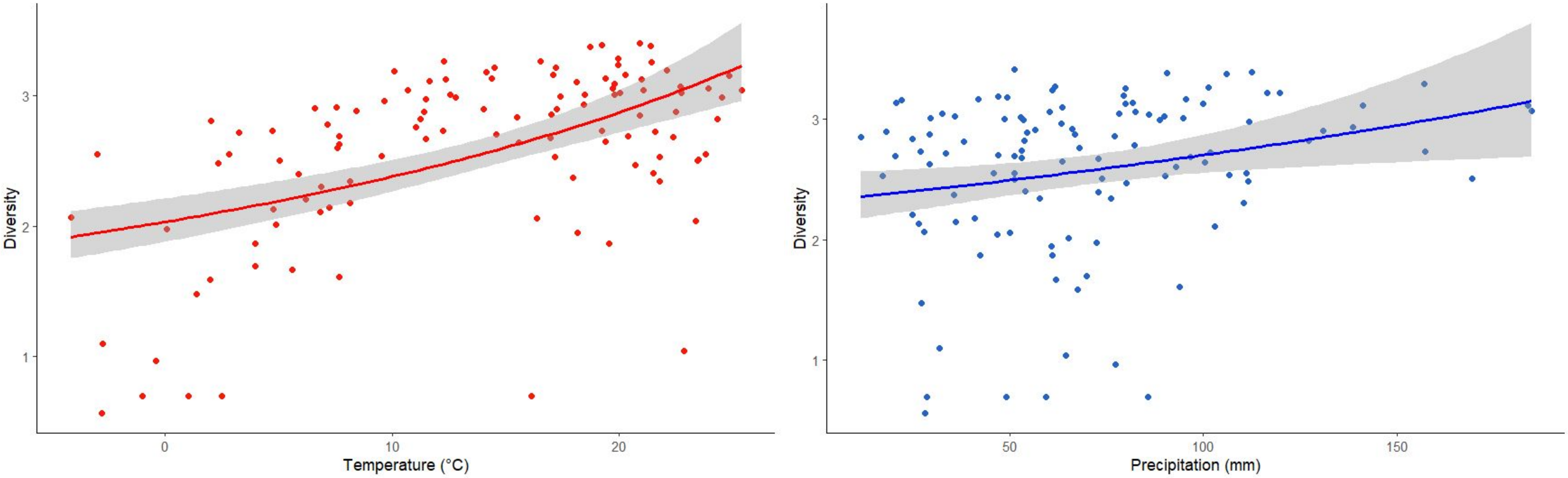




Abundance of observations (green), precipitation (blue), and temperature (red) in Ontario, Canada (2010-2022)



