Analyses of species distributions in peatlands

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Contents

Load the R packages that you will use

If you do not have the R packages installed, you need to install them.

```
library(tidyverse)
library(readxl)
library(knitr)
library(ggeffects)
library(car)
library(glmmTMB)
library(ggplot2)
library(vegan)
library(rdacca.hp)
library(gridExtra)
library(ggthemes)
```

Data preparation

Read data from Excel file

Note that you need to change the path to the folder where you have the Excel file

```
data_peat<-read_excel("data/edited/Modelling_SDM_species_data.xlsx",
                      sheet="SDM Data")
```

Have a look at the data

This shows the first rows of your data file in "tibble" format. You can also see the variable type for each variable (double or character).

```
data_peat
```

```
## # A tibble: 115 x 29
##    n_samples depth depth_corrected fen   tot_Sphagnum  Erio Carex Erica
##        <dbl> <chr>           <dbl> <chr>        <dbl> <dbl> <dbl> <dbl>
##  1         1 0                   0 N              100     0     0     0
##  2         2 14-15              14 N               87     3     2     8
##  3         3 20-21              20 N               74     6     6    14
##  4         4 30-31              30 N               87     5     4     4
##  5         5 40-41              40 N               90     2     3     5
##  6         6 50-51              50 N               41    46     9     4
##  7         7 55-56              55 N               74    19     6     1
##  8         8 60-61              60 N               94     4     1     1
```

```
##  9         9 65-66              65 N               95     3     1     1
## 10        10 70-71              70 N               90     3     4     3
##    other_veg Balticum Medium Cuspidata Austinii Fuscum Rubellum Acutifolia
##        <dbl>    <dbl>  <dbl>     <dbl>    <dbl>  <dbl>    <dbl>      <dbl>
##  1         0     32    68         0           0      0      0         0
##  2         0     72.4  25.3       2.30        0      0      0         0
##  3         0     32.4  64.9       0           0      0      0         2.70
##  4         0     26.4  27.6       0           0      0     36.8       9.20
##  5         0     18.9   5.56      3.33        0      0      0        72.2
##  6         0     17.1  41.5      22.0         0      0     19.5       0
##  7         0     56.8  21.6      21.6         0      0      0         0
##  8         0     48.9  38.3      12.8         0      0      0         0
##  9         0     58.9  26.3      14.7         0      0      0         0
## 10         0     54.4  11.1      34.4         0      0      0         0
##    'Diseased Acutifolia' Angustifolium Tenellum Papillosum Fallax Stems   age
##                    <dbl>         <dbl>    <dbl>      <dbl>  <dbl> <dbl> <dbl>
##  1                     0             0        0          0      0     0     0
##  2                     0             0        0          0      0     0    75
##  3                     0             0        0          0      0     0   136
##  4                     0             0        0          0      0     0   244
##  5                     0             0        0          0      0     0   352
##  6                     0             0        0          0      0     0   452
##  7                     0             0        0          0      0     0   505
##  8                     0             0        0          0      0     0   555
##  9                     0             0        0          0      0     0   606
## 10                     0             0        0          0      0     0   643
##     temp imp_temp moist nutrient  fire   dry
##    <dbl>    <dbl> <chr>    <dbl> <dbl> <dbl>
##  1  6.35        0 NA           0     0     0
##  2  6.92        1 NA           0     0     0
##  3  7.39        1 NA           0     0     0
##  4  8.21        0 NA           0     0     0
##  5  8.00        1 -0.38        1     0     0
##  6  7.81        1 -0.3         1     0     0
##  7  7.71        1 0.01          1     0     0
##  8  7.62        1 -0.26        1     0     0
##  9  7.52        1 0.22          1     0     0
## 10  7.45        1 -0.25        1     0     0
## # i 105 more rows
```

Convert some variables to factors

It is better to convert some variables (those that are Y/N or 0/1) to factors.

```
data_peat<-data_peat%>%
  mutate(fen=as.factor(fen),imp_temp=as.factor(imp_temp),
         nutrient=as.factor(nutrient),fire=as.factor(fire),dry=as.factor(dry))
# with mutate you create new variables that are equal to the old variables
# but are coded as factors
```

Convert moist to numeric

For some reason, moist appears as a character variable. It should be numeric, so we convert it.

```r
data_peat<-data_peat%>%
  mutate(moist=as.numeric(moist))
```

Ordinations (vegan package)

Suggested reading: https://www.davidzeleny.net/anadat-r/doku.php/en:ordination

(lots of info on this webpage!)

Chapter 10 in this pdf: https://apps.worldagroforestry.org/downloads/Publications/PDFS/b13695.pdf

Using the vegan package.

I performed some ordinations with Sphagnum species. I tried different methods, but if I would need to choose one, I would do a constrained ordination, specifically a Distance-based redundancy analysis (db-RDA) with Bray-Curtis distance. You can read about all types in the webpage above if you feel like it.

Data for ordination:

```r
data_ordi2<-data_peat %>%
  filter_at(vars(Balticum:Fallax),
            all_vars(!is.na(.)))%>% # Remove rows with all NAs
  filter_at(vars(Balticum:Fallax),
            any_vars(.>0))%>% # Remove rows with all zeros - WHY?
  filter(!is.na(age)&!is.na(temp)&!is.na(moist)&!is.na(nutrient)&!is.na(fire)&
           !is.na(dry))%>% # Remove rows with NA in predictors
  rename(Deformed_Acutifolia=`Diseased Acutifolia`) #Rename to avoid problems
```

Distance-based redundancy analysis (db-RDA) with Bray-Curtis distance.

See https://www.davidzeleny.net/anadat-r/doku.php/en:similarity for info on distances.

Calculate ordination:

```r
ordi6<-capscale(data_ordi2[10:21]~ # species data matrix
              age+temp+moist+nutrient+fire+dry, # Environmental variables
              data = data_ordi2, distance="bray") # Bray-Curtis distance
```

Result of the ordination:

```r
ordi6
```

```
## Call: capscale(formula = data_ordi2[10:21] ~ age + temp + moist +
## nutrient + fire + dry, data = data_ordi2, distance = "bray")
##
##               Inertia Proportion Rank
## Total         31.0247     1.0000
## Constrained    8.3890     0.2704    6
## Unconstrained 26.3953     0.8508   34
## Imaginary     -3.7596    -0.1212   38
## Inertia is squared Bray distance
## Species scores projected from '[' 'data_ordi2' '10:21'
##
## Eigenvalues for constrained axes:
```

```
##  CAP1  CAP2  CAP3  CAP4  CAP5  CAP6
## 4.886 2.239 0.760 0.275 0.138 0.090
##
## Eigenvalues for unconstrained axes:
##  MDS1  MDS2  MDS3  MDS4  MDS5  MDS6  MDS7  MDS8
## 7.438 4.231 3.327 2.484 2.345 2.009 1.231 0.598
## (Showing 8 of 34 unconstrained eigenvalues)
```

"Intertia" is the total variance - your environmental variables explain 0.2704 of this variance ("constrained" part).

Proportion explained by each ordination axis. CAP1-CAP6 are the "constrained" axes, explained by your environmental variables. MDS1-MDS34 are the "unconstrained" axes.

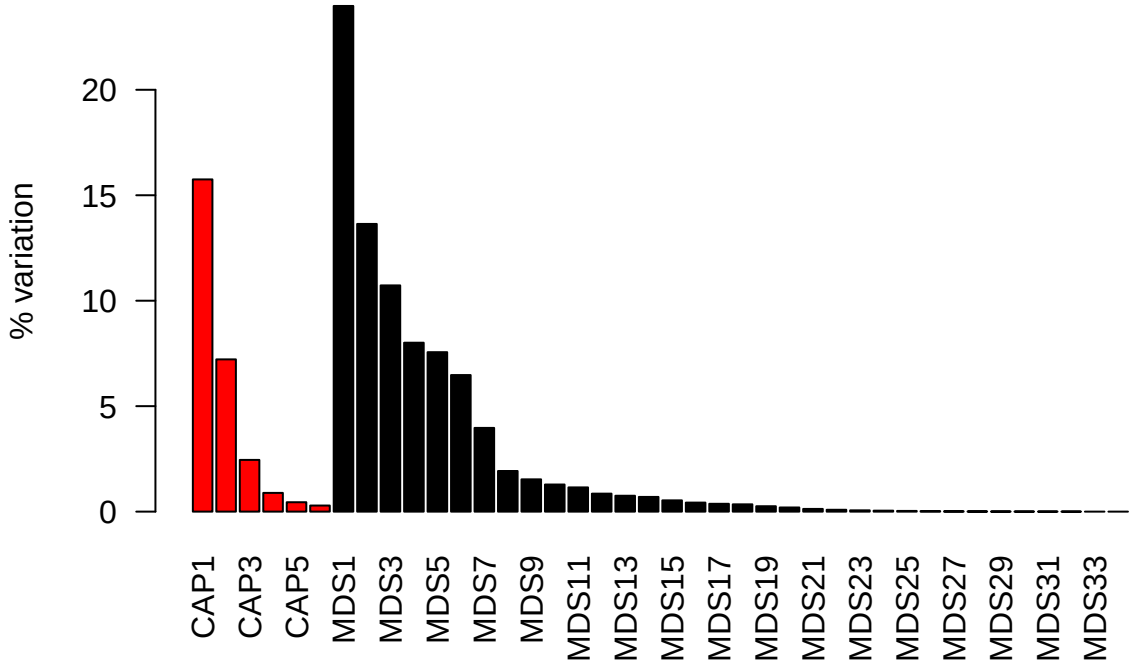
```
eigenvals(ordi6) %>%
  summary()
```

```
## Importance of components:
##                           CAP1    CAP2    CAP3     CAP4     CAP5     CAP6   MDS1
## Eigenvalue            4.8864 2.23908 0.76034 0.275418 0.138257 0.089584 7.4376
## Proportion Explained  0.1405 0.06437 0.02186 0.007918 0.003975 0.002575 0.2138
## Cumulative Proportion 0.1405 0.20485 0.22670 0.234623 0.238597 0.241173 0.4550
##                           MDS2    MDS3    MDS4    MDS5    MDS6    MDS7    MDS8
## Eigenvalue            4.2314 3.32744 2.48429 2.34529 2.00858 1.23102 0.59753
## Proportion Explained  0.1216 0.09566 0.07142 0.06742 0.05774 0.03539 0.01718
## Cumulative Proportion 0.5766 0.67230 0.74372 0.81114 0.86889 0.90428 0.92146
##                           MDS9   MDS10   MDS11    MDS12    MDS13    MDS14
## Eigenvalue            0.47441 0.39839 0.35604 0.264432 0.233304 0.216297
## Proportion Explained  0.01364 0.01145 0.01024 0.007602 0.006707 0.006218
## Cumulative Proportion 0.93509 0.94655 0.95678 0.964385 0.971092 0.977311
##                          MDS15    MDS16    MDS17    MDS18    MDS19   MDS20
## Eigenvalue            0.165550 0.132735 0.114764 0.107089 0.079177 0.06086
## Proportion Explained  0.004759 0.003816 0.003299 0.003079 0.002276 0.00175
## Cumulative Proportion 0.982070 0.985886 0.989185 0.992264 0.994540 0.99629
##                          MDS21     MDS22     MDS23     MDS24     MDS25
## Eigenvalue            0.039731 0.0271939 0.0187321 0.0140133 0.0100910
## Proportion Explained  0.001142 0.0007818 0.0005385 0.0004029 0.0002901
## Cumulative Proportion 0.997432 0.9982138 0.9987523 0.9991552 0.9994453
##                          MDS26     MDS27     MDS28     MDS29     MDS30
## Eigenvalue            0.0072592 0.0045627 3.097e-03 1.820e-03 1.307e-03
## Proportion Explained  0.0002087 0.0001312 8.905e-05 5.231e-05 3.757e-05
## Cumulative Proportion 0.9996540 0.9997852 9.999e-01 9.999e-01 1.000e+00
##                          MDS31     MDS32     MDS33     MDS34
## Eigenvalue            7.537e-04 4.030e-04 9.125e-05 9.071e-07
## Proportion Explained  2.167e-05 1.158e-05 2.623e-06 2.608e-08
## Cumulative Proportion 1.000e+00 1.000e+00 1.000e+00 1.000e+00
```

Barplot of percentage variance explained by individual axes

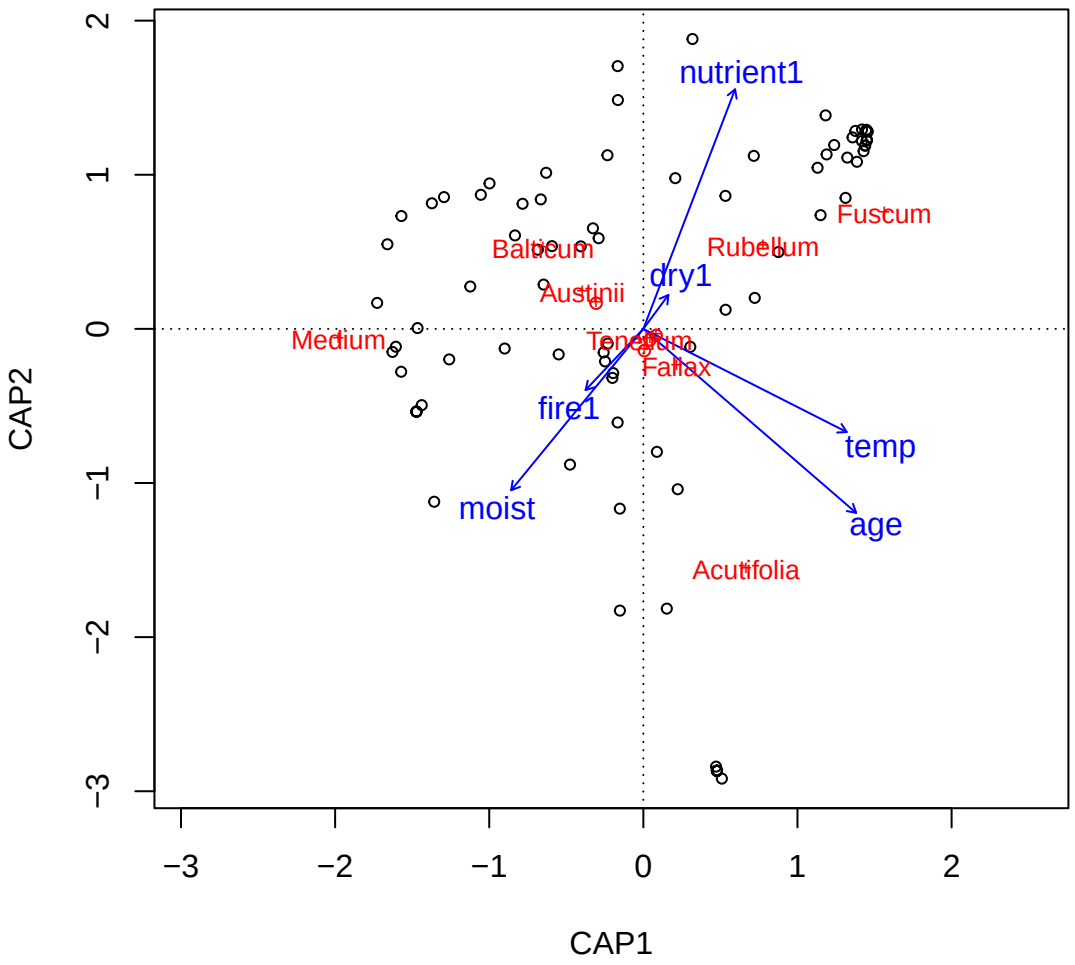
```
expl_var_ordi6 <- c(ordi6$CCA$eig/ordi6$tot.chi*100,
                    ordi6$CA$eig/ordi6$tot.chi*100)
barplot (expl_var_ordi6, col = c(rep ('red',
                                      length (ordi6$CCA$eig/ordi6$tot.chi*100)),
```

```
                                rep ('black',
                                    length (ordi6$CA$eig/ordi6$tot.chi*100))),
        las = 2, ylab = '% variation')
```



Plot of the ordination (species in red and sites-samples in black):

```
vegan::ordiplot(ordi6,display = c('species', 'sites', 'bp'))
orditorp(ordi6,display="species",cex=0.8,col="red")
```



This shows the two first constrained axes of the ordination. You can see how the sites and species distribute along these axes.

