AB plant and invert responses to disturbance

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The goal of this project is to compare and contrast the responses of plants and insects to environmental gradients. It uses the following data:

1. Plant occurence data + These are presence-absence data from ABMI monitoring sites sampled with the Terrestrial and Wetland protocols + Sites are restricted to those classified as wetlands (bogs, fens, marshes, SOWWs, wet meadows) **2. Insect abundance data** + These are frequency data from ABMI monitoring sites sampled with the *Wetland protocol only.* + Insects were not identified at ABMI sites sampled with the Terrestrial protocol **3. Climatic data** + These include standard measure of temperature and precip (e.g. evaporation, frost-free period, MAP, MAT. . .) + These are fromavailable from ABMI via Martin + We currently only have data for one year (**which?**) and for sites sampled with the wetland protocol + Must request climate data for sites sampled with Terrestrial protocol **4. Human footprint data (HF)** + We now only have data for grassland sites sampled with Wetland protocol & boreal sites sampled with both protocols; we are missing HF data for grassland sites sampled with Terrestrial procotol

1. Load vegegtation datasets

We have two plant datasets. `plant_pa` excludes sites classified as SOWWs; `plant_pa2` includes sites classified as SOWWs. For the moment, let's proceed using the df which *includes* SOWWs.

```
veg_pa <- plant_pa2
veg_pa <- veg_pa %>% mutate(Site = str_replace(Site, pattern="-ABMI-", replacement = "-")) %>%
  mutate(Site = str_replace(Site, pattern="-ALPAC-", replacement = "-")) %>%
  mutate(Site = str_replace(Site, pattern="-DH-", replacement = "-"))
head(veg_pa)
```

```
## # A tibble: 6 x 6
##   Protocol    WetlandType Site   Year Species                  PA
##   <chr>       <chr>       <chr> <int> <chr>                 <dbl>
## 1 Terrestrial Fen         329    2015 Lycopodium dendroideum     1
## 2 Terrestrial Fen         329    2015 Equisetum scirpoides       1
## 3 Terrestrial Fen         329    2015 Equisetum arvense          1
## 4 Terrestrial Fen         329    2015 Viburnum edule             1
## 5 Terrestrial Fen         329    2015 Symphoricarpos albus       1
## 6 Terrestrial Fen         329    2015 Linnaea borealis           1
```

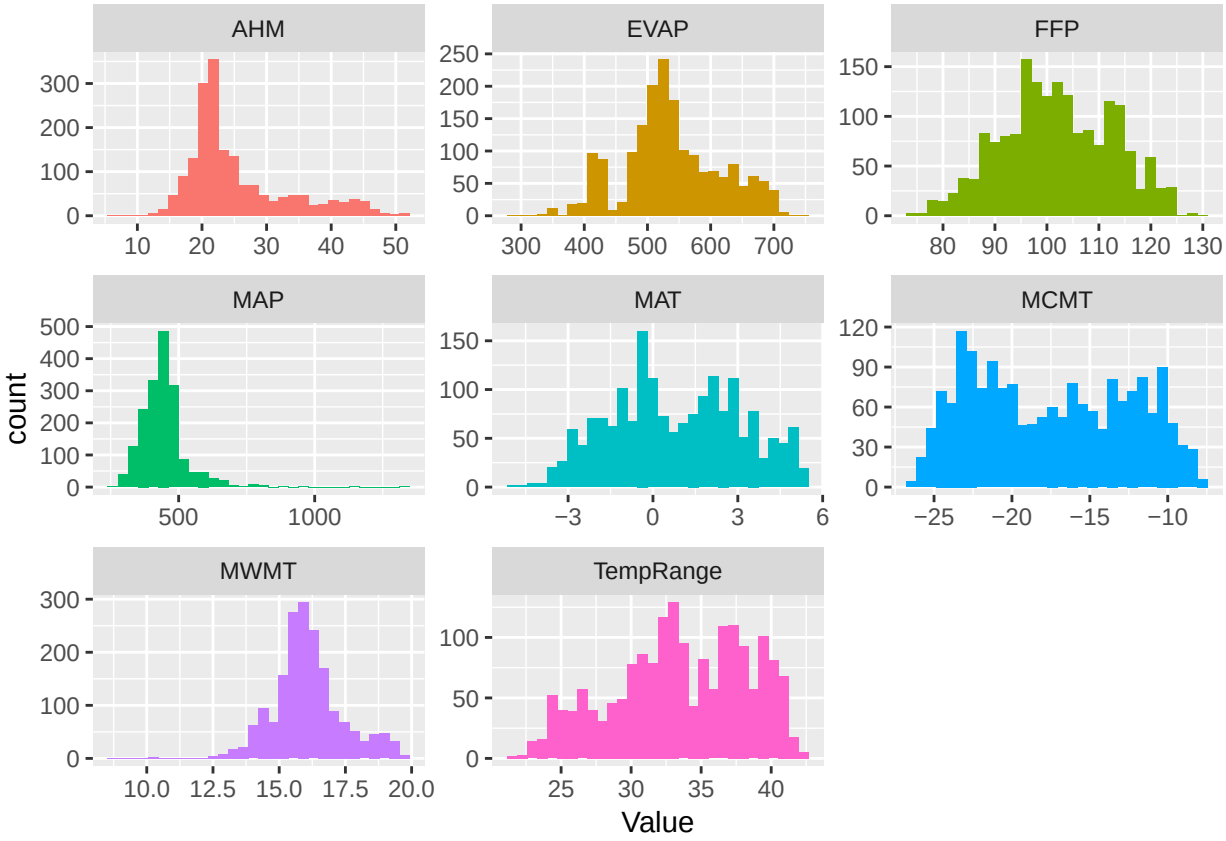
Make a df of the focal sites (i.e. wetlands from Terrestrial and Wetland sampling protocols); name it `sites`

2. Load climatic data

Load and examine the available climate data. The histogram below shows the distribution of climatic variables for each focal site.

- AHM =
- EVAP =
- FFP = frost-free period (days)
- MAP = mean annual precipitation (cm?)