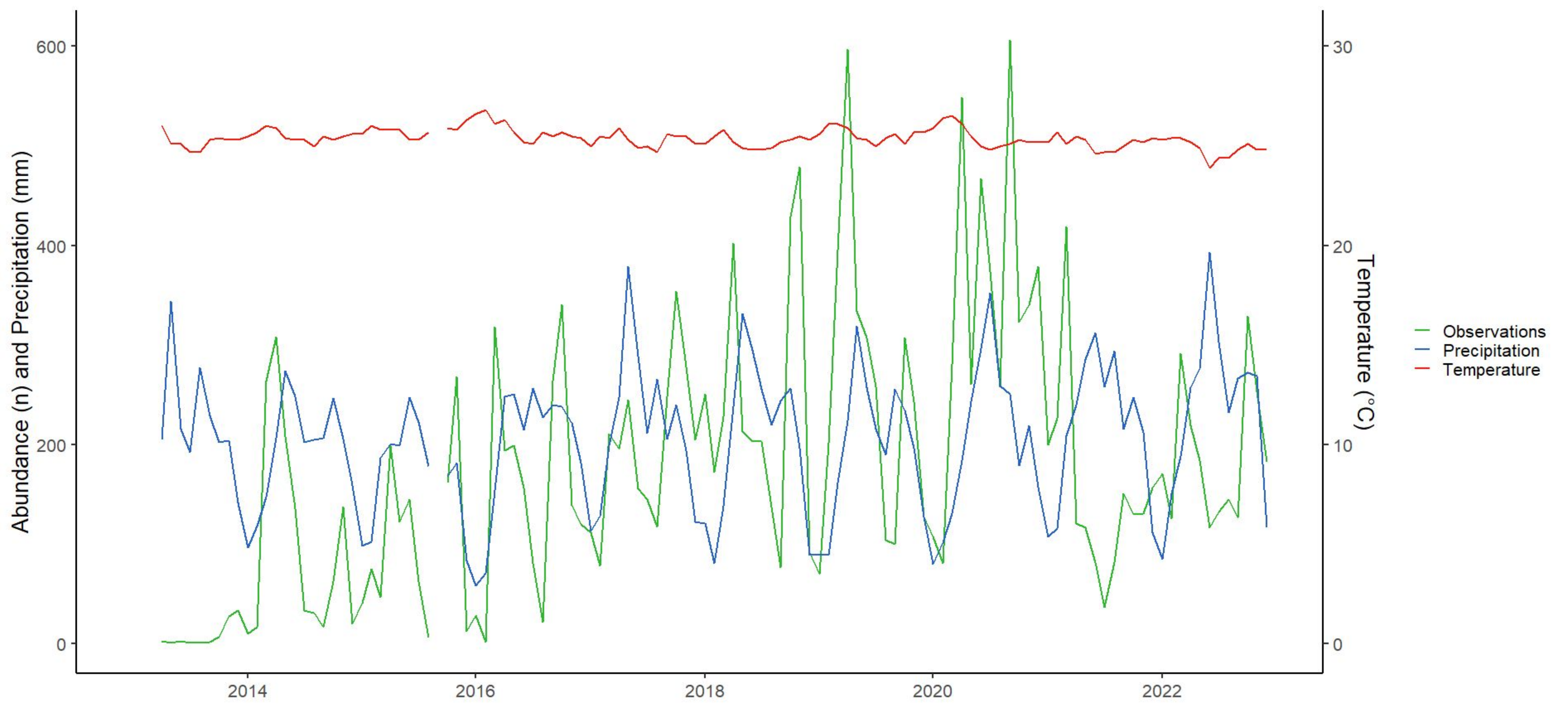
Fungal diversity (green), precipitation (blue), and temperature (red) in Ontario, Canada (2010-2022)