Test significance of the ordination with Monte Carlo permutation test.

For the whole model:

```
anova (ordi6, permutations = 999)
```

```
## Permutation test for capscale under reduced model
## Permutation: free
## Number of permutations: 999
##
## Model: capscale(formula = data_ordi2[10:21] ~ age + temp + moist + nutrient + fire + dry, data = data
##          Df SumOfSqs      F Pr(>F)
## Model     6    8.389 4.2376  0.001 ***
## Residual 80   26.395
## ---
```

```
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

The model is significant.

For each explanatory variable (with all the others used as covariables, independently from their order in the model):

```
anova (ordi6, by = 'margin', permutations = 999)
```

```
## Permutation test for capscale under reduced model
## Marginal effects of terms
## Permutation: free
## Number of permutations: 999
##
## Model: capscale(formula = data_ordi2[10:21] ~ age + temp + moist + nutrient + fire + dry, data = data
##          Df SumOfSqs      F Pr(>F)
## age       1   1.2989 3.9369  0.001 ***
## temp      1   0.3226 0.9778  0.414
## moist     1   0.8303 2.5164  0.021 *
## nutrient  1   1.1292 3.4225  0.003 **
## fire      1   0.1145 0.3471  0.955
## dry       1   0.8159 2.4728  0.026 *
## Residual 80  26.3953
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

Age, moist, nutrient and dry show significant effects.

For each axis:

```
anova (ordi6, by = 'axis', permutations = 999)
```

```
## Permutation test for capscale under reduced model
## Forward tests for axes
## Permutation: free
## Number of permutations: 999
##
## Model: capscale(formula = data_ordi2[10:21] ~ age + temp + moist + nutrient + fire + dry, data = data
##          Df SumOfSqs       F Pr(>F)
## CAP1      1   4.8864 14.8098  0.001 ***
## CAP2      1   2.2391  6.7863  0.002 **
## CAP3      1   0.7603  2.3045  0.309
## CAP4      1   0.2754  0.8347  0.968
## CAP5      1   0.1383  0.4190  0.997
## CAP6      1   0.0896  0.2715  0.985
## Residual 80  26.3953
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

Axis 1 and 2 are significant.

Ordination plot with ggplot2.

Install ggord package (you only need to do this once):

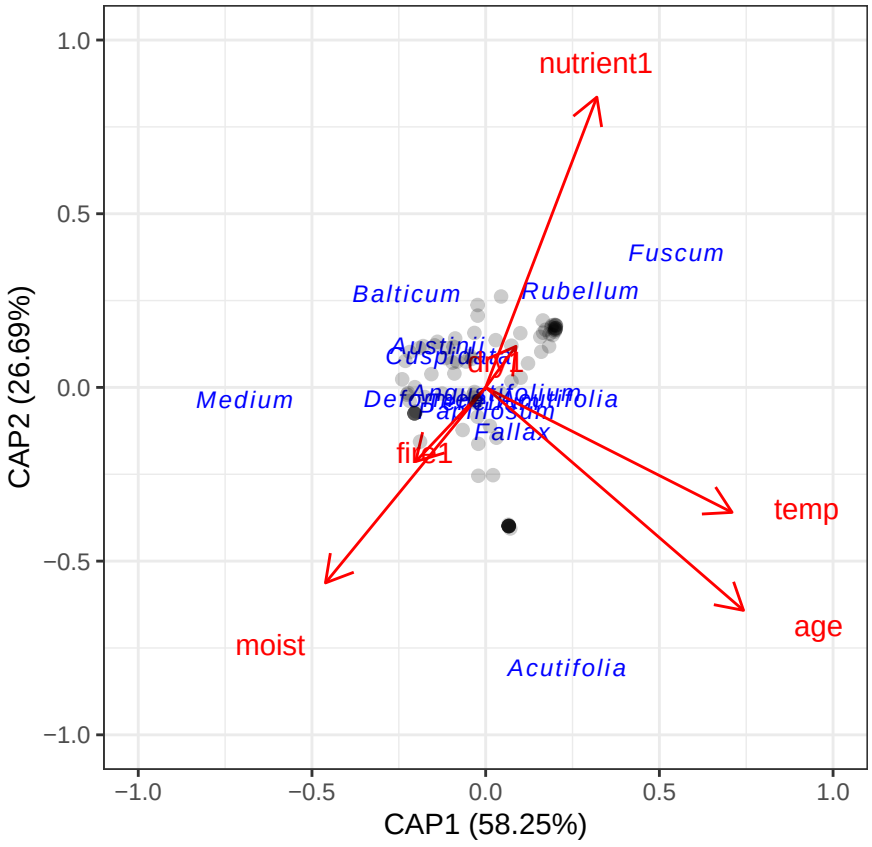
```
# Enable the r-universe repo
options(repos = c(
    fawda123 = 'https://fawda123.r-universe.dev',
    CRAN = 'https://cloud.r-project.org'))

# Install ggord
install.packages('ggord')
```

```
## package 'ggord' successfully unpacked and MD5 sums checked
##
## The downloaded binary packages are in
##  C:\Users\alici\AppData\Local\Temp\Rtmpcvm8lT\downloaded_packages
```

Load ggord package:

```
library(ggord)
```

```
ggord(ordi6,ptslab=T,repel=T,labcol="red",veccol="red",size=NA,addsize=3,
      xlims=c(-1.1,1.1),ylims=c(-1.1,1.1))+
  geom_point(size=3,shape=20,color="black",alpha=0.2)
```



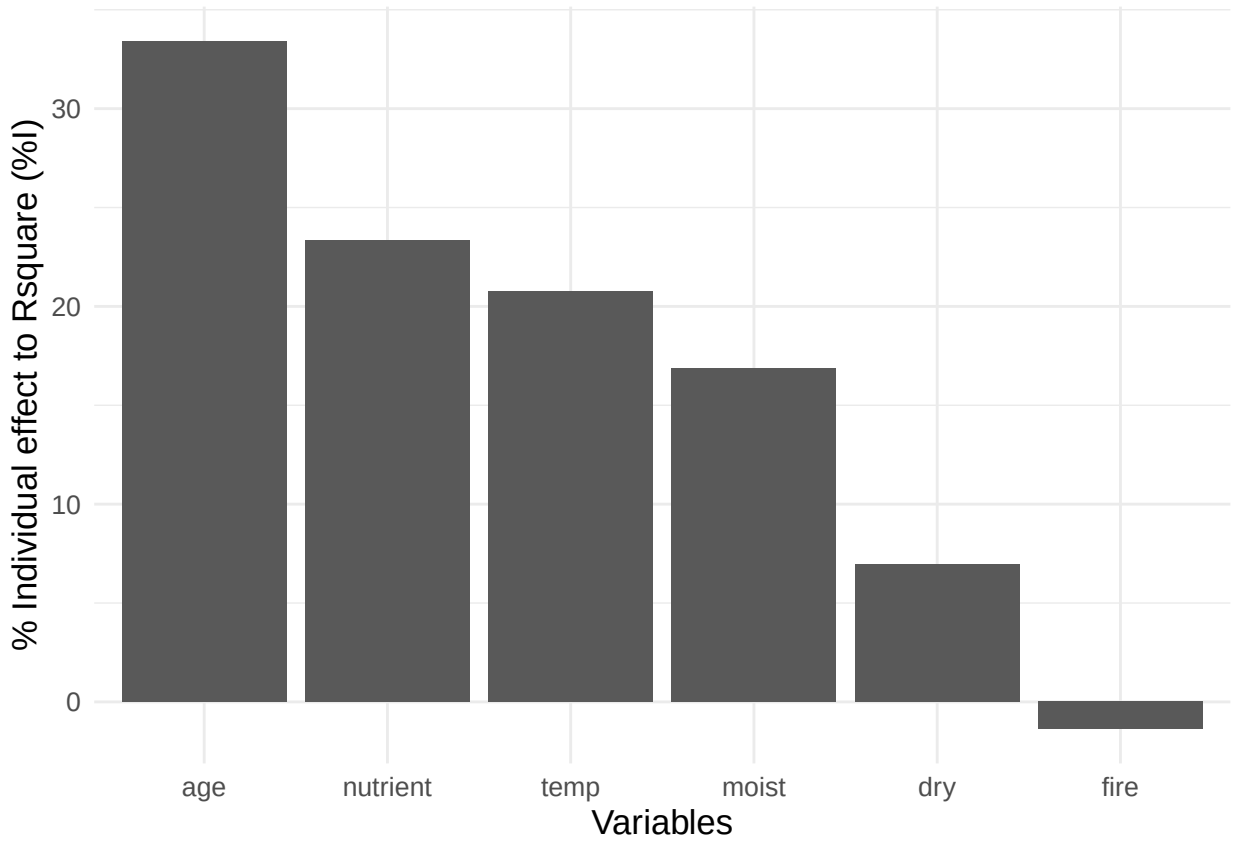
Hierarchical partitioning

```
dist_matrix<-vegdist(data_ordi2[10:21],method="bray")
```

```
hierpart1<-rdacca.hp(dist_matrix,data_ordi2[c(23:24,26:29)],method = "dbRDA",
          type ="adjR2",scale = F,add = T,sqrt.dist = T)
hierpart1
```

```
## $Method_Type
## [1] "dbRDA" "adjR2"
##
## $Total_explained_variation
## [1] 0.161
##
## $Hier.part
##           Unique Average.share Individual I.perc(%)
## age       0.0229        0.0309     0.0538     33.42
## temp     -0.0001        0.0335     0.0334     20.75
## moist     0.0133        0.0139     0.0272     16.89
## nutrient  0.0236        0.0140     0.0376     23.35
## fire     -0.0036        0.0014    -0.0022     -1.37
## dry       0.0146       -0.0034     0.0112      6.96
##
## attr(,"class")
## [1] "rdaccahp"
```

```
plot(hierpart1,plot.perc=T)
```




```
cor(data_ordi2[c(23:24)]) # Correlation among age and temp is 0.762
```

```
##           age     temp
## age  1.000000 0.762464
## temp 0.762464 1.000000
```

```
vif.cca(ordi6)
```

```
##       age      temp     moist nutrient1     fire1      dry1
##  3.041744  2.902858  1.437491  1.748558  1.237429  1.145366
```

```
# But VIF of the ordination is not super high, probably ok to keep both
```

Abundance models (zero-inflated beta regressions)

Without interactions

Check how many rows with each species absent:

```
nrow(data_peat%>%filter(tot_Sphagnum==0))
```

```
## [1] 22
```

```
nrow(data_peat%>%filter(Erio==0)) # 1 row
```

```
## [1] 1
```

```
nrow(data_peat%>%filter(Carex==0)) # 2 rows
```

```
## [1] 2
```

```
nrow(data_peat%>%filter(Erica==0)) # 5 rows
```

```
## [1] 5
```

```
nrow(data_peat%>%filter(Balticum==0))
```

```
## [1] 65
```

```
nrow(data_peat%>%filter(Medium==0))
```

```
## [1] 49
```

```
nrow(data_peat%>%filter(Cuspidata==0))
```

```
## [1] 68
```

```
nrow(data_peat%>%filter(Austinii==0))
```

```
## [1] 82
```

```
nrow(data_peat%>%filter(Fuscum==0))
```

```
## [1] 56
```

```
nrow(data_peat%>%filter(Rubellum==0))
```

```
## [1] 61
```

```
# More species?
```

Erio, Erica and Carex have too few rows with absences. Presence/absence models will not work for these species. Fit models oinly for the abundance of those species.

Abundance of Medium and Fuscum includes 0 and 100 - change 100 to 99.

```
data_peat$Medium<-ifelse(data_peat$Medium>99,99,data_peat$Medium)
data_peat$Fuscum<-ifelse(data_peat$Fuscum>99,99,data_peat$Fuscum)
```

Convert variables to proportions (from 0 to 1) instead of percentages:

```
data_peat<-data_peat%>%
  mutate(tot_Sphagnum_prop=tot_Sphagnum/100,
         Erio_prop=Erio/100,
         Erica_prop=Erica/100,
         Carex_prop=Carex/100,
         Medium_prop=Medium/100,
         Fuscum_prop=Fuscum/100,
         Rubellum_prop=Rubellum/100,
         Balticum_prop=Balticum/100,
         Cuspidata_prop=Cuspidata/100)
```

Check combinations of the three factors and the fen-bog factor:

```
with(data_peat,table(fen,nutrient))
```

```
##    nutrient
## fen  0  1
##   N 33 50
##   Y 32  0
```

```
with(data_peat,table(fen,fire))
```

```
##    fire
## fen  0  1
##   N 71 12
##   Y 26  6
```

```
with(data_peat,table(fen,dry))
```

```
##    dry
## fen  0  1
##   N 52 31
##   Y 18 14
```

There are 0 cases where fen=Y and nutrient=1 so we will not be able to test the fen*nutrient interactions. We can include all interactions but this one in the models.

Plant groups

```
mod_abund_tot_Sphagnum<-glmmTMB(tot_Sphagnum_prop~age+temp+moist+nutrient+
                                  fire+dry,family="beta_family",
                                ziformula=~.,data=data_peat)
mod_abund_Erio_nozi<-glmmTMB(Erio_prop~age+temp+moist+nutrient+
                               fire+dry,family="beta_family",
                             ziformula=~0,data=subset(data_peat,Erio_prop>0))
mod_abund_Erica_nozi<-glmmTMB(Erica_prop~age+temp+moist+nutrient+
                                fire+dry,family="beta_family",
                              ziformula=~0, data_erica<-subset(data_peat,Erica>0))
mod_abund_Carex_nozi<-glmmTMB(Carex_prop~age+temp+moist+nutrient+
                                fire+dry,family="beta_family",
                              ziformula=~0,data=subset(data_peat,Carex_prop>0))
```

```r
summary(mod_abund_tot_Sphagnum)
```

```
##  Family: beta  ( logit )
## Formula:
## tot_Sphagnum_prop ~ age + temp + moist + nutrient + fire + dry
## Zero inflation:                      ~.
## Data: data_peat
##
##      AIC      BIC   logLik deviance df.resid
##     76.4    116.6    -23.2     46.4       93
##
##
## Dispersion parameter for beta family (): 2.46
##
## Conditional model:
##               Estimate Std. Error z value Pr(>|z|)
## (Intercept)  9.117e-01  1.303e+00   0.700  0.48422
## age         -4.403e-05  8.234e-05  -0.535  0.59285
## temp        -1.801e-01  1.953e-01  -0.922  0.35661
## moist       -2.880e-01  2.865e-01  -1.005  0.31489
## nutrient1    1.015e+00  3.129e-01   3.244  0.00118 **
## fire1       -1.350e-01  3.547e-01  -0.381  0.70346
## dry1         7.583e-01  2.503e-01   3.030  0.00244 **
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Zero-inflation model:
##               Estimate Std. Error z value Pr(>|z|)
## (Intercept) -5.4314844  2.9936427  -1.814   0.0696 .
## age          0.0003262  0.0001725   1.891   0.0587 .
## temp         0.2926684  0.4086025   0.716   0.4738
## moist       -0.1308289  0.6963095  -0.188   0.8510
## nutrient1   -1.1397037  0.8525940  -1.337   0.1813
## fire1        0.6592571  0.7035135   0.937   0.3487
## dry1         0.1581995  0.7156631   0.221   0.8251
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```r
summary(mod_abund_Erio_nozi)
```

```
##  Family: beta  ( logit )
## Formula:          Erio_prop ~ age + temp + moist + nutrient + fire + dry
## Data: subset(data_peat, Erio_prop > 0)
##
##      AIC      BIC   logLik deviance df.resid
##    -96.5    -75.1     56.3   -112.5      100
##
##
## Dispersion parameter for beta family ():  3.9
##
## Conditional model:
##               Estimate Std. Error z value Pr(>|z|)
```