- MAT = mean annual temperature (C)
- MCMT = mean temperature in the coldest month (C)
- MWMT = mean temperature in the warmest month (C)
- TempRange = the temperature difference between the coldest and warmest months



There are 155 terrestrial sites & 91 wetland sites w/o climate data. Must exclude them for now.

```
tmp <- filter(climate3, is.na(MAT))
tmp %>% group_by(Protocol) %>% tally()
```

```
## # A tibble: 2 x 2
##   Protocol        n
##   <chr>       <int>
## 1 Terrestrial   155
## 2 Wetland        91
```

```
climate3 <- climate3 %>% filter(!is.na(MAP))
```

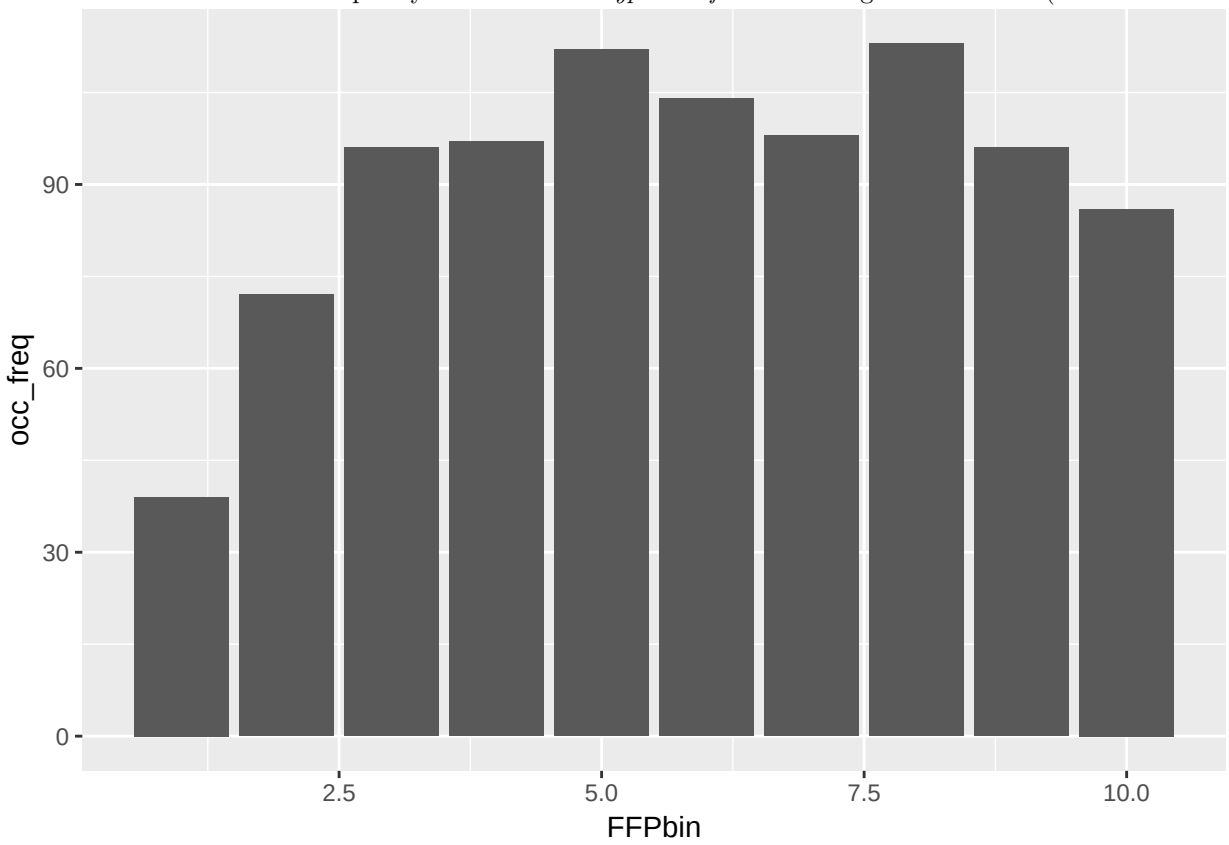
Bin the continuous climatic variables into 10 bins each with a similar number of sites. Assign each site to a bin.

```
## # A tibble: 6 x 11
##   Protocol Site   Year   FFP   MAP    MAT TempRange FFPbin MAPbin MATbin
##   <chr>    <chr> <int> <int> <int>  <dbl>     <dbl>  <int>  <int>  <int>
## 1 Terrest~ 329    2015   104   407 -0.700      39.7      6      4      3
## 2 Terrest~ 330    2015   103   413 -0.900      39.1      6      4      3
## 3 Terrest~ 331    2015   101   417 -1.10       38.9      5      4      3
## 4 Terrest~ 358    2015   103   417 -0.700      39.2      6      4      3
## 5 Terrest~ 359    2015   101   424 -0.800      38.2      5      5      3
## 6 Terrest~ 360    2015    98   432 -1.20       38.9      4      5      3
```

```
## # ... with 1 more variable: TempRangebin <int>
```

3. Calculate species sensitivity index (SSI)

We can examine the of occurrences of each species in each climate bin. To do so, we join the vegetation df (`veg_pa`) to the climate df (`climate3`), sum the number of occurrencs in each bin, and plot a histogram. For example, below we can see the occurence frequency distribution of *Typha latifolia* across a gradient of FFP (frost free period).