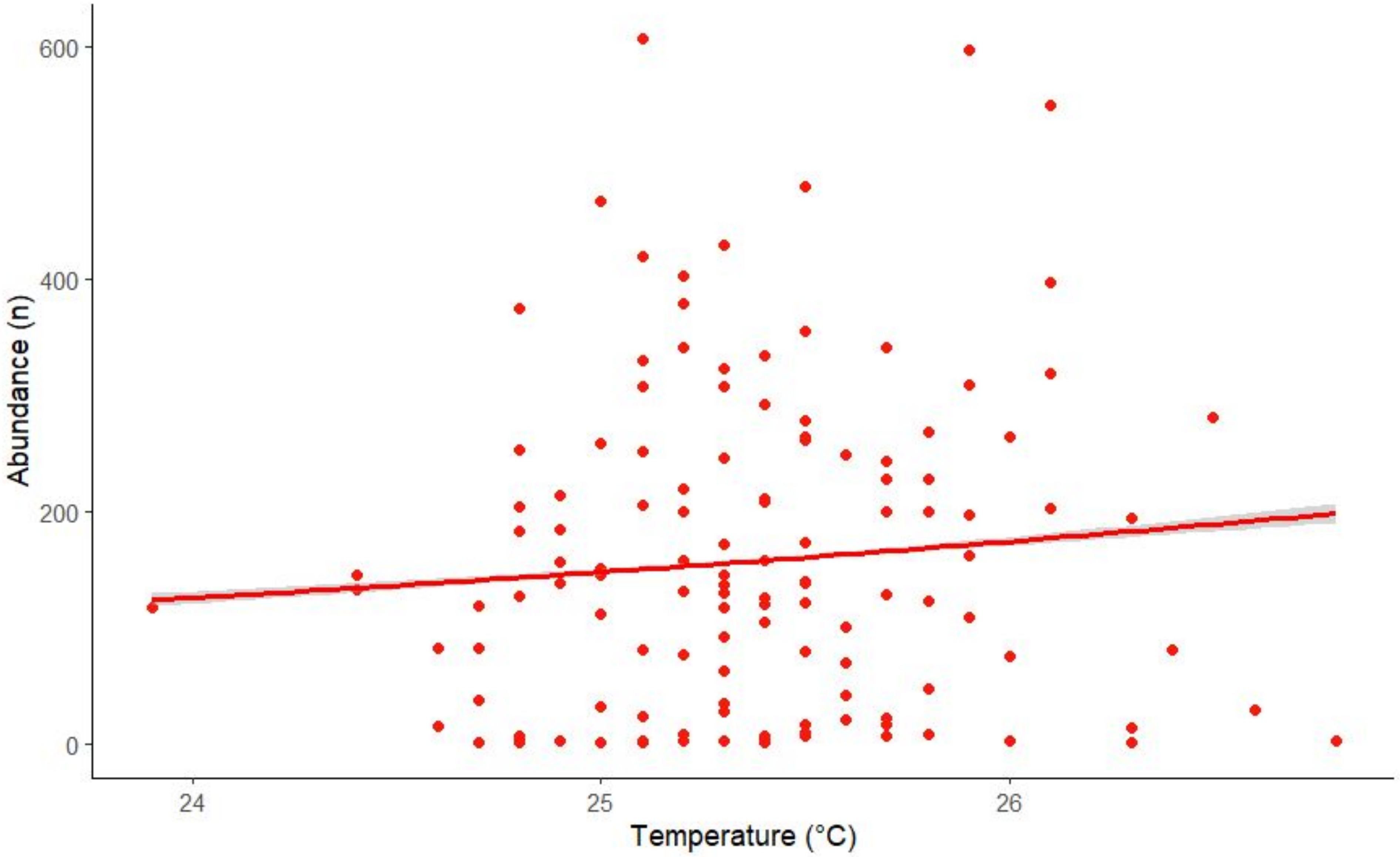
Correlations between observed fungal diversity, temperature (red) and precipitation (blue) in Ontario, Canada