```
## (Intercept) -2.087e+00  9.468e-01  -2.204  0.02749 *
## age          2.145e-05  5.668e-05   0.378  0.70508
## temp         1.721e-01  1.382e-01   1.246  0.21286
## moist        3.196e-01  2.175e-01   1.469  0.14180
## nutrient1   -7.430e-01  2.439e-01  -3.047  0.00231 **
## fire1        7.265e-02  2.558e-01   0.284  0.77636
## dry1        -4.806e-01  2.064e-01  -2.328  0.01992 *
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
summary(mod_abund_Erica_nozi)
```

```
##  Family: beta  ( logit )
## Formula:          Erica_prop ~ age + temp + moist + nutrient + fire + dry
## Data: data_erica <- subset(data_peat, Erica > 0)
##
##      AIC      BIC   logLik deviance df.resid
##   -198.6   -177.2    107.3   -214.6       99
##
##
## Dispersion parameter for beta family (): 7.03
##
## Conditional model:
##               Estimate Std. Error z value Pr(>|z|)
## (Intercept) -3.746e+00  8.731e-01  -4.291 1.78e-05 ***
## age         -3.391e-05  5.321e-05  -0.637   0.5239
## temp         2.798e-01  1.278e-01   2.189   0.0286 *
## moist        4.131e-02  1.978e-01   0.209   0.8346
## nutrient1   -3.559e-01  2.267e-01  -1.570   0.1164
## fire1        3.320e-01  2.408e-01   1.379   0.1679
## dry1        -2.546e-01  1.931e-01  -1.319   0.1872
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

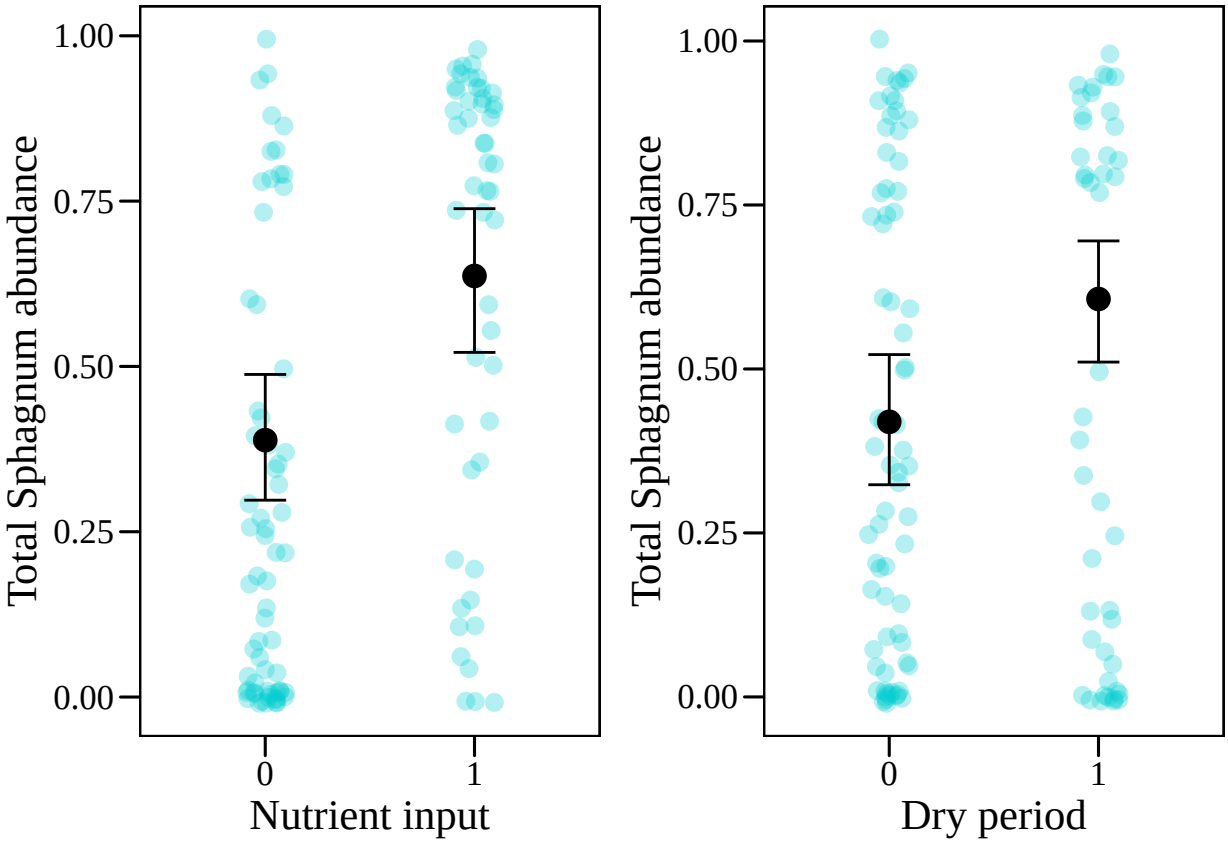
```
summary(mod_abund_Carex_nozi)
```

```
##  Family: beta  ( logit )
## Formula:          Carex_prop ~ age + temp + moist + nutrient + fire + dry
## Data: subset(data_peat, Carex_prop > 0)
##
##      AIC      BIC   logLik deviance df.resid
##   -238.7   -217.2    127.3   -254.7      100
##
##
## Dispersion parameter for beta family (): 11.5
##
## Conditional model:
##               Estimate Std. Error z value Pr(>|z|)
## (Intercept) -2.714e+00  7.175e-01  -3.782 0.000155 ***
## age         -6.023e-05  4.506e-05  -1.337 0.181341
## temp         2.142e-01  1.062e-01   2.018 0.043632 *
## moist       -1.623e-01  1.731e-01  -0.938 0.348474
## nutrient1   -1.175e+00  1.986e-01  -5.914 3.33e-09 ***
```

```
## fire1        1.802e-01  1.999e-01   0.902 0.367288
## dry1        -4.603e-01  1.647e-01  -2.795 0.005188 **
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

Plots Total Sphagnum Using ggemmeans: averages over the proportions of the categories of factors.

```
plots_sphagnum<-grid.arrange(
  # nutrient
  ggplot()+
    geom_jitter(data=data_peat,aes(x=nutrient,y=tot_Sphagnum_prop),
                position = position_jitter(0.1,0.01),
                size=3,alpha=0.3,shape=16,color="darkturquoise")+
    geom_point(data=data.frame(ggemmeans(mod_abund_tot_Sphagnum,
                                         type="fixed",terms=c("nutrient"))),
                aes(x=x,y=predicted),size=4,shape=16)+
    geom_errorbar(data=data.frame(ggemmeans(mod_abund_tot_Sphagnum,
                                            type="fixed",terms=c("nutrient"))),
                  aes(x=x,y=predicted,ymin=conf.low,ymax=conf.high),
                  width=0.2,size=0.5)+
    my_theme()+xlab("Nutrient input")+ylab("Total Sphagnum abundance"),
  # dry
  ggplot()+
    geom_jitter(data=data_peat,aes(x=dry,y=tot_Sphagnum_prop),
                position = position_jitter(0.1,0.01),
                size=3,alpha=0.3,shape=16,color="darkturquoise")+
    geom_point(data=data.frame(ggemmeans(mod_abund_tot_Sphagnum,
                                         type="fixed",terms=c("dry"))),
                aes(x=x,y=predicted),size=4,shape=16)+
    geom_errorbar(data=data.frame(ggemmeans(mod_abund_tot_Sphagnum,
                                            type="fixed",terms=c("dry"))),
                  aes(x=x,y=predicted,ymin=conf.low,ymax=conf.high),
                  width=0.2,size=0.5)+
    my_theme()+xlab("Dry period")+ylab("Total Sphagnum abundance"),
  ncol=2
)
```

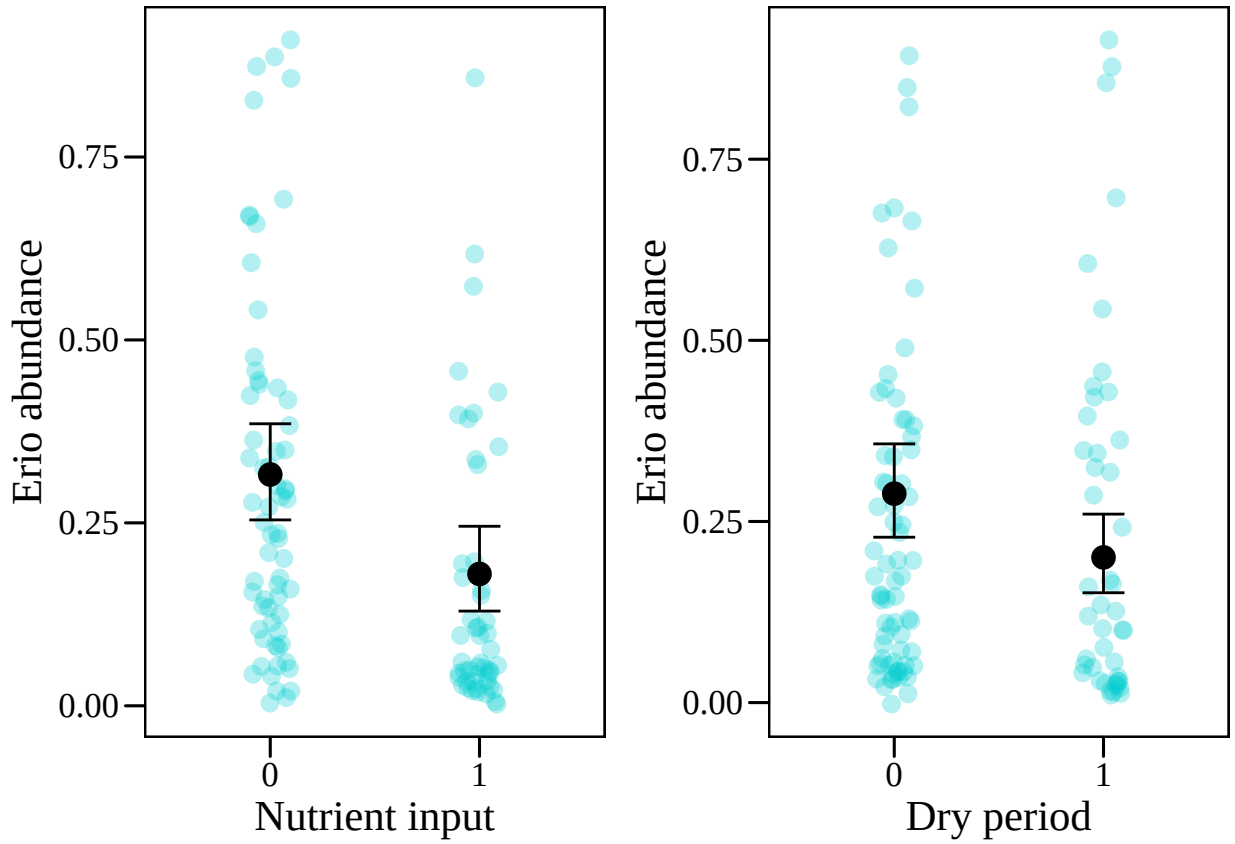



```
ggsave(filename="output/figures/plots_sphagnum.tiff",plot=plots_sphagnum,
       width=24,height=12,units="cm",dpi=300)
ggsave(filename="output/figures/plots_sphagnum.pdf",plot=plots_sphagnum,
       width=24,height=12,units="cm",dpi=300)
# ADD: fen for abundance, fen:fire for presence
```

Plots Erio Using ggemmeans: averages over the proportions of the categories of factors.

```
plots_Erio<-grid.arrange(
  # nutrient
  ggplot()+
    geom_jitter(data=data_peat,aes(x=nutrient,y=Erio_prop),
                position = position_jitter(0.1,0.01),
                size=3,alpha=0.3,shape=16,color="darkturquoise")+
    geom_point(data=data.frame(ggemmeans(mod_abund_Erio_nozi,
                                         type="fixed",terms=c("nutrient"))),
               aes(x=x,y=predicted),size=4,shape=16)+
    geom_errorbar(data=data.frame(ggemmeans(mod_abund_Erio_nozi,
                                            type="fixed",terms=c("nutrient"))),
                  aes(x=x,y=predicted,ymin=conf.low,ymax=conf.high),
                  width=0.2,size=0.5)+
    my_theme()+xlab("Nutrient input")+ylab("Erio abundance"),
  # dry
  ggplot()+
    geom_jitter(data=data_peat,aes(x=dry,y=Erio_prop),
```

```
                position = position_jitter(0.1,0.01),
                size=3,alpha=0.3,shape=16,color="darkturquoise")+
    geom_point(data=data.frame(ggemmeans(mod_abund_Erio_nozi,
                                         type="fixed",terms=c("dry"))),
               aes(x=x,y=predicted),size=4,shape=16)+
    geom_errorbar(data=data.frame(ggemmeans(mod_abund_Erio_nozi,
                                            type="fixed",terms=c("dry"))),
                  aes(x=x,y=predicted,ymin=conf.low,ymax=conf.high),
                  width=0.2,size=0.5)+
    my_theme()+xlab("Dry period")+ylab("Erio abundance"),
  ncol=2
)
```




```
## Error in if (!all(chk == tbl)) stop("Data appear to be randomized -- ",  :
##   missing value where TRUE/FALSE needed
## Error in if (!all(chk == tbl)) stop("Data appear to be randomized -- ",  :
##   missing value where TRUE/FALSE needed
## Error in if (!all(chk == tbl)) stop("Data appear to be randomized -- ",  :
##   missing value where TRUE/FALSE needed
## Error in if (!all(chk == tbl)) stop("Data appear to be randomized -- ",  :
##   missing value where TRUE/FALSE needed
```

```
ggsave(filename="output/figures/plots_Erio.tiff",plot=plots_Erio,
       width=24,height=12,units="cm",dpi=300)
```

```
ggsave(filename="output/figures/plots_Erio.pdf",plot=plots_Erio,
       width=24,height=12,units="cm",dpi=300)
```

Plots Erica Using ggemmeans: averages over the proportions of the categories of factors.