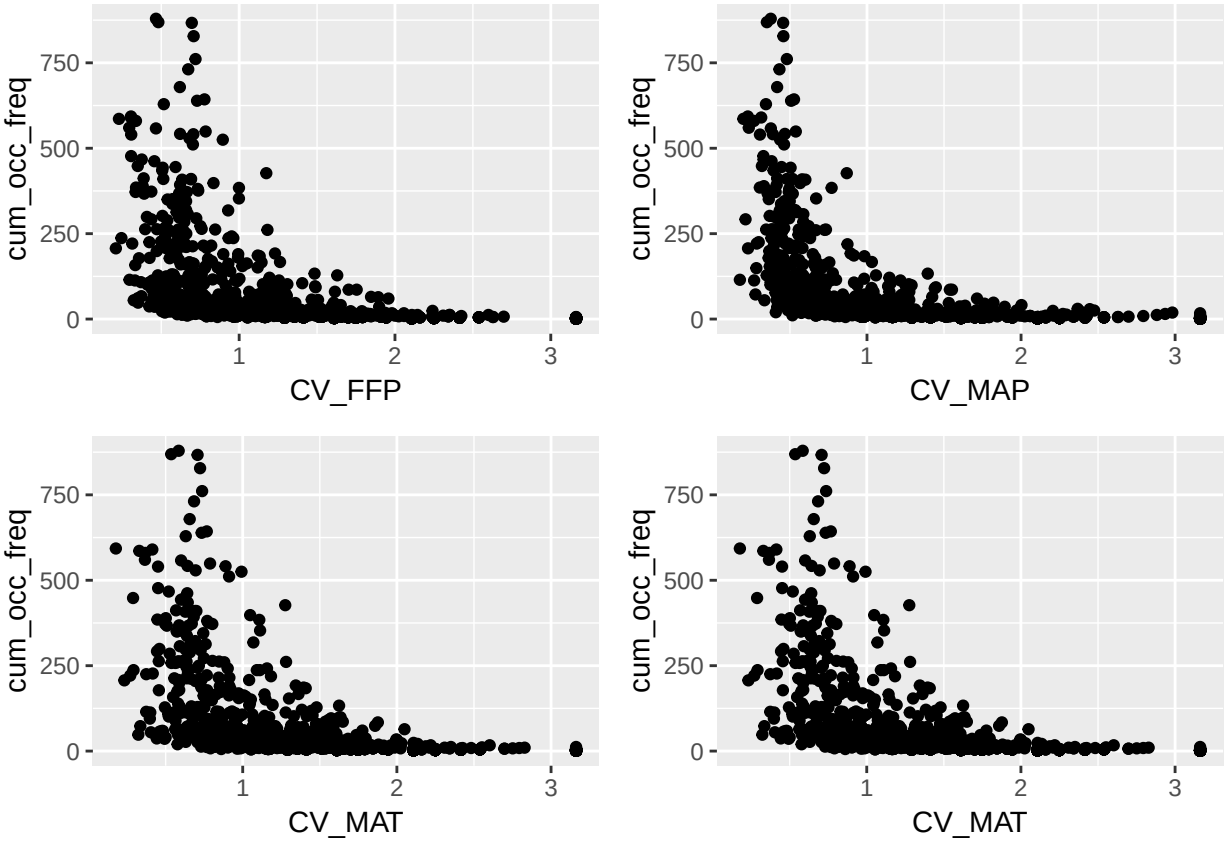


Now calculate the occurrence frequency distribution for every species, across each climatic gradient. We will exclude species which occur only 1x, since they will have high sensitivity to the gradient.

Also calculate the specicies sensitivity index (SSI), the coeffient of variation (sd/mean) of each species's occurrence frequency distribution across each climatic gradient. This df is called `sp_SSI`.

```
## # A tibble: 6 x 5
##   Species              CV_FFP CV_MAP CV_MAT CV_TempRange
##   <chr>                 <dbl>  <dbl>  <dbl>        <dbl>
## 1 Abies balsamea        0.535  1.21   0.976        0.839
## 2 Abies bifolia         1.32   3.16   1.94         3.16
## 3 Acer negundo          1.79   1.41   2.25         1.79
## 4 Achillea alpina       1.08   0.710  1.40         1.07
## 5 Achillea millefolium  0.229  0.198  0.329        0.344
## 6 Acorus americanus     1.18   1.40   1.36         1.76
```

3.1 Relationships between species occurrence frequency and CV:



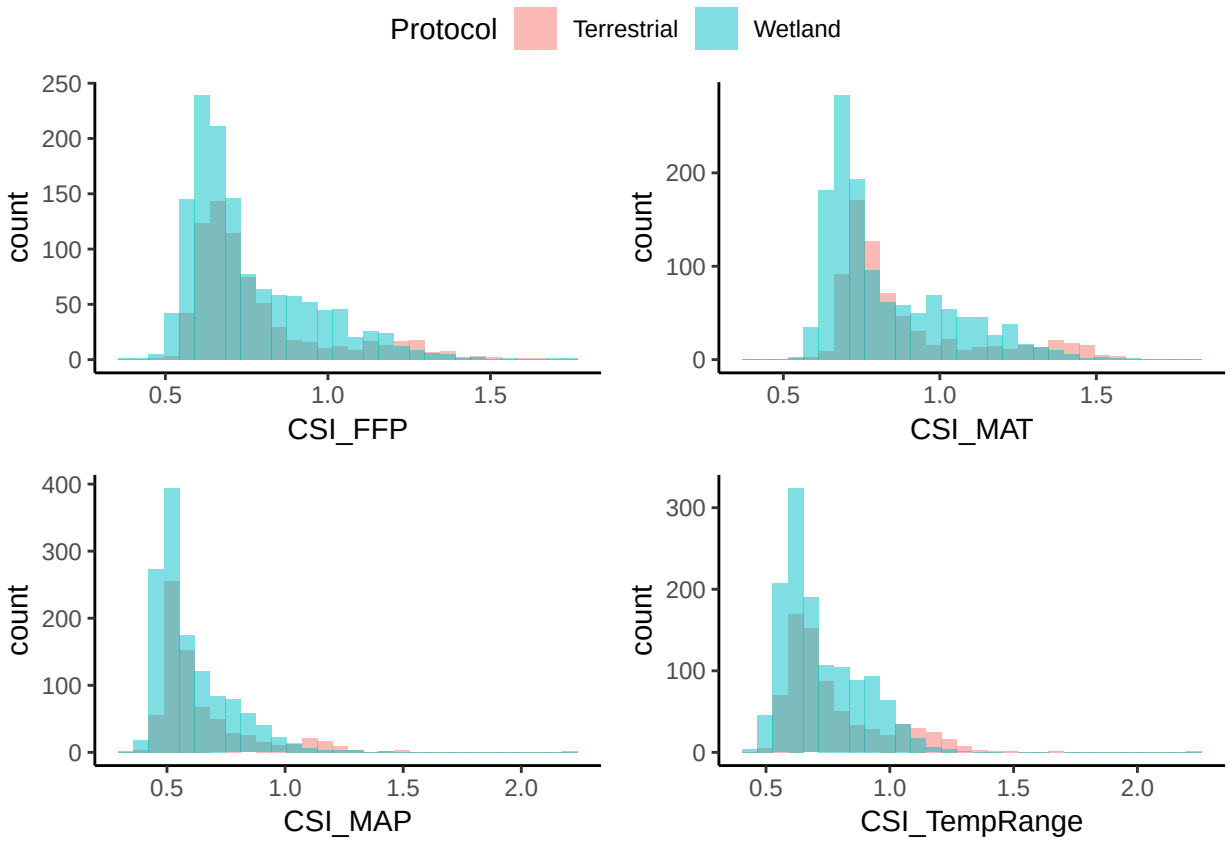
4. Calculate community sensitivity index (CSI)

Add SSI of each species (`sp_SSI`) to the vegetation df (`veg_pa`). Calculate the mean SSI of species at each site. Add the climate df (`climate3`).

```
veg_CSI_climate %>% group_by(Protocol) %>% tally()
```

```
## # A tibble: 2 x 2
##   Protocol        n
##   <chr>       <int>
## 1 Terrestrial   734
## 2 Wetland      1298
```