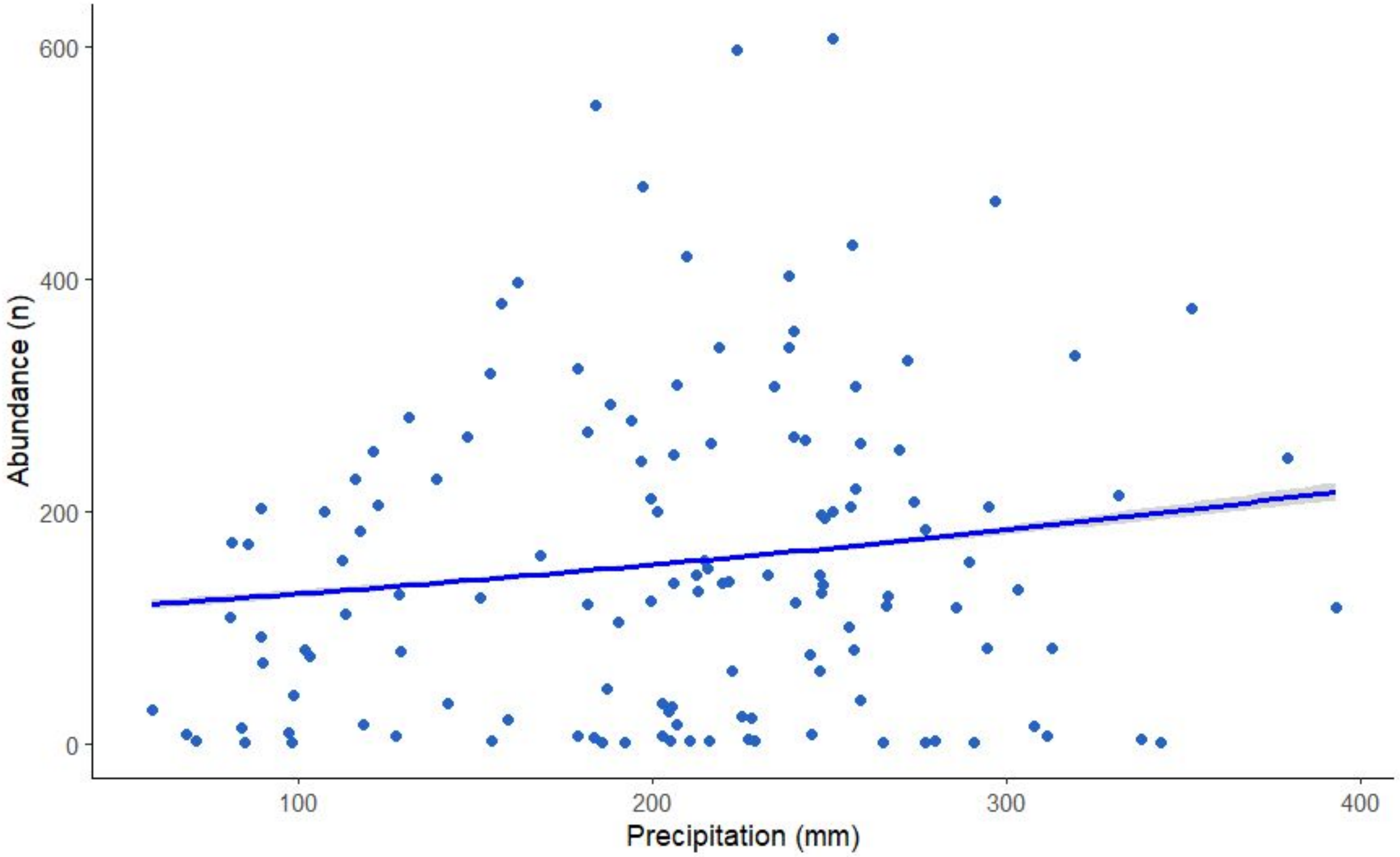
Colombia

- n = 20870 (133 months)
- Mostly Tropical
  - *24 °C - 27 °C*
  - *50 mm - 400 mm precipitation*