```
plots_Erica<-ggplot()+
  geom_ribbon(data=data.frame(ggemmeans(mod_abund_Erica_nozi,
                                        type="fixed",terms=c("temp[all]"))),
              aes(x=x,y=predicted,ymin=conf.low,ymax=conf.high),alpha=0.2)+
  geom_line(data=data.frame(ggemmeans(mod_abund_Erica_nozi,
                                      type="fixed",terms=c("temp[all]"))),
            aes(x=x,y=predicted))+
  geom_point(data=subset(data_peat,Erica_prop>0),aes(x=temp,y=Erica_prop),
             size=3,alpha=0.3,shape=16,color="darkturquoise")+
  my_theme()+xlab("Temperature")+ylab("Erica abundance")
```

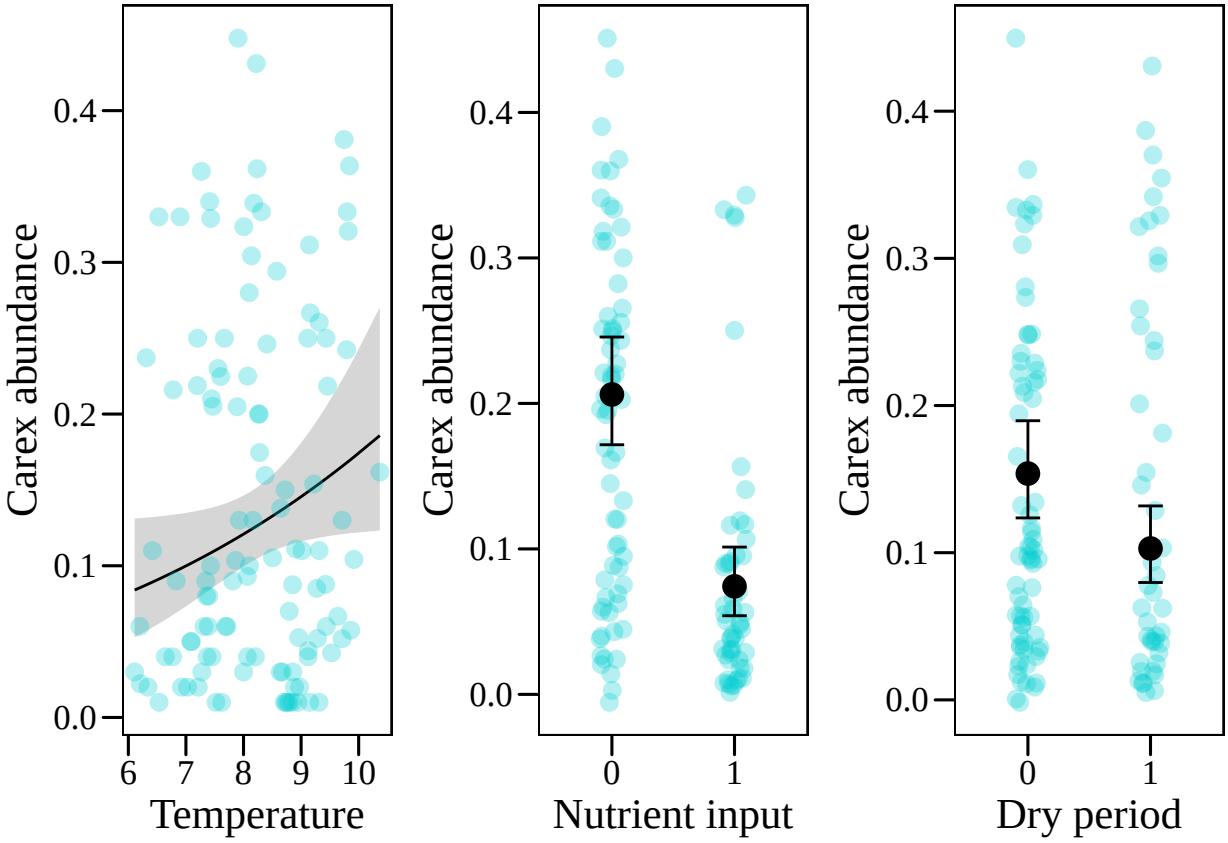
```
## Error in if (!all(chk == tbl)) stop("Data appear to be randomized -- ",  :
##   missing value where TRUE/FALSE needed
## Error in if (!all(chk == tbl)) stop("Data appear to be randomized -- ",  :
##   missing value where TRUE/FALSE needed
```

```
ggsave(filename="output/figures/plots_Erica.tiff",plot=plots_Erica,
       width=12,height=12,units="cm",dpi=300)
ggsave(filename="output/figures/plots_Erica.pdf",plot=plots_Erica,
       width=12,height=12,units="cm",dpi=300)
```

Plots Carex Using ggemmeans: averages over the proportions of the categories of factors.

```
plots_Carex<-grid.arrange(
  # temp
  ggplot()+
    geom_ribbon(data=data.frame(ggemmeans(mod_abund_Carex_nozi,
                                          type="fixed",terms=c("temp[all]"))),
                aes(x=x,y=predicted,ymin=conf.low,ymax=conf.high),
                alpha=0.2)+
    geom_line(data=data.frame(ggemmeans(mod_abund_Carex_nozi,
                                        type="fixed",terms=c("temp[all]"))),
              aes(x=x,y=predicted))+
    geom_point(data=subset(data_peat,Carex_prop>0),aes(x=temp,y=Carex_prop),
              size=3,alpha=0.3,shape=16,color="darkturquoise")+
    my_theme()+xlab("Temperature")+ylab("Carex abundance"),
  # nutrient
  ggplot()+
    geom_jitter(data=data_peat,aes(x=nutrient,y=Carex_prop),
              position = position_jitter(0.1,0.01),
              size=3,alpha=0.3,shape=16,color="darkturquoise")+
    geom_point(data=data.frame(ggemmeans(mod_abund_Carex_nozi,
                                          type="fixed",terms=c("nutrient"))),
               aes(x=x,y=predicted),size=4,shape=16)+
    geom_errorbar(data=data.frame(ggemmeans(mod_abund_Carex_nozi,
                                            type="fixed",terms=c("nutrient"))),
```

```
                  aes(x=x,y=predicted,ymin=conf.low,ymax=conf.high),
                  width=0.2,size=0.5)+
    my_theme()+xlab("Nutrient input")+ylab("Carex abundance"),
  # dry
  ggplot()+
    geom_jitter(data=data_peat,aes(x=dry,y=Carex_prop),
                position = position_jitter(0.1,0.01),
                size=3,alpha=0.3,shape=16,color="darkturquoise")+
    geom_point(data=data.frame(ggemmeans(mod_abund_Carex_nozi,
                                         type="fixed",terms=c("dry"))),
               aes(x=x,y=predicted),size=4,shape=16)+
    geom_errorbar(data=data.frame(ggemmeans(mod_abund_Carex_nozi,
                                            type="fixed",terms=c("dry"))),
                  aes(x=x,y=predicted,ymin=conf.low,ymax=conf.high),
                  width=0.2,size=0.5)+
    my_theme()+xlab("Dry period")+ylab("Carex abundance"),
  ncol=3
)
```




```
## Error in if (!all(chk == tbl)) stop("Data appear to be randomized -- ",  :
##   missing value where TRUE/FALSE needed
## Error in if (!all(chk == tbl)) stop("Data appear to be randomized -- ",  :
##   missing value where TRUE/FALSE needed
## Error in if (!all(chk == tbl)) stop("Data appear to be randomized -- ",  :
##   missing value where TRUE/FALSE needed
```

```
## Error in if (!all(chk == tbl)) stop("Data appear to be randomized -- ",  :
##   missing value where TRUE/FALSE needed
## Error in if (!all(chk == tbl)) stop("Data appear to be randomized -- ",  :
##   missing value where TRUE/FALSE needed
## Error in if (!all(chk == tbl)) stop("Data appear to be randomized -- ",  :
##   missing value where TRUE/FALSE needed
```

```
ggsave(filename="output/figures/plots_Carex.tiff",plot=plots_Carex,
       width=36,height=12,units="cm",dpi=300)
ggsave(filename="output/figures/plots_Carex.pdf",plot=plots_Carex,
       width=36,height=12,units="cm",dpi=300)
```

Selected Sphagnum species

```
mod_abund_Medium<-glmmTMB(Medium_prop~age+temp+moist+
                            nutrient+fire+dry,family="beta_family",
                          ziformula=~.,data=data_peat)
mod_abund_Fuscum<-glmmTMB(Fuscum_prop~age+temp+moist+
                            nutrient+fire+dry,family="beta_family",
                          ziformula=~.,data=data_peat)
mod_abund_Rubellum<-glmmTMB(Rubellum_prop~age+temp+moist+
                              nutrient+fire+dry,family="beta_family",
                            ziformula=~.,data=data_peat)
mod_abund_Balticum<-glmmTMB(Balticum_prop~age+temp+moist+
                              nutrient+fire+dry,family="beta_family",
                            ziformula=~.,data=data_peat)
mod_abund_Cuspidata<-glmmTMB(Cuspidata_prop~age+temp+moist+
                               nutrient+fire+dry,family="beta_family",
                             ziformula=~.,data=data_peat)
```

```
summary(mod_abund_Medium)
```

```
##  Family: beta  ( logit )
## Formula:          Medium_prop ~ age + temp + moist + nutrient + fire + dry
## Zero inflation:               ~.
## Data: data_peat
##
##      AIC      BIC   logLik deviance df.resid
##     82.1    119.3    -26.1     52.1       73
##
##
## Dispersion parameter for beta family (): 2.62
##
## Conditional model:
##               Estimate Std. Error z value Pr(>|z|)
## (Intercept)  2.3586249  1.9486076   1.210 0.226119
## age         -0.0000208  0.0001401  -0.148 0.882003
## temp        -0.1930054  0.2853186  -0.676 0.498751
## moist        0.4821143  0.4375866   1.102 0.270567
## nutrient1   -1.4568779  0.4352997  -3.347 0.000817 ***
## fire1       -2.0081896  0.6136629  -3.272 0.001066 **
```

```
## dry1         0.8929889  0.4202448   2.125 0.033593 *
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Zero-inflation model:
##               Estimate Std. Error z value Pr(>|z|)
## (Intercept) -2.2045766  3.4046432  -0.647  0.51730
## age          0.0007159  0.0002459   2.912  0.00359 **
## temp        -0.0675311  0.5082979  -0.133  0.89431
## moist       -0.6589471  0.6995785  -0.942  0.34623
## nutrient1    0.6616944  0.6724425   0.984  0.32511
## fire1       -1.5636016  0.8759200  -1.785  0.07425 .
## dry1         0.9455353  0.6363239   1.486  0.13730
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
summary(mod_abund_Fuscum)
```

```
##  Family: beta  ( logit )
## Formula:          Fuscum_prop ~ age + temp + moist + nutrient + fire + dry
## Zero inflation:               ~.
## Data: data_peat
##
##      AIC      BIC   logLik deviance df.resid
##     80.8    117.9    -25.4     50.8       73
##
##
## Dispersion parameter for beta family (): 6.28
##
## Conditional model:
##               Estimate Std. Error z value Pr(>|z|)
## (Intercept)  1.0587687  2.7311263   0.388  0.69826
## age          0.0007970  0.0002507   3.179  0.00148 **
## temp        -0.4785755  0.4317741  -1.108  0.26769
## moist       -0.0214846  0.3265308  -0.066  0.94754
## nutrient1    0.4066307  0.3507633   1.159  0.24634
## fire1        0.0704508  0.5930225   0.119  0.90543
## dry1        -1.3096631  0.3260645  -4.017  5.9e-05 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Zero-inflation model:
##               Estimate Std. Error z value Pr(>|z|)
## (Intercept)  2.0643396  2.9708333   0.695  0.48714
## age         -0.0001256  0.0001931  -0.650  0.51549
## temp        -0.0099373  0.4430835  -0.022  0.98211
## moist        2.2331278  0.7399399   3.018  0.00254 **
## nutrient1   -1.4924030  0.6839651  -2.182  0.02911 *
## fire1        0.7670151  0.9370868   0.819  0.41307
## dry1        -1.0710628  0.6403007  -1.673  0.09438 .
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```r
summary(mod_abund_Rubellum)
```

```
##  Family: beta  ( logit )
## Formula:          Rubellum_prop ~ age + temp + moist + nutrient + fire + dry
## Zero inflation:                 ~.
## Data: data_peat
##
##      AIC      BIC   logLik deviance df.resid
##     90.0    127.1    -30.0     60.0       73
##
##
## Dispersion parameter for beta family (): 7.37
##
## Conditional model:
##               Estimate Std. Error z value Pr(>|z|)
## (Intercept) -5.3780247  2.7759751  -1.937   0.0527 .
## age         -0.0001198  0.0001665  -0.720   0.4718
## temp         0.6419026  0.4104643   1.564   0.1179
## moist       -0.2320282  0.3534660  -0.656   0.5115
## nutrient1   -0.5105458  0.4208808  -1.213   0.2251
## fire1        1.6708157  0.7164921   2.332   0.0197 *
## dry1         0.3006501  0.2967661   1.013   0.3110
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Zero-inflation model:
##               Estimate Std. Error z value Pr(>|z|)
## (Intercept)  3.3950045  2.9994200   1.132  0.25768
## age         -0.0002616  0.0001957  -1.337  0.18132
## temp        -0.0114108  0.4436450  -0.026  0.97948
## moist        1.3225268  0.7146644   1.851  0.06423 .
## nutrient1   -1.9397767  0.7495122  -2.588  0.00965 **
## fire1       -0.1884497  0.8455962  -0.223  0.82364
## dry1        -1.3422541  0.6157136  -2.180  0.02926 *
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```r
summary(mod_abund_Balticum)
```

```
##  Family: beta  ( logit )
## Formula:          Balticum_prop ~ age + temp + moist + nutrient + fire + dry
## Zero inflation:                 ~.
## Data: data_peat
##
##      AIC      BIC   logLik deviance df.resid
##     67.1    104.3    -18.5     37.1       73
##
##
## Dispersion parameter for beta family (): 8.13
##
## Conditional model:
##               Estimate Std. Error z value Pr(>|z|)
```

```
## (Intercept) -4.459e+00  1.823e+00  -2.446  0.01445 *
## age         -6.073e-05  2.616e-04  -0.232  0.81643
## temp         5.261e-01  2.834e-01   1.856  0.06339 .
## moist        2.095e+00  6.526e-01   3.210  0.00133 **
## nutrient1    4.433e-01  6.980e-01   0.635  0.52541
## fire1        1.014e+00  8.748e-01   1.160  0.24624
## dry1        -1.844e+00  8.021e-01  -2.299  0.02150 *
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Zero-inflation model:
##               Estimate Std. Error z value Pr(>|z|)
## (Intercept)  2.1929832  4.1955368   0.523  0.60119
## age          0.0011615  0.0003979   2.919  0.00351 **
## temp        -0.5633297  0.6509559  -0.865  0.38683
## moist       -0.0816764  0.7730977  -0.106  0.91586
## nutrient1   -0.1654946  0.7422670  -0.223  0.82357
## fire1       -0.2917104  0.9325433  -0.313  0.75442
## dry1         0.4873056  0.7199076   0.677  0.49847
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
summary(mod_abund_Cuspidata)
```

```
##  Family: beta  ( logit )
## Formula:          Cuspidata_prop ~ age + temp + moist + nutrient + fire + dry
## Zero inflation:                  ~.
## Data: data_peat
##
##      AIC      BIC   logLik deviance df.resid
##     76.2    113.3    -23.1     46.2       73
##
##
## Dispersion parameter for beta family (): 5.53
##
## Conditional model:
##               Estimate Std. Error z value Pr(>|z|)
## (Intercept) -5.2383115  2.3764463  -2.204   0.0275 *
## age         -0.0001638  0.0001773  -0.923   0.3558
## temp         0.5650293  0.3407377   1.658   0.0973 .
## moist        0.1776240  0.6358646   0.279   0.7800
## nutrient1   -0.2404306  0.8488637  -0.283   0.7770
## fire1        0.1501792  0.6089448   0.247   0.8052
## dry1         0.2278436  0.8252935   0.276   0.7825
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Zero-inflation model:
##               Estimate Std. Error z value Pr(>|z|)
## (Intercept) -1.6911272  3.4914739  -0.484    0.628
## age          0.0004041  0.0002633   1.535    0.125
## temp         0.2646914  0.5321353   0.497    0.619
## moist       -1.0884362  0.7373014  -1.476    0.140
## nutrient1   -1.1812088  0.7509815  -1.573    0.116
```

```
## fire1       -0.5521654  0.8616638  -0.641    0.522
## dry1         0.4613000  0.6599435   0.699    0.485
```

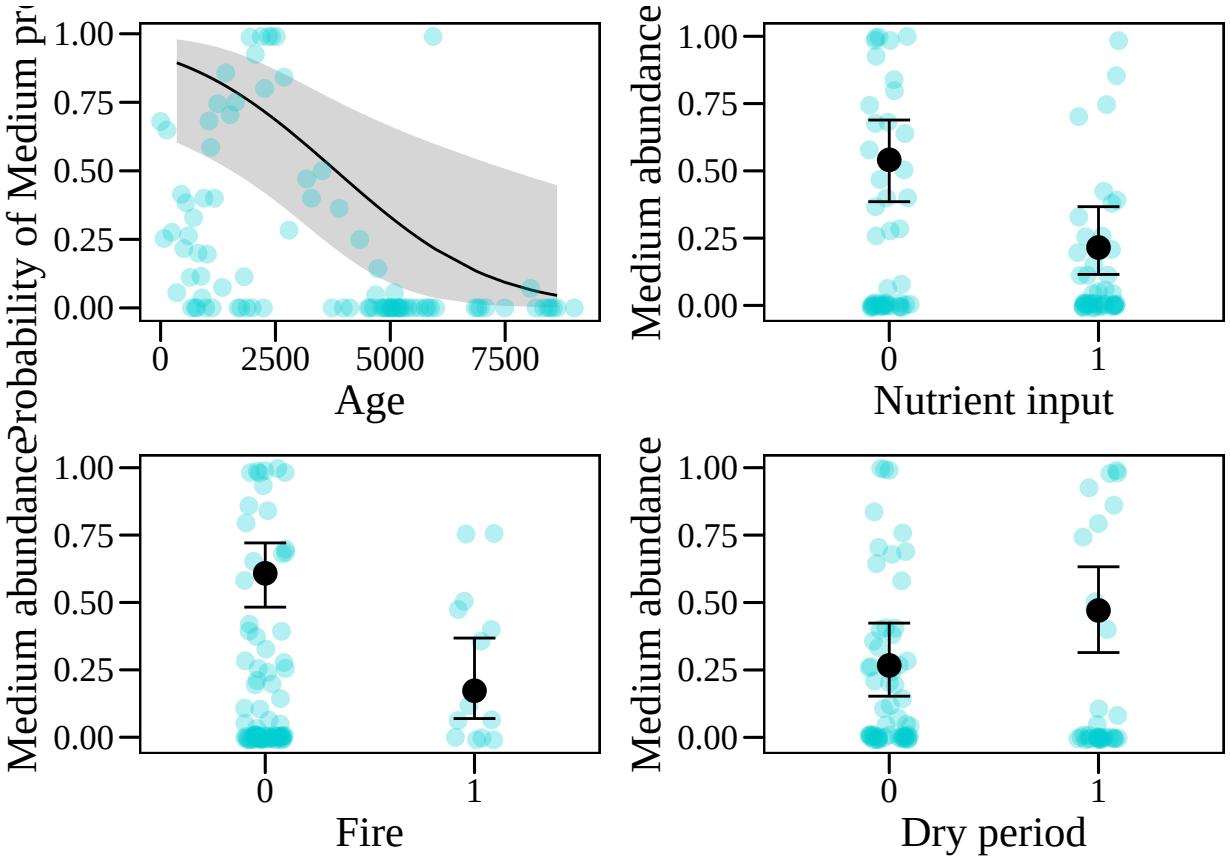
Plots Medium Using ggemmeans with type="zi_prob" gives error "Error: This prediction-type is currently not available for models of class 'glmmTMB' ".

So for age, I am using ggpredict and calculating an average prediction