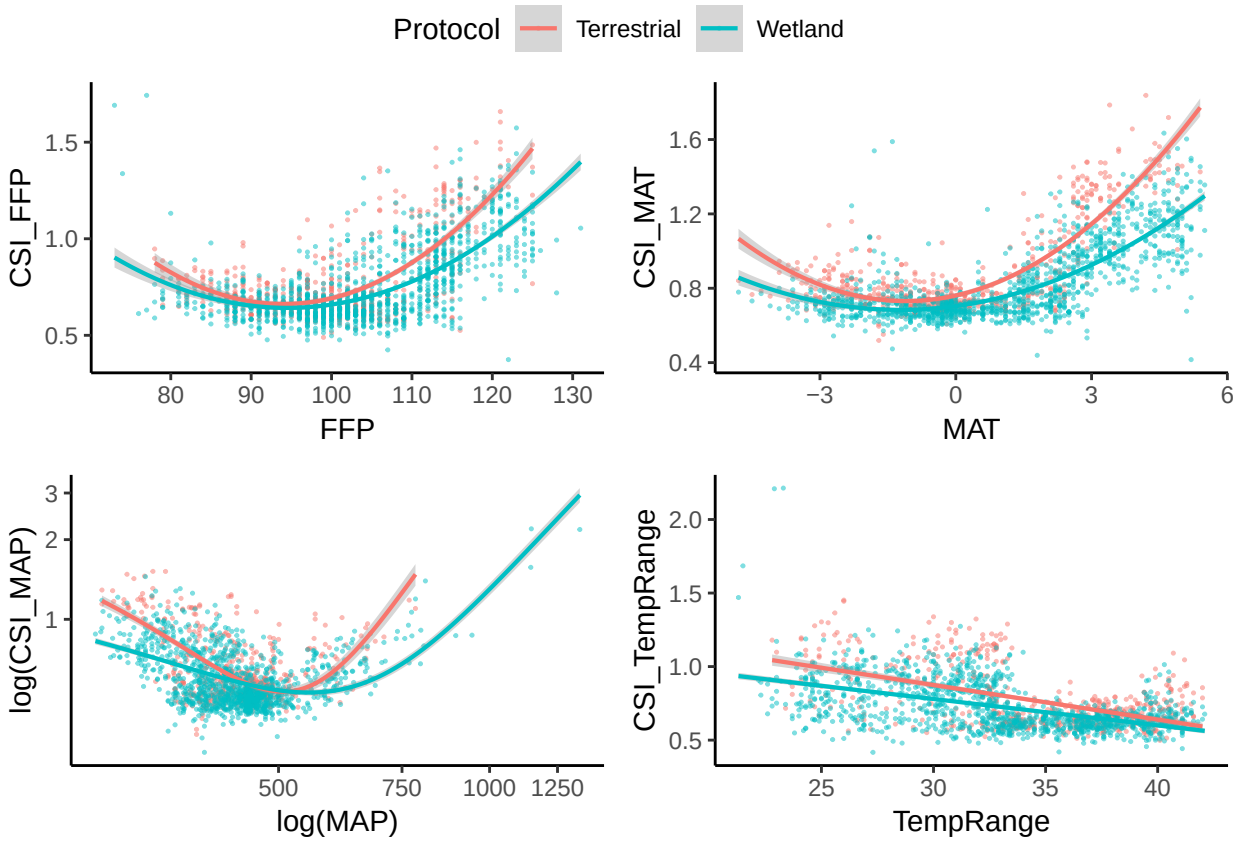
Compare the distribution of CSI values for wetland vs terrestrial sites.



5. Examine patterns of CSI across climate gradients

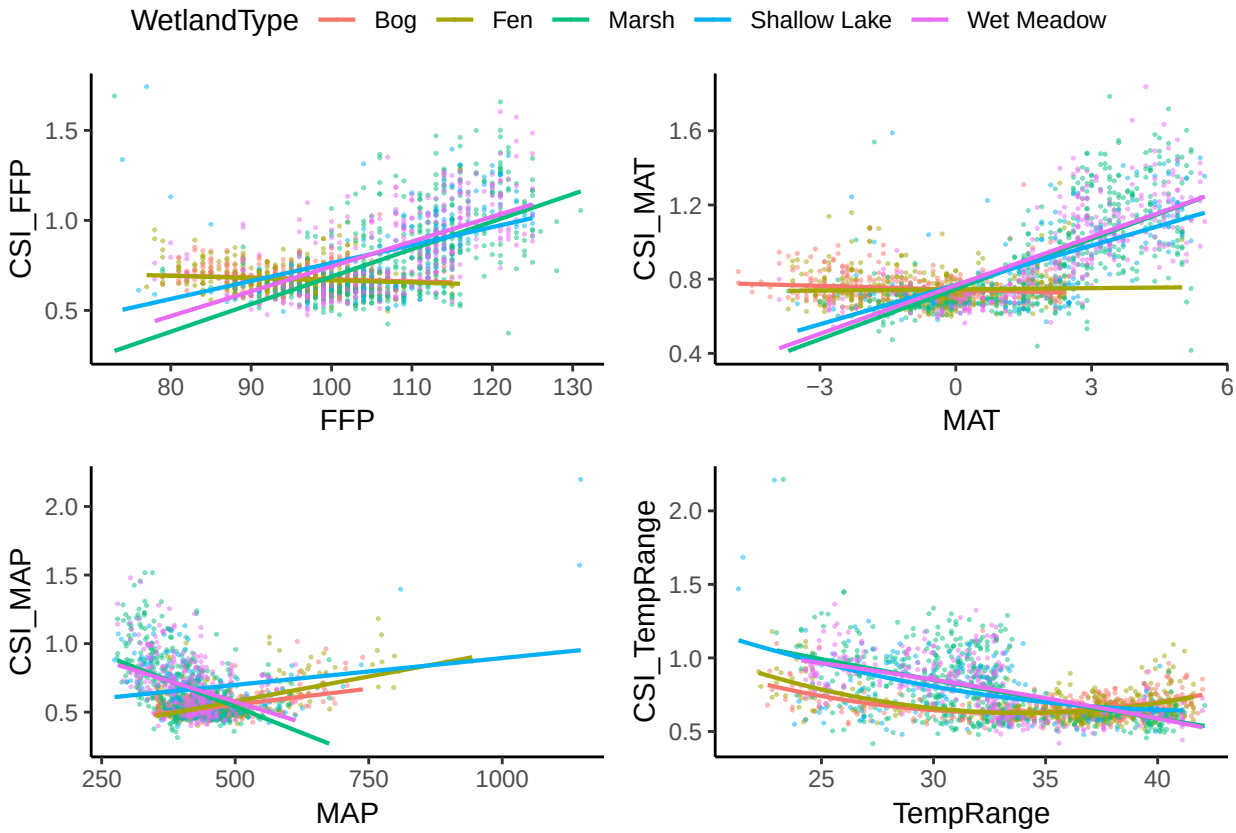
5.1 Comparisons between Terrestrial and Wetland Protocols

The Wetland protocol systematically underestimates the CSI of communities across all climatic gradients. Generally, though, communities at the extremes of each climate gradient show higher sensitivity to climatic conditions; these communities are composed to species with high fidelity to the environmental conditions.