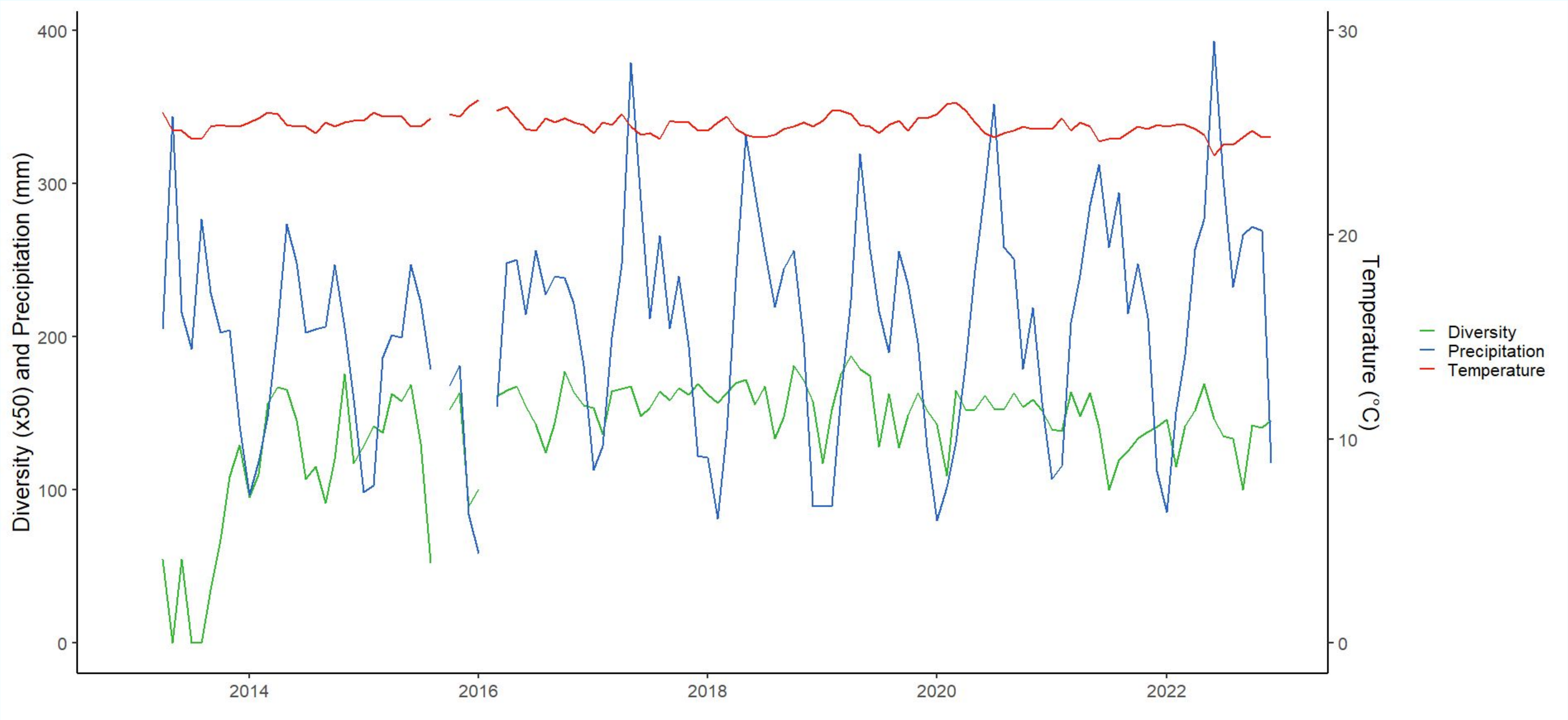


Abundance of observations (green), precipitation (blue), and temperature (red) in Colombia (2013-2022)