```
# Create average line among factors=0 and factors=1
average_prediction_Medium_age<-rbind(
  tibble(ggpredict(mod_abund_Medium,type="zi_prob",terms=c("age[all]"),
                   condition=c(nutrient=1,fire=1,dry=1)))%>%
    select(-group)%>%mutate(type="a"),
  tibble(ggpredict(mod_abund_Medium,type="zi_prob",terms=c("age[all]"),
                   condition=c(nutrient=0,fire=0,dry=0)))%>%
    select(-group)%>%mutate(type="b"),
  tibble(ggpredict(mod_abund_Medium,type="zi_prob",terms=c("age[all]"),
                   condition=c(nutrient=0,fire=1,dry=1)))%>%
    select(-group)%>%mutate(type="c"),
  tibble(ggpredict(mod_abund_Medium,type="zi_prob",terms=c("age[all]"),
                   condition=c(nutrient=1,fire=0,dry=1)))%>%
    select(-group)%>%mutate(type="d"),
  tibble(ggpredict(mod_abund_Medium,type="zi_prob",terms=c("age[all]"),
                   condition=c(nutrient=1,fire=1,dry=0)))%>%
    select(-group)%>%mutate(type="e"),
  tibble(ggpredict(mod_abund_Medium,type="zi_prob",terms=c("age[all]"),
                   condition=c(nutrient=0,fire=0,dry=1)))%>%
    select(-group)%>%mutate(type="f"),
  tibble(ggpredict(mod_abund_Medium,type="zi_prob",terms=c("age[all]"),
                   condition=c(nutrient=0,fire=1,dry=0)))%>%
    select(-group)%>%mutate(type="g"),
  tibble(ggpredict(mod_abund_Medium,type="zi_prob",terms=c("age[all]"),
                   condition=c(nutrient=1,fire=0,dry=0)))%>%
    select(-group)%>%mutate(type="h")
)%>%
  group_by(x)%>%summarise(predicted=mean(predicted),std.error=mean(std.error),
                          conf.low=mean(conf.low),conf.high=mean(conf.high))
```

```
plots_Medium<-grid.arrange(
  # age
  ggplot()+
    geom_ribbon(data=average_prediction_Medium_age,
                aes(x=x,y=1-predicted,ymin=1-conf.low,ymax=1-conf.high),
                alpha=0.2)+
    geom_line(data=average_prediction_Medium_age,
              aes(x=x,y=1-predicted))+
    geom_point(data=data_peat,aes(x=age,y=Medium_prop),
               size=3,alpha=0.3,shape=16,color="darkturquoise")+
    my_theme()+xlab("Age")+ylab("Probability of Medium presence"),
  # nutrient
  ggplot()+
    geom_jitter(data=data_peat,aes(x=nutrient,y=Medium_prop),
                position = position_jitter(0.1,0.01),
                size=3,alpha=0.3,shape=16,color="darkturquoise")+
```

```
    geom_point(data=data.frame(ggemmeans(mod_abund_Medium,
                                         type="fixed",terms=c("nutrient"))),
               aes(x=x,y=predicted),size=4,shape=16)+
    geom_errorbar(data=data.frame(ggemmeans(mod_abund_Medium,
                                           type="fixed",terms=c("nutrient"))),
                  aes(x=x,y=predicted,ymin=conf.low,ymax=conf.high),
                  width=0.2,size=0.5)+
    my_theme()+xlab("Nutrient input")+ylab("Medium abundance"),
  # fire
  ggplot()+
    geom_jitter(data=data_peat,aes(x=fire,y=Medium_prop),
              position = position_jitter(0.1,0.01),
              size=3,alpha=0.3,shape=16,color="darkturquoise")+
    geom_point(data=data.frame(ggemmeans(mod_abund_Medium,
                                         type="fixed",terms=c("fire"))),
               aes(x=x,y=predicted),size=4,shape=16)+
    geom_errorbar(data=data.frame(ggemmeans(mod_abund_Medium,
                                           type="fixed",terms=c("fire"))),
                  aes(x=x,y=predicted,ymin=conf.low,ymax=conf.high),
                  width=0.2,size=0.5)+
    my_theme()+xlab("Fire")+ylab("Medium abundance"),
  # dry
  ggplot()+
    geom_jitter(data=data_peat,aes(x=dry,y=Medium_prop),
                position = position_jitter(0.1,0.01),
                size=3,alpha=0.3,shape=16,color="darkturquoise")+
    geom_point(data=data.frame(ggemmeans(mod_abund_Medium,
                                         type="fixed",terms=c("dry"))),
               aes(x=x,y=predicted),size=4,shape=16)+
    geom_errorbar(data=data.frame(ggemmeans(mod_abund_Medium,
                                           type="fixed",terms=c("dry"))),
                  aes(x=x,y=predicted,ymin=conf.low,ymax=conf.high),
                  width=0.2,size=0.5)+
    my_theme()+xlab("Dry period")+ylab("Medium abundance"),
  ncol=2
)
```




```
ggsave(filename="output/figures/plots_Medium.tiff",plot=plots_Medium,
       width=24,height=24,units="cm",dpi=300)
ggsave(filename="output/figures/plots_Medium.pdf",plot=plots_Medium,
       width=24,height=24,units="cm",dpi=300)
```

Plots Fuscum Create average predictions for the effects of moisture and nutrients on the zero-inflated part.

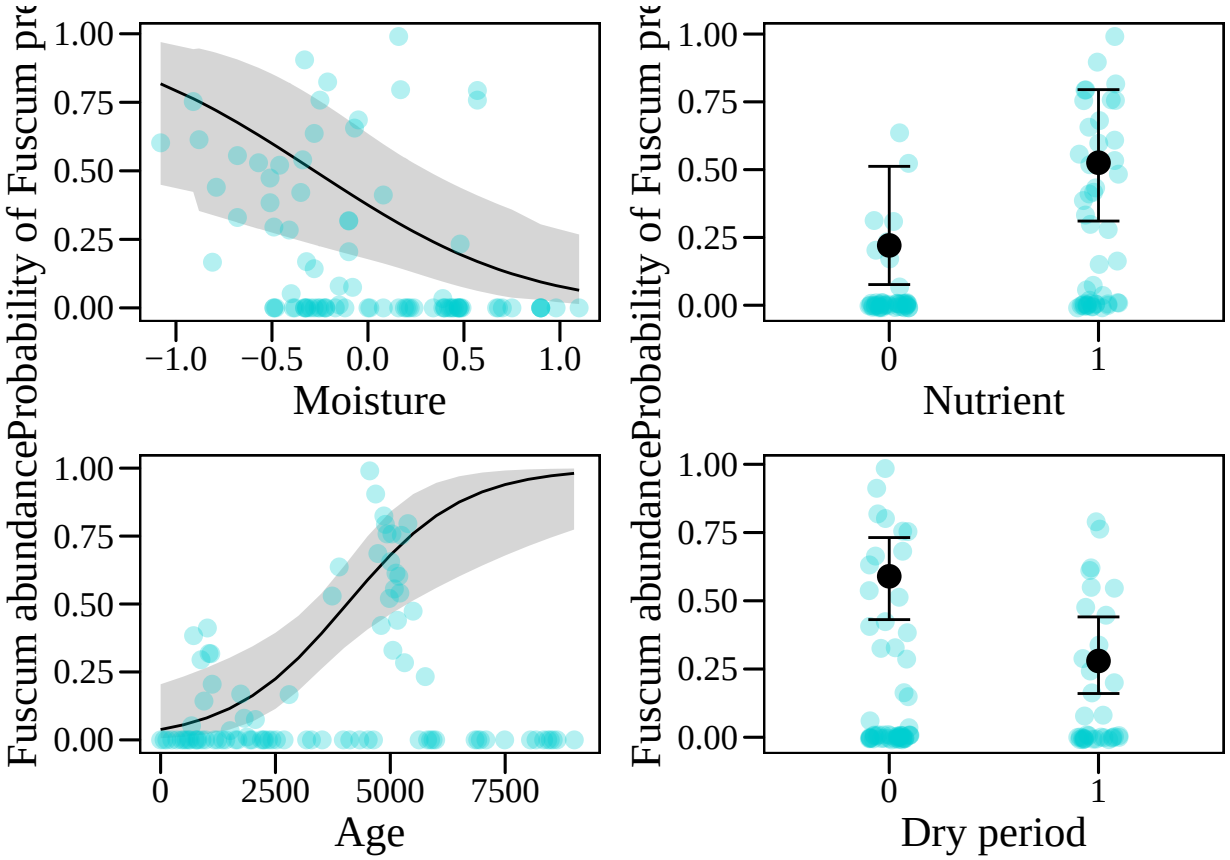
```
# Create average line among factors=0 and factors=1
average_prediction_Fuscum_moist<-rbind(
  tibble(ggpredict(mod_abund_Fuscum,type="zi_prob",terms=c("moist[all]"),
                   condition=c(nutrient=1,fire=1,dry=1)))%>%
    select(-group)%>%mutate(type="a"),
  tibble(ggpredict(mod_abund_Fuscum,type="zi_prob",terms=c("moist[all]"),
                   condition=c(nutrient=0,fire=0,dry=0)))%>%
    select(-group)%>%mutate(type="b"),
  tibble(ggpredict(mod_abund_Fuscum,type="zi_prob",terms=c("moist[all]"),
                   condition=c(nutrient=0,fire=1,dry=1)))%>%
    select(-group)%>%mutate(type="c"),
  tibble(ggpredict(mod_abund_Fuscum,type="zi_prob",terms=c("moist[all]"),
                   condition=c(nutrient=1,fire=0,dry=1)))%>%
    select(-group)%>%mutate(type="d"),
  tibble(ggpredict(mod_abund_Fuscum,type="zi_prob",terms=c("moist[all]"),
                   condition=c(nutrient=1,fire=1,dry=0)))%>%
    select(-group)%>%mutate(type="e"),
```

```
  tibble(ggpredict(mod_abund_Fuscum,type="zi_prob",terms=c("moist[all]"),
                   condition=c(nutrient=0,fire=0,dry=1)))%>%
    select(-group)%>%mutate(type="f"),
  tibble(ggpredict(mod_abund_Fuscum,type="zi_prob",terms=c("moist[all]"),
                   condition=c(nutrient=0,fire=1,dry=0)))%>%
    select(-group)%>%mutate(type="g"),
  tibble(ggpredict(mod_abund_Fuscum,type="zi_prob",terms=c("moist[all]"),
                   condition=c(nutrient=1,fire=0,dry=0)))%>%  # NaNs produced
    select(-group)%>%mutate(type="h")
)%>%
  group_by(x)%>%summarise(predicted=mean(predicted),
                          std.error=mean(std.error,na.rm=T),
                          conf.low=mean(conf.low,na.rm=T),
                          conf.high=mean(conf.high,na.rm=T))
```

```
# Create average line among factors=0 and factors=1
average_prediction_Fuscum_nutrient<-rbind(
  tibble(ggpredict(mod_abund_Fuscum,type="zi_prob",terms=c("nutrient"),
                   condition=c(fire=1,dry=1)))%>%
    select(-group)%>%mutate(type="a"),
  tibble(ggpredict(mod_abund_Fuscum,type="zi_prob",terms=c("nutrient"),
                   condition=c(fire=0,dry=0)))%>%
    select(-group)%>%mutate(type="b"),
  tibble(ggpredict(mod_abund_Fuscum,type="zi_prob",terms=c("nutrient"),
                   condition=c(fire=0,dry=1)))%>%
    select(-group)%>%mutate(type="c"),
  tibble(ggpredict(mod_abund_Fuscum,type="zi_prob",terms=c("nutrient"),
                   condition=c(fire=1,dry=0)))%>%
    select(-group)%>%mutate(type="d")
  )%>%
  group_by(x)%>%summarise(predicted=mean(predicted),
                          std.error=mean(std.error,na.rm=T),
                          conf.low=mean(conf.low,na.rm=T),
                          conf.high=mean(conf.high,na.rm=T))
```

```
plots_Fuscum<-grid.arrange(
  # moist - CI band looking a bit weird
  ggplot()+
    geom_ribbon(data=average_prediction_Fuscum_moist,
                aes(x=x,y=1-predicted,ymin=1-conf.low,ymax=1-conf.high),
                alpha=0.2)+
    geom_line(data=average_prediction_Fuscum_moist,
              aes(x=x,y=1-predicted))+
    geom_point(data=data_peat,aes(x=moist,y=Fuscum_prop),
               size=3,alpha=0.3,shape=16,color="darkturquoise")+
    my_theme()+xlab("Moisture")+ylab("Probability of Fuscum presence"),
  # nutrient
  ggplot()+
    geom_jitter(data=data_peat,aes(x=nutrient,y=Fuscum_prop),
                position=position_jitter(0.1,0.01),
                size=3,alpha=0.3,shape=16,color="darkturquoise")+
    geom_point(data=average_prediction_Fuscum_nutrient,
               aes(x=x,y=1-predicted),size=4,shape=16)+
```

```
    geom_errorbar(data=average_prediction_Fuscum_nutrient,
                  aes(x=x,y=1-predicted,ymin=1-conf.low,ymax=1-conf.high),
                  width=0.2,size=0.5)+
    my_theme()+xlab("Nutrient")+ylab("Probability of Fuscum presence"),
  # age
  ggplot()+
    geom_ribbon(data=data.frame(ggemmeans(mod_abund_Fuscum,
                                          type="fixed",terms=c("age"))),
                                aes(x=x,y=predicted,
                                    ymin=conf.low,ymax=conf.high),alpha=0.2)+
    geom_line(data=data.frame(ggemmeans(mod_abund_Fuscum,
                                          type="fixed",terms=c("age"))),
                               aes(x=x,y=predicted))+
    geom_point(data=data_peat,aes(x=age,y=Fuscum_prop),
               size=3,alpha=0.3,shape=16,color="darkturquoise")+
    my_theme()+xlab("Age")+ylab("Fuscum abundance"),
  # dry
  ggplot()+
    geom_jitter(data=data_peat,aes(x=dry,y=Fuscum_prop),
                position = position_jitter(0.1,0.01),
                size=3,alpha=0.3,shape=16,color="darkturquoise")+
    geom_point(data=data.frame(ggemmeans(mod_abund_Fuscum,
                                         type="fixed",terms=c("dry"))),
               aes(x=x,y=predicted),size=4,shape=16)+
    geom_errorbar(data=data.frame(ggemmeans(mod_abund_Fuscum,
                                            type="fixed",terms=c("dry"))),
                  aes(x=x,y=predicted,ymin=conf.low,ymax=conf.high),
                  width=0.2,size=0.5)+
    my_theme()+xlab("Dry period")+ylab("Fuscum abundance"),
  ncol=2
)
```