5.2 Comparisons among wetland classes

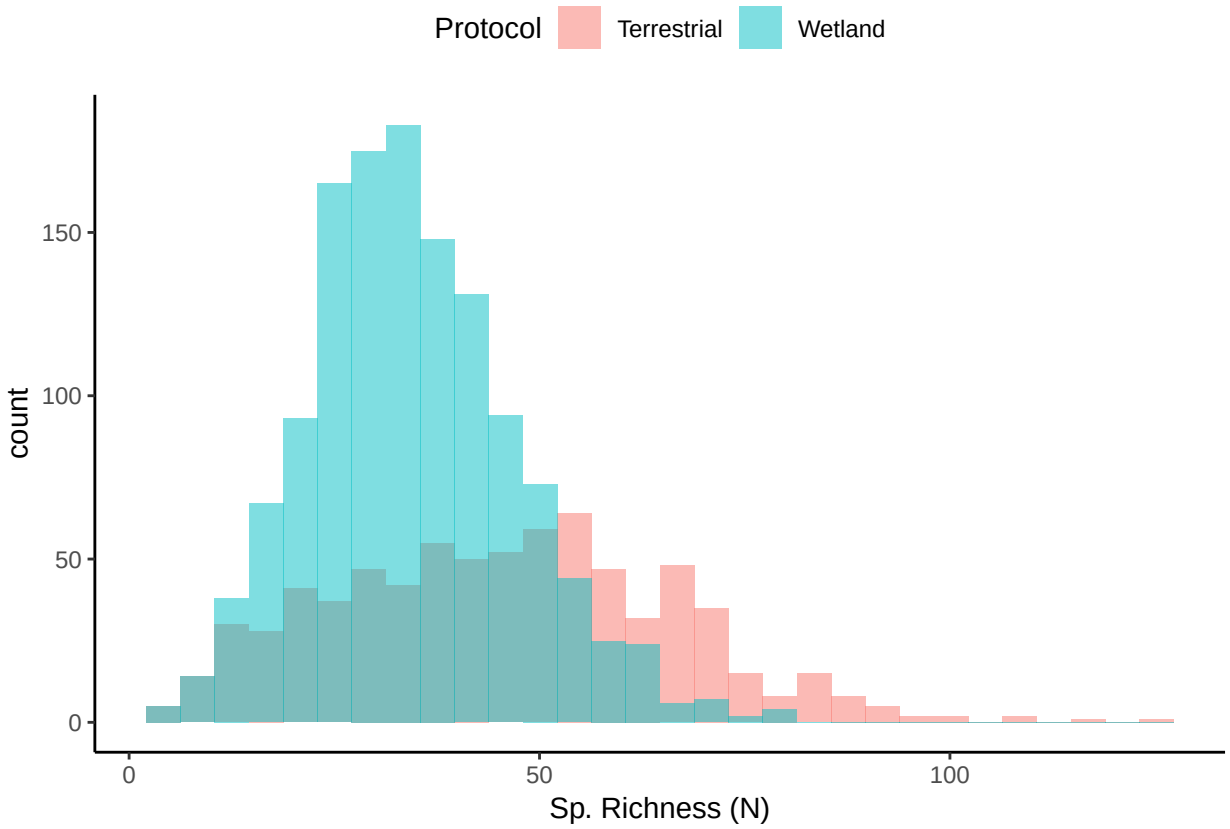
Peatland communities are relatively insensitive to climatic conditions whereas marshes, SOWWs, and wet meadows show positive correlation between CSI and climatic gradients. However, peatlands (bogs and fens) occur more often in the boreal and the other wetland types occurr in grasslands, so we are confounding wetland type with Natural Region and latitude.



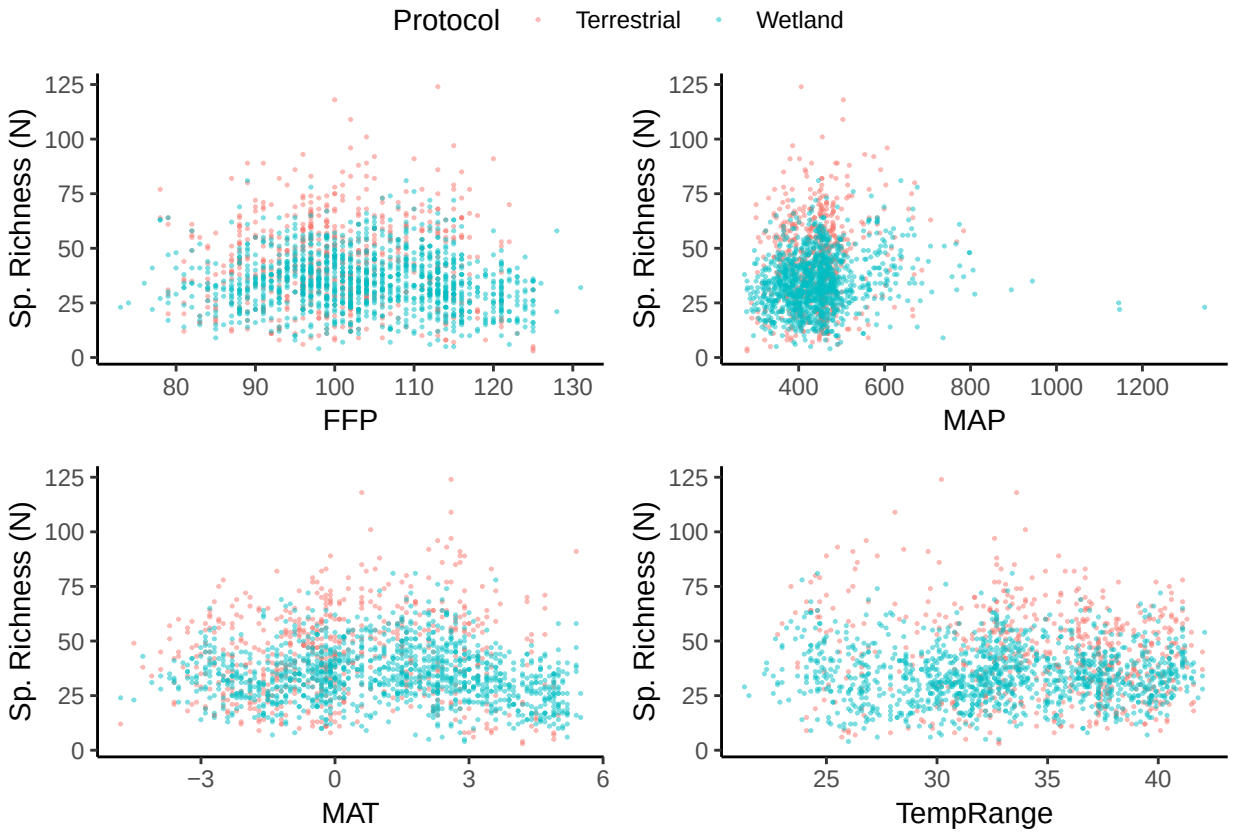
6. Examine patterns of species richness between protocols and across climate gradients

There is a difference in the species richness of site sampled with the Wetland and Terrestrial protocols. There are also differences in the number of sites sampled.