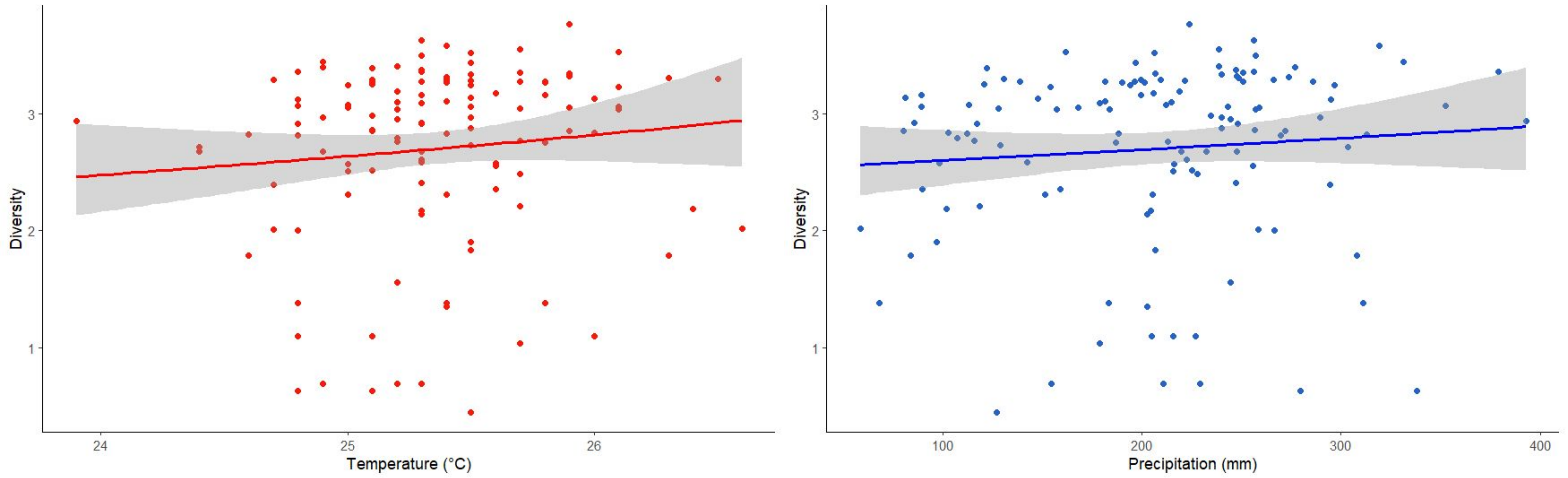




Correlations between observed fungal abundance, temperature (red) and precipitation (blue) in Colombia



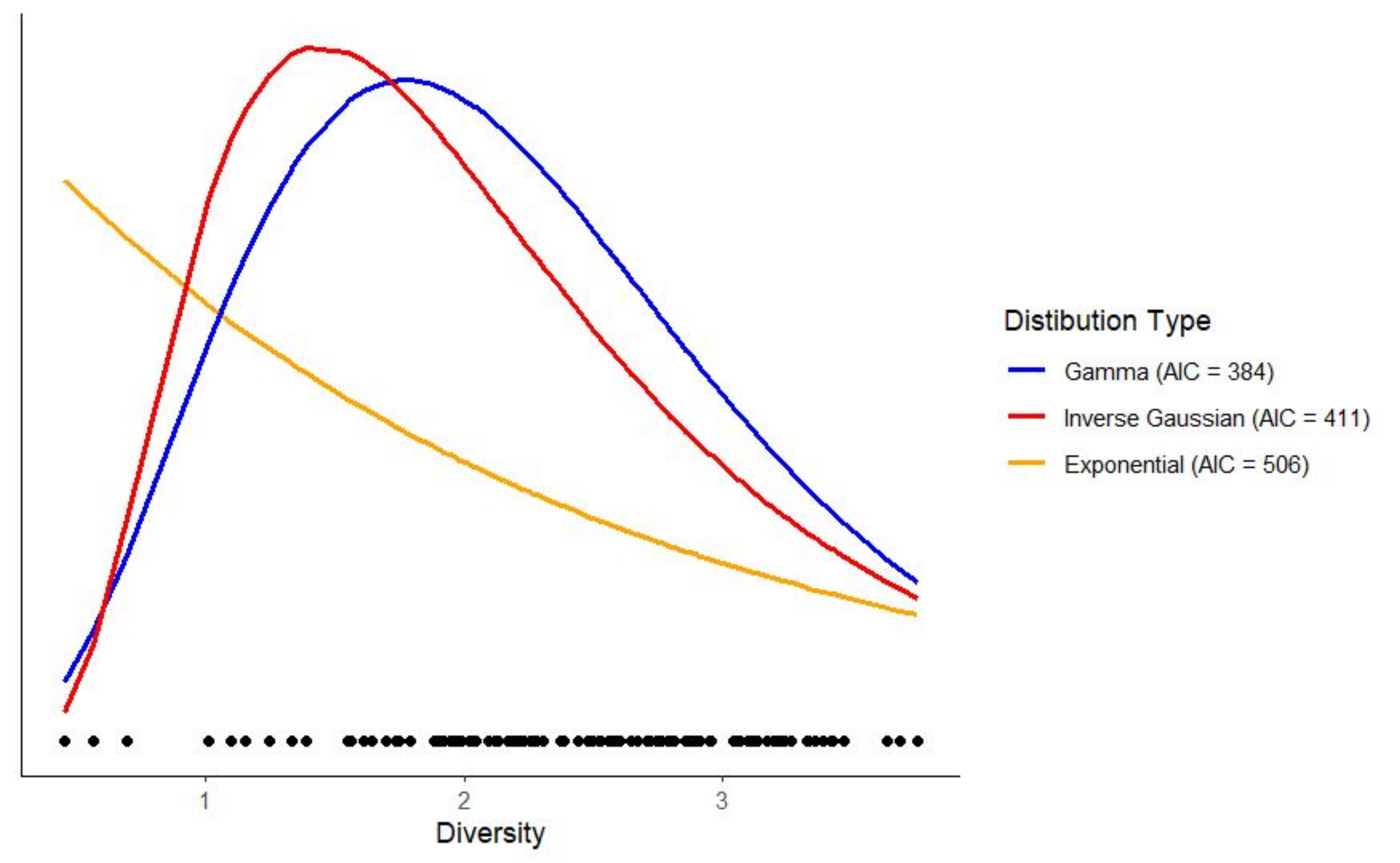
Fungal diversity (green), precipitation (blue), and temperature (red) in Colombia (2013-2022)