```
ggsave(filename="output/figures/plots_Fuscum.tiff",plot=plots_Fuscum,
       width=24,height=24,units="cm",dpi=300)
ggsave(filename="output/figures/plots_Fuscum.pdf",plot=plots_Fuscum,
       width=24,height=24,units="cm",dpi=300)
```

Plots Rubellum Create average predictions for the effects of nutrients and dry on the zero-inflated part.

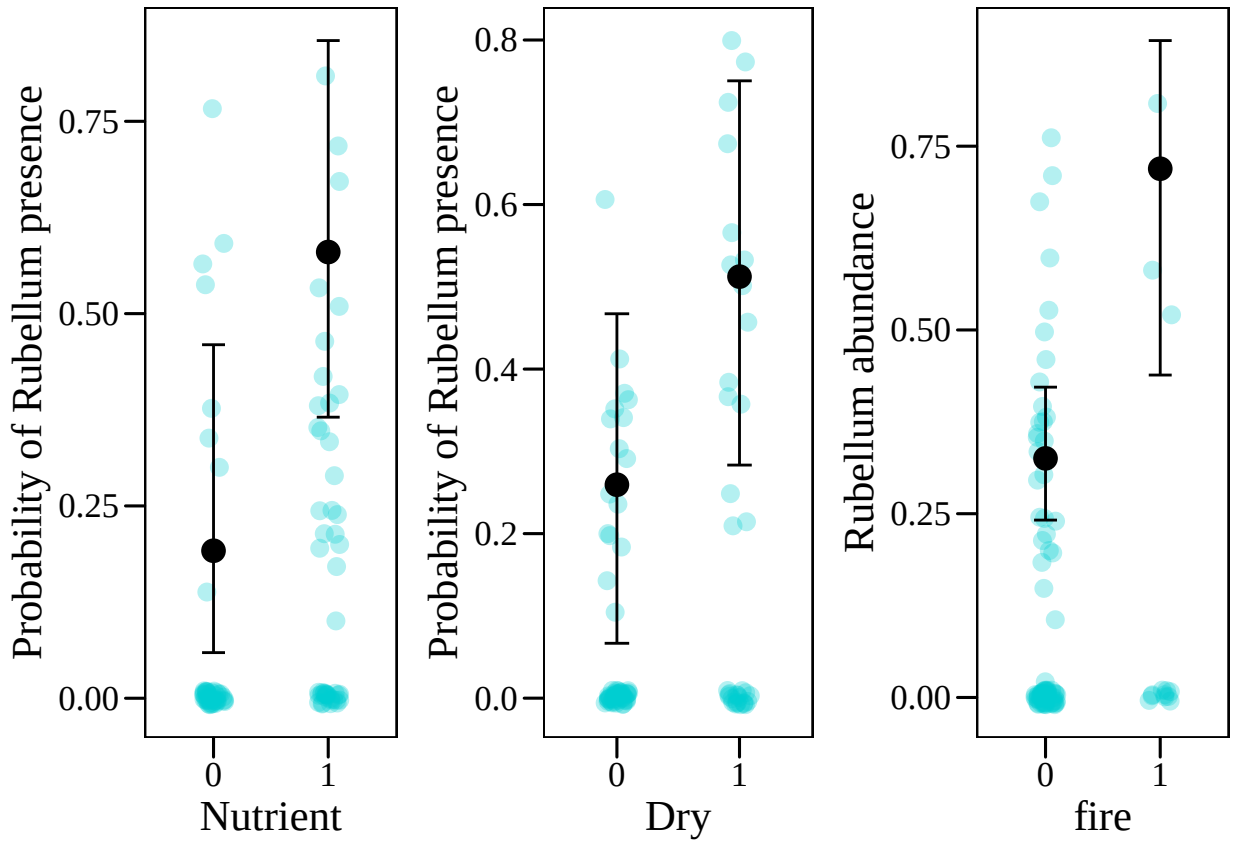
```
# Create average line among factors=0 and factors=1
average_prediction_Rubellum_nutrient<-rbind(
  tibble(ggpredict(mod_abund_Rubellum,type="zi_prob",terms=c("nutrient"),
                   condition=c(fire=1,dry=1)))%>%
    select(-group)%>%mutate(type="a"),
  tibble(ggpredict(mod_abund_Rubellum,type="zi_prob",terms=c("nutrient"),
                   condition=c(fire=0,dry=0)))%>%
    select(-group)%>%mutate(type="b"),
  tibble(ggpredict(mod_abund_Rubellum,type="zi_prob",terms=c("nutrient"),
                   condition=c(fire=0,dry=1)))%>%
    select(-group)%>%mutate(type="c"),
  tibble(ggpredict(mod_abund_Rubellum,type="zi_prob",terms=c("nutrient"),
                   condition=c(fire=1,dry=0)))%>%
    select(-group)%>%mutate(type="d")
  )%>%
  group_by(x)%>%summarise(predicted=mean(predicted),
                          std.error=mean(std.error,na.rm=T),
```

```
                          conf.low=mean(conf.low,na.rm=T),
                          conf.high=mean(conf.high,na.rm=T))
```

```
# Create average line among factors=0 and factors=1
average_prediction_Rubellum_dry<-rbind(
  tibble(ggpredict(mod_abund_Rubellum,type="zi_prob",terms=c("dry"),
                   condition=c(fire=1,nutrient=1)))%>%
    select(-group)%>%mutate(type="a"),
  tibble(ggpredict(mod_abund_Rubellum,type="zi_prob",terms=c("dry"),
                   condition=c(fire=0,nutrient=0)))%>%
    select(-group)%>%mutate(type="b"),
  tibble(ggpredict(mod_abund_Rubellum,type="zi_prob",terms=c("dry"),
                   condition=c(fire=0,nutrient=1)))%>%
    select(-group)%>%mutate(type="c"),
  tibble(ggpredict(mod_abund_Rubellum,type="zi_prob",terms=c("dry"),
                   condition=c(fire=1,nutrient=0)))%>%
    select(-group)%>%mutate(type="d")
  )%>%
  group_by(x)%>%summarise(predicted=mean(predicted),
                          std.error=mean(std.error,na.rm=T),
                          conf.low=mean(conf.low,na.rm=T),
                          conf.high=mean(conf.high,na.rm=T))
```

```
plots_Rubellum<-grid.arrange(
    # nutrient
  ggplot()+
    geom_jitter(data=data_peat,aes(x=nutrient,y=Rubellum_prop),
                position=position_jitter(0.1,0.01),
                size=3,alpha=0.3,shape=16,color="darkturquoise")+
    geom_point(data=average_prediction_Rubellum_nutrient,
               aes(x=x,y=1-predicted),size=4,shape=16)+
    geom_errorbar(data=average_prediction_Rubellum_nutrient,
               aes(x=x,y=1-predicted,ymin=1-conf.low,ymax=1-conf.high),
               width=0.2,size=0.5)+
    my_theme()+xlab("Nutrient")+ylab("Probability of Rubellum presence"),
  # dry
  ggplot()+
    geom_jitter(data=data_peat,aes(x=dry,y=Rubellum_prop),
                position=position_jitter(0.1,0.01),
                size=3,alpha=0.3,shape=16,color="darkturquoise")+
    geom_point(data=average_prediction_Rubellum_dry,
               aes(x=x,y=1-predicted),size=4,shape=16)+
    geom_errorbar(data=average_prediction_Rubellum_dry,
               aes(x=x,y=1-predicted,ymin=1-conf.low,ymax=1-conf.high),
               width=0.2,size=0.5)+
    my_theme()+xlab("Dry")+ylab("Probability of Rubellum presence"),
  # fire
  ggplot()+
    geom_jitter(data=data_peat,aes(x=fire,y=Rubellum_prop),
                position = position_jitter(0.1,0.01),
                size=3,alpha=0.3,shape=16,color="darkturquoise")+
    geom_point(data=data.frame(ggemmeans(mod_abund_Rubellum,
                                         type="fixed",terms=c("fire"))),
```

```
                aes(x=x,y=predicted),size=4,shape=16)+
    geom_errorbar(data=data.frame(ggemmeans(mod_abund_Rubellum,
                                            type="fixed",terms=c("fire"))),
                  aes(x=x,y=predicted,ymin=conf.low,ymax=conf.high),
                  width=0.2,size=0.5)+
    my_theme()+xlab("fire")+ylab("Rubellum abundance"),
  ncol=3
)
```



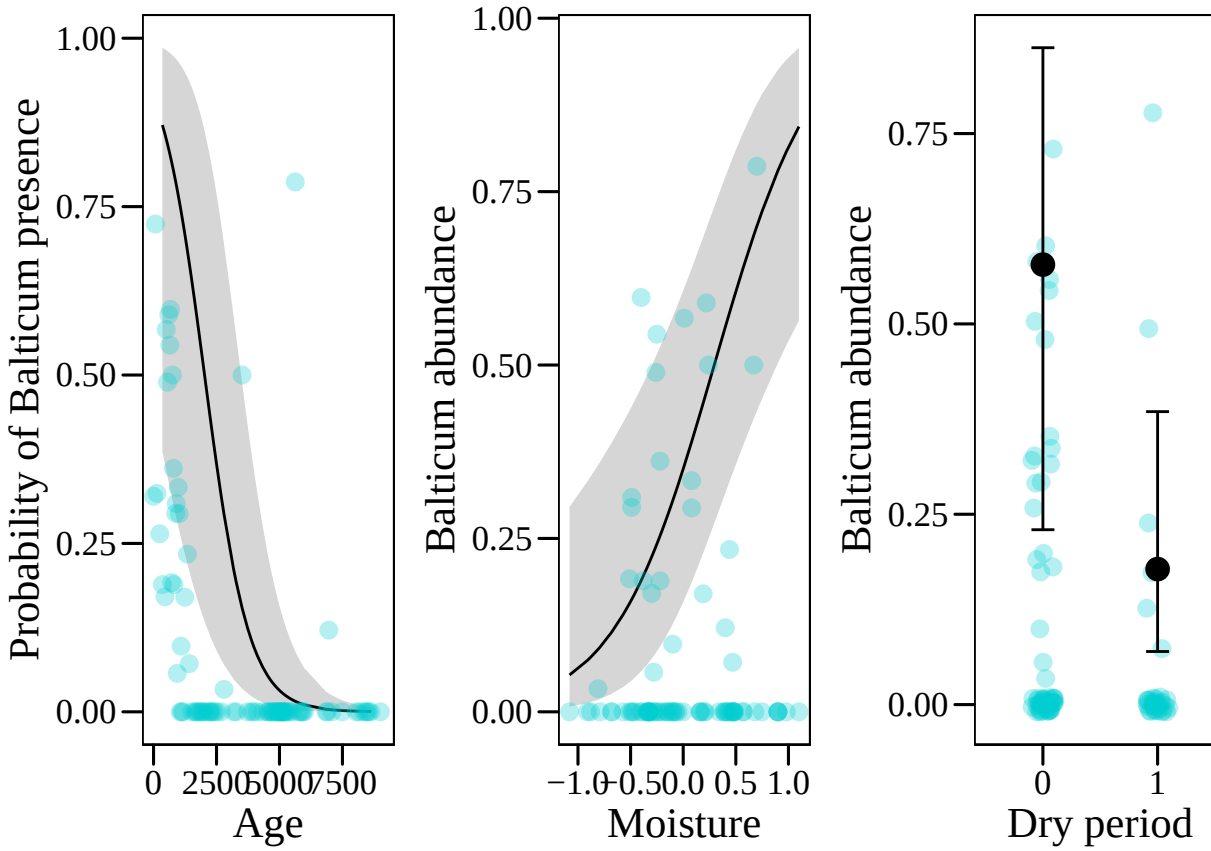

```
ggsave(filename="output/figures/plots_Rubellum.tiff",plot=plots_Rubellum,
       width=36,height=12,units="cm",dpi=300)
ggsave(filename="output/figures/plots_Rubellum.pdf",plot=plots_Rubellum,
       width=36,height=12,units="cm",dpi=300)
```

```
# Create average line among factors=0 and factors=1
average_prediction_Balticum_age<-rbind(
  tibble(ggpredict(mod_abund_Balticum,type="zi_prob",terms=c("age[all]"),
                   condition=c(nutrient=1,fire=1,dry=1)))%>%
    select(-group)%>%mutate(type="a"),
  tibble(ggpredict(mod_abund_Balticum,type="zi_prob",terms=c("age[all]"),
                   condition=c(nutrient=0,fire=0,dry=0)))%>%
    select(-group)%>%mutate(type="b"),
```

```
  tibble(ggpredict(mod_abund_Balticum,type="zi_prob",terms=c("age[all]"),
                   condition=c(nutrient=0,fire=1,dry=1)))%>%
    select(-group)%>%mutate(type="c"),
  tibble(ggpredict(mod_abund_Balticum,type="zi_prob",terms=c("age[all]"),
                   condition=c(nutrient=1,fire=0,dry=1)))%>%
    select(-group)%>%mutate(type="d"),
  tibble(ggpredict(mod_abund_Balticum,type="zi_prob",terms=c("age[all]"),
                   condition=c(nutrient=1,fire=1,dry=0)))%>%
    select(-group)%>%mutate(type="e"),
  tibble(ggpredict(mod_abund_Balticum,type="zi_prob",terms=c("age[all]"),
                   condition=c(nutrient=0,fire=0,dry=1)))%>%
    select(-group)%>%mutate(type="f"),
  tibble(ggpredict(mod_abund_Balticum,type="zi_prob",terms=c("age[all]"),
                   condition=c(nutrient=0,fire=1,dry=0)))%>%
    select(-group)%>%mutate(type="g"),
  tibble(ggpredict(mod_abund_Balticum,type="zi_prob",terms=c("age[all]"),
                   condition=c(nutrient=1,fire=0,dry=0)))%>%
    select(-group)%>%mutate(type="h")
)%>%
  group_by(x)%>%summarise(predicted=mean(predicted),std.error=mean(std.error),
                          conf.low=mean(conf.low),conf.high=mean(conf.high))
```

```
plots_Balticum<-grid.arrange(
  # age
  ggplot()+
    geom_ribbon(data=average_prediction_Balticum_age,
                aes(x=x,y=1-predicted,ymin=1-conf.low,ymax=1-conf.high),
                alpha=0.2)+
    geom_line(data=average_prediction_Balticum_age,
              aes(x=x,y=1-predicted))+
    geom_point(data=data_peat,aes(x=age,y=Balticum_prop),
               size=3,alpha=0.3,shape=16,color="darkturquoise")+
    my_theme()+xlab("Age")+ylab("Probability of Balticum presence"),
  # moist
  ggplot()+
    geom_ribbon(data=data.frame(ggemmeans(mod_abund_Balticum,
                                          type="fixed",terms=c("moist[all]"))),
                aes(x=x,y=predicted,ymin=conf.low,ymax=conf.high),alpha=0.2)+
    geom_line(data=data.frame(ggemmeans(mod_abund_Balticum,
                                        type="fixed",terms=c("moist[all]"))),
              aes(x=x,y=predicted))+
    geom_point(data=data_peat,aes(x=moist,y=Balticum_prop),
               size=3,alpha=0.3,shape=16,color="darkturquoise")+
    my_theme()+xlab("Moisture")+ylab("Balticum abundance"),
  # dry
  ggplot()+
    geom_jitter(data=data_peat,aes(x=dry,y=Balticum_prop),
                position = position_jitter(0.1,0.01),
                size=3,alpha=0.3,shape=16,color="darkturquoise")+
    geom_point(data=data.frame(ggemmeans(mod_abund_Balticum,
                                         type="fixed",terms=c("dry"))),
               aes(x=x,y=predicted),size=4,shape=16)+
```

```
    geom_errorbar(data=data.frame(ggemmeans(mod_abund_Balticum,
                                            type="fixed",terms=c("dry"))),
                  aes(x=x,y=predicted,ymin=conf.low,ymax=conf.high),
                  width=0.2,size=0.5)+
    my_theme()+xlab("Dry period")+ylab("Balticum abundance"),
  ncol=3
)
```



Plots Balticum

```
ggsave(filename="output/figures/plots_Balticum.tiff",plot=plots_Balticum,
       width=36,height=12,units="cm",dpi=300)
ggsave(filename="output/figures/plots_Balticum.pdf",plot=plots_Balticum,
       width=36,height=12,units="cm",dpi=300)
```

With fen-bog and interactions

Plant groups

Step 1: Models with all interactions (except fen*nutrient) In these models I include all interactions of fen with the other variables (except for fen*nutrient which will give problems).