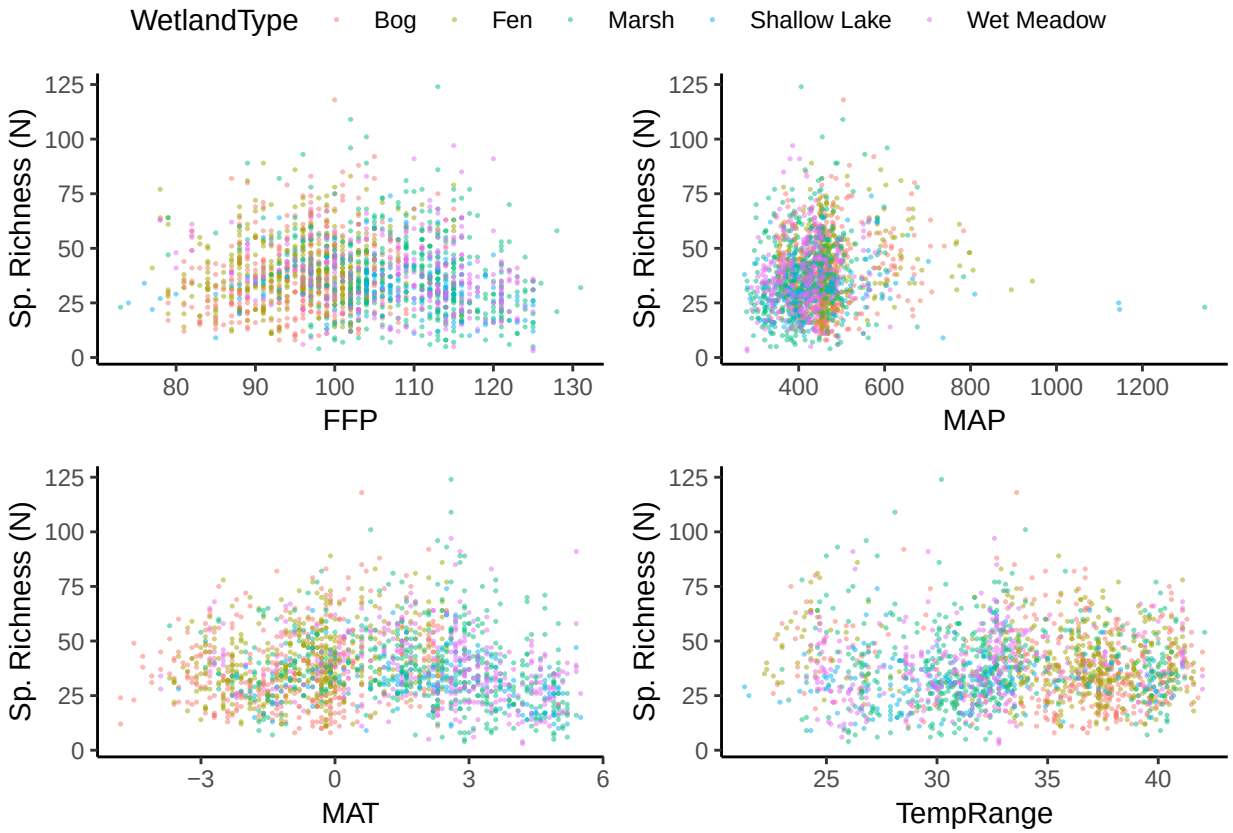
```
## # A tibble: 2 x 2
##   Protocol        n
##   <chr>       <int>
## 1 Terrestrial   745
## 2 Wetland      1298
```



There is no systematic difference in species richness at sites sampled with the Terrestrial vs Wetland protocols across climatic gradients.



Wetland classes are found in different ranges of the climatic gradients, but do not show systematic differences in species richness.



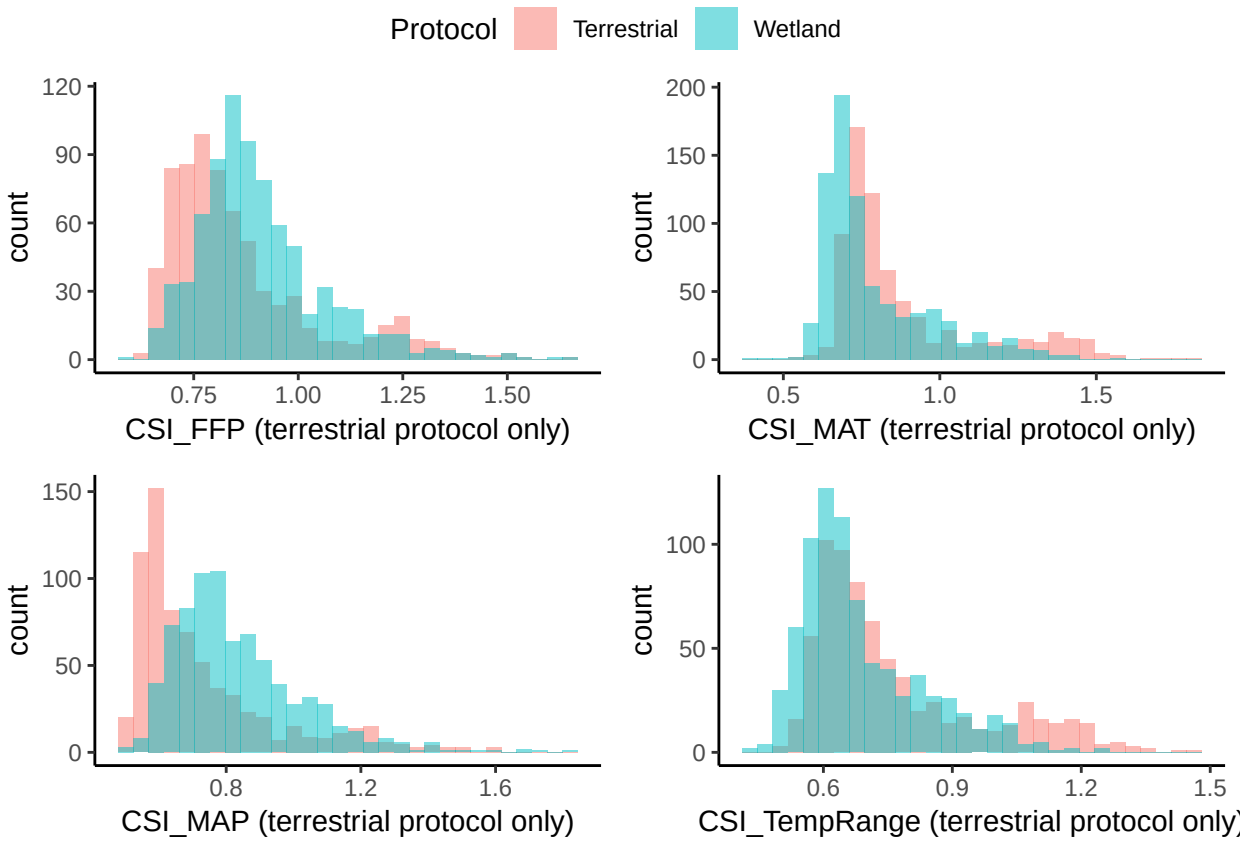
7. Calculate SSI only using terrestrial veg data