Correlations between observed fungal diversity, temperature (red) and precipitation (blue) in Colombia

Diversity Distribution?

$$H = -\sum_{j=1}^{S} p_i \ln p_i$$



Abundance GLMs

San Francisco

Coefficients:

	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	5.200e+00	6.155e-02	84.483	< 2e-16	***
precipitation	-4.011e-03	4.896e-04	-8.192	2.57e-16	***
temp	-1.460e-01	4.933e-03	-29.605	< 2e-16	***
precipitation:temp	9.587e-04	5.185e-05	18.487	< 2e-16	***

Ontario

Coefficients:

	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	3.9261635	0.0194367	202.00	<2e-16	***
precipitation	0.0017011	0.0001551	10.97	<2e-16	***
temp	0.0855267	0.0009053	94.47	<2e-16	***

Colombia

Coefficients:

	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	16.8019084	1.1947446	14.06	<2e-16	***
precipitation	-0.1201076	0.0052710	-22.79	<2e-16	***
temp	-0.4918155	0.0467676	-10.52	<2e-16	***
precipitation:temp	0.0048859	0.0002077	23.52	<2e-16	***

Diversity GLMs

San Francisco

```
Coefficients:
                        Estimate Std. Error t value Pr(>|t|)    
(Intercept)            2.410e-01  6.714e-02   3.590 0.000461 ***
precipitation          1.582e-03  5.983e-04   2.644 0.009152 ** 
temp                   2.093e-02  4.983e-03   4.201 4.77e-05 ***
precipitation:temp    -2.238e-04  6.068e-05  -3.688 0.000326 ***
```

Ontario

```
Coefficients:
             Estimate Std. Error t value Pr(>|t|)    
(Intercept)  0.491988   0.020421   24.09  < 2e-16 ***
temp        -0.007196   0.001189   -6.05 1.96e-08 ***
```

Colombia

```
Coefficients:
                Estimate Std. Error t value Pr(>|t|)   
(Intercept)    1.8218637  0.6559387   2.777  0.00635 **
precipitation -0.0003391  0.0001658  -2.045  0.04303 * 
temp          -0.0544165  0.0250123  -2.176  0.03153 * 
```


Questions?

References :)

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The End
Thanks :D