```
mod_abund_tot_Sphagnum_all_ints<-glmmTMB(tot_Sphagnum_prop~(age+temp+moist+
                                   fire+dry)*fen+nutrient,family="beta_family",
                                 ziformula=~.,data=data_peat)
mod_abund_Erio_nozi_all_ints<-glmmTMB(Erio_prop~(age+temp+moist+
```

```
                                fire+dry)*fen+nutrient,family="beta_family",
                               ziformula=~0,data=subset(data_peat,Erio_prop>0))
mod_abund_Erica_nozi_all_ints<-glmmTMB(Erica_prop~(age+temp+moist+
                                fire+dry)*fen+nutrient,family="beta_family",
                               ziformula=~0, data_erica<-subset(data_peat,Erica>0))
mod_abund_Carex_nozi_all_ints<-glmmTMB(Carex_prop~(age+temp+moist+
                                fire+dry)*fen+nutrient,family="beta_family",
                               ziformula=~0,data=subset(data_peat,Carex_prop>0))
```

```
summary(mod_abund_tot_Sphagnum_all_ints)
```

```
##  Family: beta  ( logit )
## Formula:
## tot_Sphagnum_prop ~ (age + temp + moist + fire + dry) * fen +      nutrient
## Zero inflation:                      ~.
## Data: data_peat
##
##      AIC      BIC   logLik deviance df.resid
##     81.0    153.4    -13.5     27.0       81
##
##
## Dispersion parameter for beta family (): 2.74
##
## Conditional model:
##               Estimate Std. Error z value Pr(>|z|)
## (Intercept)  3.832e-01  1.800e+00   0.213  0.83139
## age          1.157e-05  1.379e-04   0.084  0.93314
## temp        -1.049e-01  2.731e-01  -0.384  0.70105
## moist       -2.728e-01  2.901e-01  -0.940  0.34703
## fire1       -9.947e-02  4.046e-01  -0.246  0.80577
## dry1         7.628e-01  2.701e-01   2.824  0.00473 **
## fenY        -8.790e+00  8.085e+00  -1.087  0.27693
## nutrient1    7.878e-01  3.139e-01   2.510  0.01207 *
## age:fenY     9.004e-04  6.355e-04   1.417  0.15654
## temp:fenY    6.164e-02  5.664e-01   0.109  0.91335
## moist:fenY   1.129e+00  1.039e+00   1.087  0.27721
## fire1:fenY   4.227e-01  8.434e-01   0.501  0.61627
## dry1:fenY    3.360e-01  1.159e+00   0.290  0.77199
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Zero-inflation model:
##               Estimate Std. Error z value Pr(>|z|)
## (Intercept) -6.6025897  7.4371631  -0.888   0.3747
## age          0.0001263  0.0005669   0.223   0.8237
## temp         0.4498500  1.0938874   0.411   0.6809
## moist       -0.8377479  1.0523549  -0.796   0.4260
## fire1        2.3896444  1.0723382   2.228   0.0259 *
## dry1        -0.7659542  0.9918775  -0.772   0.4400
## fenY        -1.4402594 15.4436623  -0.093   0.9257
## nutrient1   -0.6577288  1.0310583  -0.638   0.5235
## age:fenY     0.0006959  0.0012043   0.578   0.5634
## temp:fenY   -0.3387310  1.3593388  -0.249   0.8032
```

```
## moist:fenY  -0.5369502  1.9241618  -0.279   0.7802
## fire1:fenY  -3.1842388  1.5191645  -2.096   0.0361 *
## dry1:fenY    3.8767479  2.5535563   1.518   0.1290
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
summary(mod_abund_Erio_nozi_all_ints)
```

```
##  Family: beta  ( logit )
## Formula:
## Erio_prop ~ (age + temp + moist + fire + dry) * fen + nutrient
## Data: subset(data_peat, Erio_prop > 0)
##
##      AIC      BIC   logLik deviance df.resid
##   -111.5    -74.0     69.8   -139.5       94
##
##
## Dispersion parameter for beta family (): 5.12
##
## Conditional model:
##               Estimate Std. Error z value Pr(>|z|)
## (Intercept) -9.753e-02  1.524e+00  -0.064   0.9490
## age         -2.523e-05  1.162e-04  -0.217   0.8281
## temp        -1.080e-01  2.318e-01  -0.466   0.6414
## moist        7.507e-02  2.439e-01   0.308   0.7582
## fire1       -2.014e-01  3.318e-01  -0.607   0.5438
## dry1        -4.922e-01  2.279e-01  -2.160   0.0308 *
## fenY         3.702e+00  5.313e+00   0.697   0.4859
## nutrient1   -4.194e-01  2.595e-01  -1.616   0.1061
## age:fenY    -6.744e-04  4.255e-04  -1.585   0.1130
## temp:fenY    3.219e-01  3.848e-01   0.837   0.4029
## moist:fenY   9.676e-01  6.402e-01   1.511   0.1307
## fire1:fenY   3.749e-01  5.164e-01   0.726   0.4679
## dry1:fenY   -1.395e+00  8.871e-01  -1.573   0.1158
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
summary(mod_abund_Erica_nozi_all_ints)
```

```
##  Family: beta  ( logit )
## Formula:
## Erica_prop ~ (age + temp + moist + fire + dry) * fen + nutrient
## Data: data_erica <- subset(data_peat, Erica > 0)
##
##      AIC      BIC   logLik deviance df.resid
##   -204.8   -167.3    116.4   -232.8       93
##
##
## Dispersion parameter for beta family (): 8.68
##
## Conditional model:
##               Estimate Std. Error z value Pr(>|z|)
## (Intercept) -4.929e+00  1.533e+00  -3.214 0.001307 **
```

```
## age          2.298e-05  1.089e-04   0.211 0.832925
## temp         4.107e-01  2.274e-01   1.806 0.070943 .
## moist        1.415e-01  2.063e-01   0.686 0.492882
## fire1        9.932e-01  2.711e-01   3.663 0.000249 ***
## dry1        -5.244e-01  2.150e-01  -2.439 0.014728 *
## fenY         6.820e+00  5.349e+00   1.275 0.202339
## nutrient1   -4.412e-01  2.277e-01  -1.938 0.052652 .
## age:fenY    -3.058e-04  4.130e-04  -0.740 0.459109
## temp:fenY   -5.596e-01  3.851e-01  -1.453 0.146195
## moist:fenY  -1.103e+00  6.527e-01  -1.691 0.090911 .
## fire1:fenY  -1.526e+00  4.806e-01  -3.175 0.001499 **
## dry1:fenY    1.227e+00  9.051e-01   1.356 0.175055
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
summary(mod_abund_Carex_nozi_all_ints)
```

```
##  Family: beta  ( logit )
## Formula:
## Carex_prop ~ (age + temp + moist + fire + dry) * fen + nutrient
## Data: subset(data_peat, Carex_prop > 0)
##
##      AIC      BIC   logLik deviance df.resid
##   -231.9   -194.3    129.9   -259.9       94
##
##
## Dispersion parameter for beta family (): 12.2
##
## Conditional model:
##               Estimate Std. Error z value Pr(>|z|)
## (Intercept) -3.551e+00  1.282e+00  -2.769  0.00563 **
## age         -1.444e-04  9.564e-05  -1.510  0.13111
## temp         3.506e-01  1.928e-01   1.818  0.06907 .
## moist       -2.183e-01  1.981e-01  -1.102  0.27067
## fire1        2.985e-01  2.644e-01   1.129  0.25901
## dry1        -5.450e-01  1.950e-01  -2.795  0.00519 **
## fenY        -2.507e+00  4.333e+00  -0.579  0.56292
## nutrient1   -1.211e+00  2.205e-01  -5.493 3.94e-08 ***
## age:fenY     5.178e-04  3.371e-04   1.536  0.12456
## temp:fenY   -1.665e-01  3.142e-01  -0.530  0.59618
## moist:fenY  -3.445e-01  5.124e-01  -0.672  0.50139
## fire1:fenY  -5.860e-02  4.129e-01  -0.142  0.88715
## dry1:fenY    1.305e+00  6.933e-01   1.882  0.05981 .
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

Step 2: Models with only significant interactions In these models I include only the interactions of fen with the other variables that were significant in step 1. If one interaction was significant only in the abundance part ("conditional model") or on the presence part ("zero-inflation model") I inlcude it only on that part of the model.

```
# Total Sphagnum: significant interaction fire*fen
# included ONLY in the zero-inflated part
mod_abund_tot_Sphagnum_sig_ints<-glmmTMB(tot_Sphagnum_prop~age+temp+moist+
                                  nutrient+dry+fire+fen,family="beta_family",
                                ziformula=~age+temp+moist+
                                  nutrient+dry+fire+fen+fire:fen,data=data_peat)
# Erio: no significant interactions
# Erica: significant interaction fire*fen
mod_abund_Erica_nozi_sig_ints<-glmmTMB(Erica_prop~age+temp+moist+
                                 fire*fen+dry+nutrient,family="beta_family",
                               ziformula=~0, data_erica<-subset(data_peat,Erica>0))
# Carex: no significant interactions
```

```
summary(mod_abund_tot_Sphagnum_sig_ints)
```

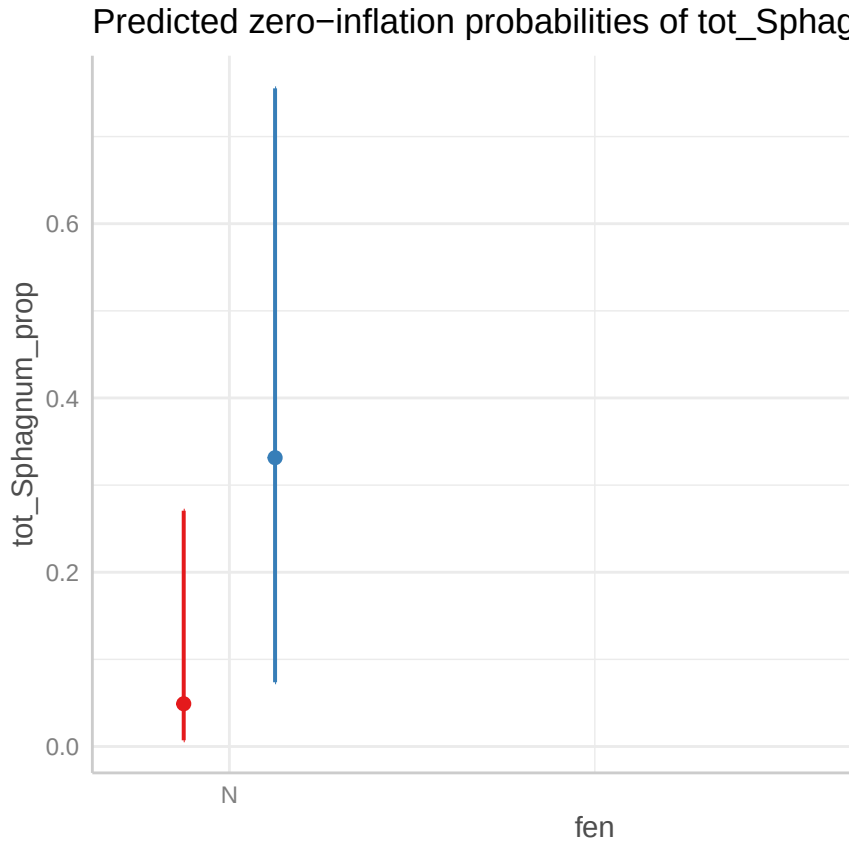
```
##  Family: beta  ( logit )
## Formula:
## tot_Sphagnum_prop ~ age + temp + moist + nutrient + dry + fire +      fen
## Zero inflation:
## ~age + temp + moist + nutrient + dry + fire + fen + fire:fen
## Data: data_peat
##
##      AIC      BIC   logLik deviance df.resid
##     69.6    117.9    -16.8     33.6       90
##
##
## Dispersion parameter for beta family (): 2.65
##
## Conditional model:
##               Estimate Std. Error z value Pr(>|z|)
## (Intercept)  1.302e+00  1.311e+00   0.994  0.32045
## age          9.669e-05  9.948e-05   0.972  0.33110
## temp        -2.538e-01  1.976e-01  -1.284  0.19914
## moist       -1.858e-01  2.808e-01  -0.662  0.50812
## nutrient1    8.576e-01  3.088e-01   2.777  0.00548 **
## dry1         6.762e-01  2.474e-01   2.733  0.00627 **
## fire1       -7.560e-02  3.483e-01  -0.217  0.82817
## fenY        -1.179e+00  4.606e-01  -2.559  0.01050 *
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Zero-inflation model:
##               Estimate Std. Error z value Pr(>|z|)
## (Intercept) -6.660e+00  3.290e+00  -2.024   0.0430 *
## age          6.176e-05  2.728e-04   0.226   0.8209
## temp         4.206e-01  4.184e-01   1.005   0.3148
## moist       -4.905e-01  7.755e-01  -0.632   0.5271
## nutrient1   -3.000e-01  1.013e+00  -0.296   0.7671
## dry1         1.765e-01  7.625e-01   0.231   0.8170
## fire1        2.263e+00  1.020e+00   2.219   0.0265 *
## fenY         2.575e+00  1.480e+00   1.740   0.0819 .
## fire1:fenY  -3.091e+00  1.427e+00  -2.166   0.0303 *
## ---
```

```
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
summary(mod_abund_Erica_nozi_sig_ints)
```