To compare the sensitivity of species captured in sites from Terrestrial vs. Wetland protocols, try calculating SSI based only on the distribution of species from sites in one protocol. First calculate SSI based on occurrence freqency of terrestrial sites. Then calculate CSI of terrestrial *and* wetland sites. Could be interesting to see if the resulting CSI shows wetland sites generally with higher or lower or the same CSI values relative to terrestrial sites.

```
## # A tibble: 6 x 5
##   Species              CV_FFP CV_MAP CV_MAT CV_TempRange
##   <chr>                 <dbl>  <dbl>  <dbl>        <dbl>
## 1 Abies balsamea        0.690  1.07   0.976        0.839
## 2 Abies bifolia         1.94   3.16   1.94         3.16
## 3 Acer negundo          2.11   2.11   2.25         1.79
## 4 Achillea alpina       1.04   0.820  1.40         1.07
## 5 Achillea millefolium  0.264  0.166  0.329        0.344
## 6 Acorus americanus     2.11   2.11   1.36         1.76
```

7.1 Compare the distribution of CSI_t between protocols and among wetland classes

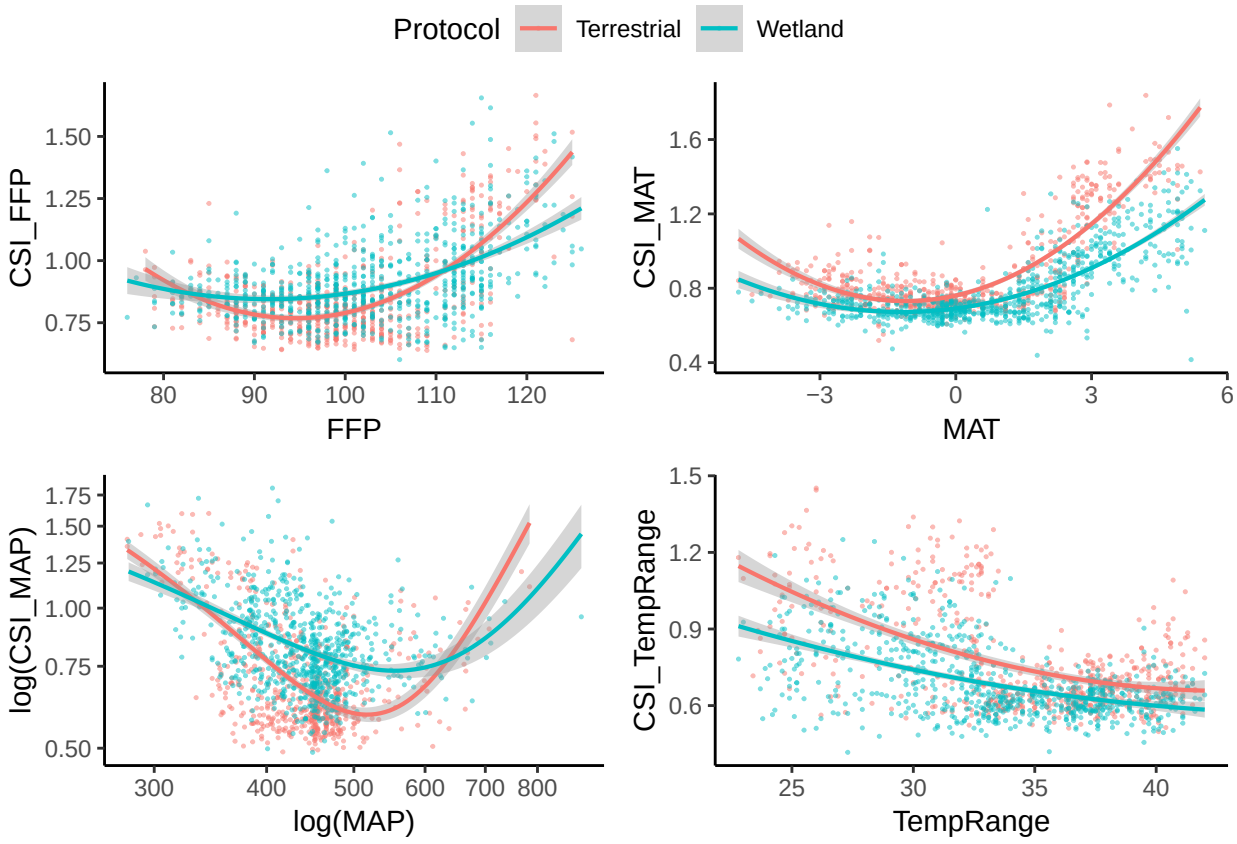
There are some slight differeences in the distribution of CSI values between wetland and terrestrial sites when CSI is calculated based on occurrence frequency of terrestrial sites only, but wetland sites don't have systematically higher or lower CSI than terrestrial sites across diff gradients.



7.2 Examine patterns of CSI_t across climate gradients

Using only species from terrestrial sites to create SSI results in pretty similar patterns of CSIs of Wetland and Terrestrial sites across climatic gradients. Compare this graph to the one created from SSI of both wetland and terrestrial sites (in section 4.2).

There are some qualitative differences especially in the response to FFP and TempRange. Using terrestrial and wetland sites to calculate SSI, the CSI of sites sampled with the wetland protocol pretty consistently always have lower CSI than terrestrial sites (i.e. wetland sites are less sensitivie than terrestrial sites). When SSI is calculated using only terrestrial sites, however, sites sampled with the wetland protocol show higher sensitivity under moderate climatic condition whereas terrestrial sites show a strong reduction in sensitivity under moderate climatic conditions. That is, wetland sites show relatively more consistent CSI then terrestrial sites.



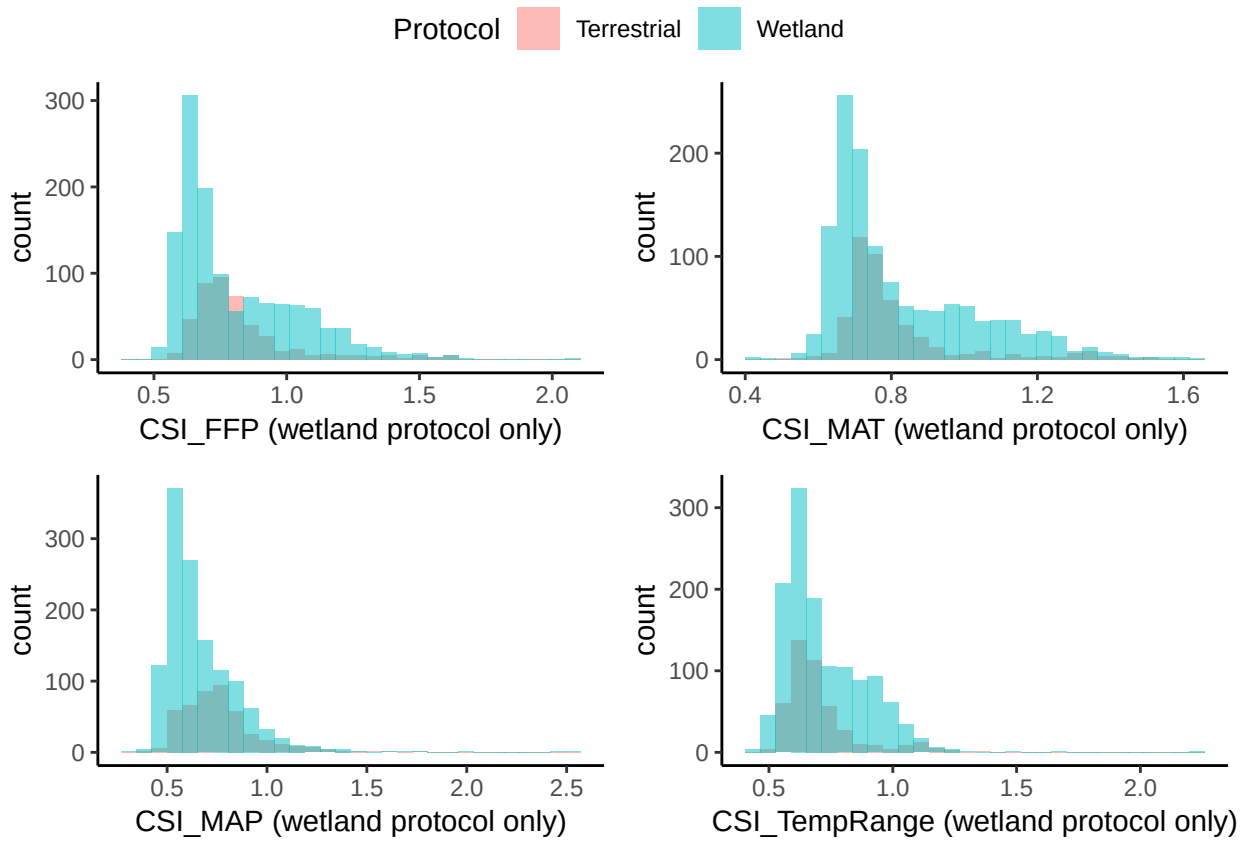
8. Calculate SSI only using wetland veg data

Now calculate SSI based on occurrence freqency of wetland sites.

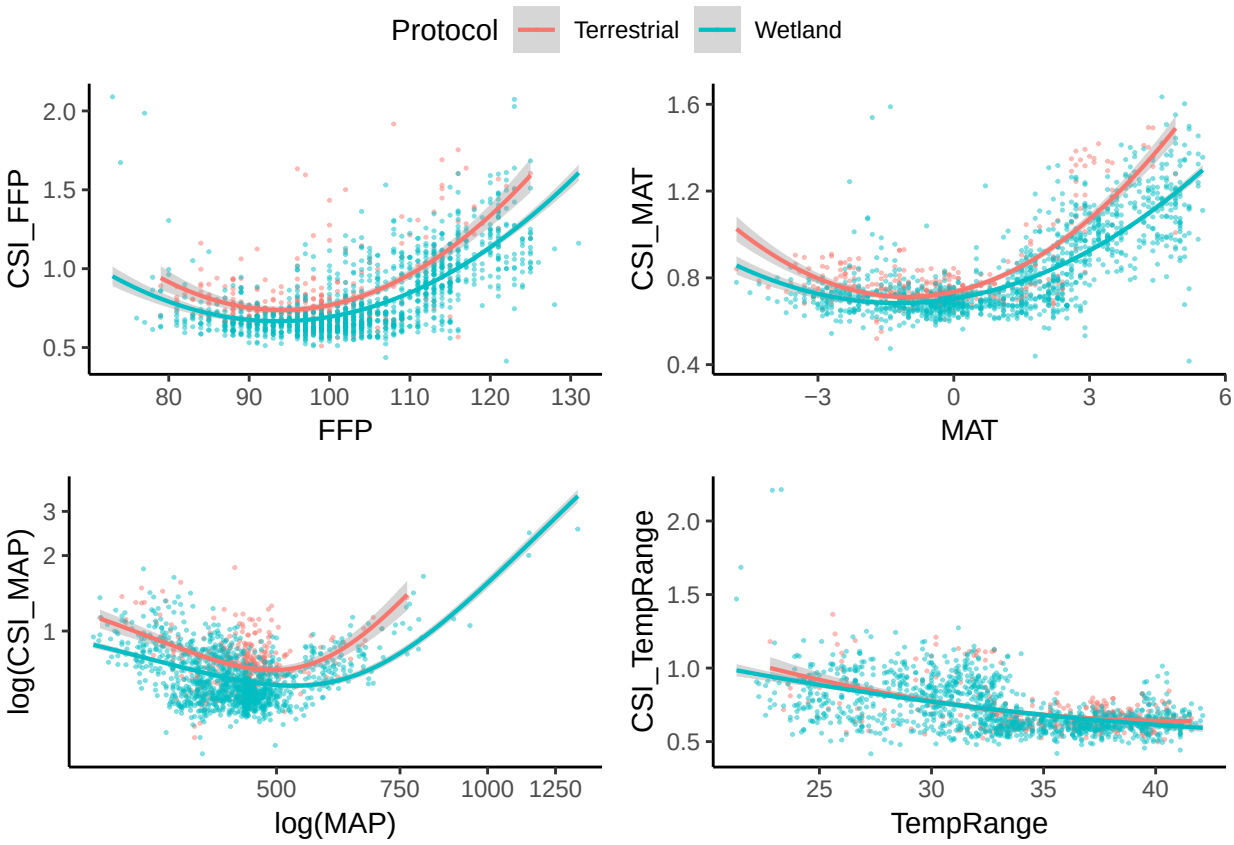
```
## # A tibble: 6 x 5
##   Species              CV_FFP CV_MAP CV_MAT CV_TempRange
##   <chr>                 <dbl>  <dbl>  <dbl>        <dbl>
## 1 Abies balsamea        0.672  1.75   0.976        0.839
## 2 Abies bifolia         1.61   3.16   1.94         3.16
## 3 Acer negundo          2.11   2.11   2.25         1.79
## 4 Achillea alpina       1.25   0.884  1.40         1.07
## 5 Achillea millefolium  0.501  0.377  0.329        0.344
## 6 Acorus americanus     1.10   1.35   1.36         1.76
```

8.1 Compare the distribution of CSI_w between protocols and among wetland classes

The distributions of CSI values don't really differ between terrestrial and wetland sites when SSI is calculated with wetland data only. However we can see that there are much fewer terrestrial sites for which we can assign CSI values, probably b/c there are many species in the wetland dataset which are not found in the terrestrial dataset.


Protocol
Terrestrial
Wetland
count
CSI_FFP (wetland protocol only)
CSI_MAT (wetland protocol only)
CSI_MAP (wetland protocol only)
CSI_TempRange (wetland protocol only)

8.2 Examine patterns of CSI_w across climate gradients



8.3 Correlations among SSI calculated with full and partial datasets