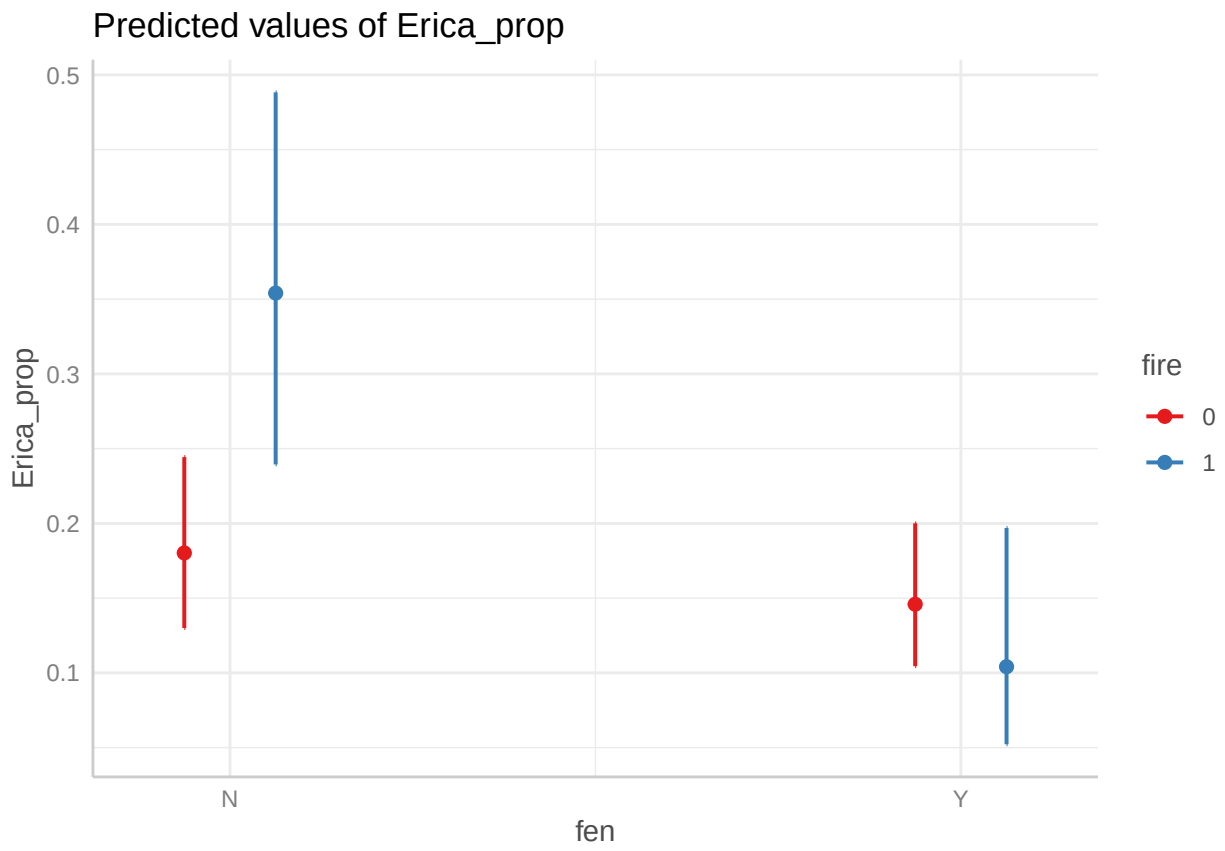
```
##  Family: beta  ( logit )
## Formula:          Erica_prop ~ age + temp + moist + fire * fen + dry + nutrient
## Data: data_erica <- subset(data_peat, Erica > 0)
##
##      AIC      BIC   logLik deviance df.resid
##   -205.3   -178.6    112.7   -225.3       97
##
##
## Dispersion parameter for beta family (): 7.98
##
## Conditional model:
##               Estimate Std. Error z value Pr(>|z|)
## (Intercept) -4.692e+00  9.107e-01  -5.153 2.57e-07 ***
## age          8.699e-06  6.480e-05   0.134 0.893202
## temp         3.818e-01  1.291e-01   2.957 0.003107 **
## moist        9.684e-02  1.918e-01   0.505 0.613671
## fire1        9.137e-01  2.743e-01   3.331 0.000866 ***
## fenY        -2.522e-01  3.411e-01  -0.739 0.459722
## dry1        -3.639e-01  1.867e-01  -1.949 0.051250 .
## nutrient1   -4.066e-01  2.262e-01  -1.797 0.072280 .
## fire1:fenY  -1.299e+00  4.804e-01  -2.704 0.006860 **
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
plot(ggpredict(mod_abund_tot_Sphagnum_sig_ints,terms=c("fen","fire"),
               type="zi_prob"))
```



Plots interactions Total Sphagnum & Erica

```
plot(ggpredict(mod_abund_Erica_nozi_sig_ints,terms=c("fen","fire")))
```




```
summary(mod_abund_tot_Sphagnum_sig_ints)
```

```
##  Family: beta  ( logit )
## Formula:
## tot_Sphagnum_prop ~ age + temp + moist + nutrient + dry + fire +      fen
## Zero inflation:
## ~age + temp + moist + nutrient + dry + fire + fen + fire:fen
## Data: data_peat
##
##      AIC      BIC   logLik deviance df.resid
##     69.6    117.9    -16.8     33.6       90
##
##
## Dispersion parameter for beta family (): 2.65
##
## Conditional model:
##               Estimate Std. Error z value Pr(>|z|)
## (Intercept)  1.302e+00  1.311e+00   0.994  0.32045
## age          9.669e-05  9.948e-05   0.972  0.33110
## temp        -2.538e-01  1.976e-01  -1.284  0.19914
## moist       -1.858e-01  2.808e-01  -0.662  0.50812
## nutrient1    8.576e-01  3.088e-01   2.777  0.00548 **
## dry1         6.762e-01  2.474e-01   2.733  0.00627 **
## fire1       -7.560e-02  3.483e-01  -0.217  0.82817
## fenY        -1.179e+00  4.606e-01  -2.559  0.01050 *
```

```
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Zero-inflation model:
##               Estimate Std. Error z value Pr(>|z|)
## (Intercept) -6.660e+00  3.290e+00  -2.024   0.0430 *
## age          6.176e-05  2.728e-04   0.226   0.8209
## temp         4.206e-01  4.184e-01   1.005   0.3148
## moist       -4.905e-01  7.755e-01  -0.632   0.5271
## nutrient1   -3.000e-01  1.013e+00  -0.296   0.7671
## dry1         1.765e-01  7.625e-01   0.231   0.8170
## fire1        2.263e+00  1.020e+00   2.219   0.0265 *
## fenY         2.575e+00  1.480e+00   1.740   0.0819 .
## fire1:fenY  -3.091e+00  1.427e+00  -2.166   0.0303 *
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
summary(mod_abund_Erica_nozi_sig_ints)
```

```
##  Family: beta  ( logit )
## Formula:          Erica_prop ~ age + temp + moist + fire * fen + dry + nutrient
## Data: data_erica <- subset(data_peat, Erica > 0)
##
##      AIC      BIC   logLik deviance df.resid
##   -205.3   -178.6    112.7   -225.3       97
##
##
## Dispersion parameter for beta family (): 7.98
##
## Conditional model:
##               Estimate Std. Error z value Pr(>|z|)
## (Intercept) -4.692e+00  9.107e-01  -5.153 2.57e-07 ***
## age          8.699e-06  6.480e-05   0.134 0.893202
## temp         3.818e-01  1.291e-01   2.957 0.003107 **
## moist        9.684e-02  1.918e-01   0.505 0.613671
## fire1        9.137e-01  2.743e-01   3.331 0.000866 ***
## fenY        -2.522e-01  3.411e-01  -0.739 0.459722
## dry1        -3.639e-01  1.867e-01  -1.949 0.051250 .
## nutrient1   -4.066e-01  2.262e-01  -1.797 0.072280 .
## fire1:fenY  -1.299e+00  4.804e-01  -2.704 0.006860 **
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

Selected Sphagnum species

Step 1: Models with all interactions (except fen*nutrient) For these models, we will use the subset of data_peat where total proportion of Sphagnum is > 0, and moist is not NA.

```
nrow(subset(data_peat,tot_Sphagnum_prop>0&!is.na(moist)))
```

```
## [1] 88
```

These are 88 rows of data_peat.

Check combinations of the three factors and the fen-bog factor in this subset:

```
with(subset(data_peat,tot_Sphagnum_prop>0&!is.na(moist)),table(fen,nutrient))
```

```
##    nutrient
## fen  0  1
##   N 26 47
##   Y 15  0
```

```
with(subset(data_peat,tot_Sphagnum_prop>0&!is.na(moist)),table(fen,fire))
```

```
##    fire
## fen  0  1
##   N 64  9
##   Y 11  4
```

```
with(subset(data_peat,tot_Sphagnum_prop>0&!is.na(moist)),table(fen,dry))
```

```
##    dry
## fen  0  1
##   N 44 29
##   Y  9  6
```

Interaction with nutrient should give problems as before, but I do not see why the others should give problems.

In these models I include all interactions of fen with the other variables (except for fen*nutrient which will give problems).

```
mod_abund_Medium_all_ints<-glmmTMB(Medium_prop~(age+temp+moist+
                             fire+dry)*fen+nutrient,family="beta_family",
                           ziformula=~.,data=data_peat)
mod_abund_Fuscum_all_ints<-glmmTMB(Fuscum_prop~(age+temp+moist+
                             fire+dry)*fen+nutrient,family="beta_family",
                           ziformula=~.,data=data_peat)
mod_abund_Rubellum_all_ints<-glmmTMB(Rubellum_prop~(age+temp+moist+
                             fire+dry)*fen+nutrient,family="beta_family",
                             ziformula=~.,data=data_peat)
mod_abund_Balticum_all_ints<-glmmTMB(Balticum_prop~(age+temp+moist+
                             fire+dry)*fen+nutrient,family="beta_family",
                             ziformula=~.,data=data_peat)
mod_abund_Cuspidata_all_ints<-glmmTMB(Cuspidata_prop~(age+temp+moist+
                             fire+dry)*fen+nutrient,family="beta_family",
                              ziformula=~.,data=data_peat)
```

I get these warnings for each model: Warning messages: 1: In fitTMB(TMBStruc) : Model convergence problem; non-positive-definite Hessian matrix. See vignette('troubleshooting') 2: In fitTMB(TMBStruc) : Model convergence problem; singular convergence (7). See vignette('troubleshooting')

```
summary(mod_abund_Medium_all_ints)
```

```
##  Family: beta  ( logit )
## Formula:
## Medium_prop ~ (age + temp + moist + fire + dry) * fen + nutrient
## Zero inflation:               ~.
## Data: data_peat
##
##      AIC      BIC   logLik deviance df.resid
##       NA       NA       NA       NA       61
##
##
## Dispersion parameter for beta family (): 2.62
##
## Conditional model:
##               Estimate Std. Error z value Pr(>|z|)
## (Intercept)  2.828e+00        NaN     NaN      NaN
## age          1.574e-05        NaN     NaN      NaN
## temp        -2.690e-01        NaN     NaN      NaN
## moist        4.748e-01        NaN     NaN      NaN
## fire1       -1.779e+00        NaN     NaN      NaN
## dry1         7.114e-01        NaN     NaN      NaN
## fenY         2.680e-02        NaN     NaN      NaN
## nutrient1   -1.385e+00        NaN     NaN      NaN
## age:fenY    -4.295e-04        NaN     NaN      NaN
## temp:fenY    3.489e-01        NaN     NaN      NaN
## moist:fenY   1.559e-02        NaN     NaN      NaN
## fire1:fenY  -7.494e-02        NaN     NaN      NaN
## dry1:fenY    1.017e-01        NaN     NaN      NaN
##
## Zero-inflation model:
##               Estimate Std. Error z value Pr(>|z|)
## (Intercept)  1.953e+00        NaN     NaN      NaN
## age          1.030e-03        NaN     NaN      NaN
## temp        -7.050e-01        NaN     NaN      NaN
## moist       -5.829e-01        NaN     NaN      NaN
## fire1       -2.057e+00        NaN     NaN      NaN
## dry1         8.197e-01        NaN     NaN      NaN
## fenY        -6.940e+03        NaN     NaN      NaN
## nutrient1    7.611e-01        NaN     NaN      NaN
## age:fenY     3.617e-01        NaN     NaN      NaN
## temp:fenY    5.279e+02        NaN     NaN      NaN
## moist:fenY  -5.034e+02        NaN     NaN      NaN
## fire1:fenY   6.760e+01        NaN     NaN      NaN
## dry1:fenY    1.467e+02        NaN     NaN      NaN
```

```
summary(mod_abund_Fuscum_all_ints)
```

```
##  Family: beta  ( logit )
## Formula:
## Fuscum_prop ~ (age + temp + moist + fire + dry) * fen + nutrient
## Zero inflation:               ~.
```

```
## Data: data_peat
##
##      AIC      BIC   logLik deviance df.resid
##       NA       NA       NA       NA       61
##
##
## Dispersion parameter for beta family (): 6.28
##
## Conditional model:
##              Estimate Std. Error z value Pr(>|z|)
## (Intercept)  1.058767        NaN     NaN      NaN
## age          0.000797        NaN     NaN      NaN
## temp        -0.478575        NaN     NaN      NaN
## moist       -0.021485        NaN     NaN      NaN
## fire1        0.070451        NaN     NaN      NaN
## dry1        -1.309663        NaN     NaN      NaN
## fenY         0.000000        NaN     NaN      NaN
## nutrient1    0.406631        NaN     NaN      NaN
## age:fenY     0.000000        NaN     NaN      NaN
## temp:fenY    0.000000        NaN     NaN      NaN
## moist:fenY   0.000000        NaN     NaN      NaN
## fire1:fenY   0.000000        NaN     NaN      NaN
## dry1:fenY    0.000000        NaN     NaN      NaN
##
## Zero-inflation model:
##              Estimate Std. Error z value Pr(>|z|)
## (Intercept) -7.178295        NaN     NaN      NaN
## age         -0.001256        NaN     NaN      NaN
## temp         1.492431        NaN     NaN      NaN
## moist        2.549162        NaN     NaN      NaN
## fire1        1.141552        NaN     NaN      NaN
## dry1        -0.551847        NaN     NaN      NaN
## fenY        -0.007616        NaN     NaN      NaN
## nutrient1   -1.336959        NaN     NaN      NaN
## age:fenY     0.003771        NaN     NaN      NaN
## temp:fenY   -0.113672        NaN     NaN      NaN
## moist:fenY  -0.028394        NaN     NaN      NaN
## fire1:fenY  -0.021857        NaN     NaN      NaN
## dry1:fenY   -0.026769        NaN     NaN      NaN
```

```
summary(mod_abund_Rubellum_all_ints)
```

```
##  Family: beta  ( logit )
## Formula:
## Rubellum_prop ~ (age + temp + moist + fire + dry) * fen + nutrient
## Zero inflation:                 ~.
## Data: data_peat
##
##      AIC      BIC   logLik deviance df.resid
##       NA       NA       NA       NA       61
##
##
## Dispersion parameter for beta family (): 8.62
##
```

```
## Conditional model:
##               Estimate Std. Error z value Pr(>|z|)
## (Intercept) -2.845e+00        NaN     NaN      NaN
## age          1.404e-04        NaN     NaN      NaN
## temp         2.429e-01        NaN     NaN      NaN
## moist       -3.119e-01        NaN     NaN      NaN
## fire1        1.744e+00        NaN     NaN      NaN
## dry1         1.179e-01        NaN     NaN      NaN
## fenY        -2.961e-08        NaN     NaN      NaN
## nutrient1   -6.738e-01        NaN     NaN      NaN
## age:fenY    -2.530e-04        NaN     NaN      NaN
## temp:fenY   -2.712e-07        NaN     NaN      NaN
## moist:fenY   6.810e-09        NaN     NaN      NaN
## fire1:fenY   0.000e+00        NaN     NaN      NaN
## dry1:fenY    0.000e+00        NaN     NaN      NaN
##
## Zero-inflation model:
##               Estimate Std. Error z value Pr(>|z|)
## (Intercept) -2.487e+00        NaN     NaN      NaN
## age         -9.737e-04        NaN     NaN      NaN
## temp         9.267e-01        NaN     NaN      NaN
## moist        9.997e-01        NaN     NaN      NaN
## fire1       -3.500e-01        NaN     NaN      NaN
## dry1        -1.099e+00        NaN     NaN      NaN
## fenY         5.344e+02        NaN     NaN      NaN
## nutrient1   -1.619e+00        NaN     NaN      NaN
## age:fenY     3.122e-01        NaN     NaN      NaN
## temp:fenY   -3.170e+02        NaN     NaN      NaN
## moist:fenY   1.393e+03        NaN     NaN      NaN
## fire1:fenY   3.448e+02        NaN     NaN      NaN
## dry1:fenY    6.982e+02        NaN     NaN      NaN
```

```
summary(mod_abund_Balticum_all_ints)
```

```
##  Family: beta  ( logit )
## Formula:
## Balticum_prop ~ (age + temp + moist + fire + dry) * fen + nutrient
## Zero inflation:                  ~.
## Data: data_peat
##
##      AIC      BIC   logLik deviance df.resid
##       NA       NA       NA       NA       61
##
##
## Dispersion parameter for beta family (): 10.7
##
## Conditional model:
##               Estimate Std. Error z value Pr(>|z|)
## (Intercept) -5.741e+00        NaN     NaN      NaN
## age          2.697e-04        NaN     NaN      NaN
## temp         5.914e-01        NaN     NaN      NaN
## moist        1.945e+00        NaN     NaN      NaN
## fire1        1.196e+00        NaN     NaN      NaN
## dry1        -1.930e+00        NaN     NaN      NaN
```

```
## fenY        -5.271e-08        NaN     NaN      NaN
## nutrient1    9.672e-01        NaN     NaN      NaN
## age:fenY    -3.668e-04        NaN     NaN      NaN
## temp:fenY   -5.227e-07        NaN     NaN      NaN
## moist:fenY  -2.108e-08        NaN     NaN      NaN
## fire1:fenY   0.000e+00        NaN     NaN      NaN
## dry1:fenY   -5.271e-08        NaN     NaN      NaN
##
## Zero-inflation model:
##               Estimate Std. Error z value Pr(>|z|)
## (Intercept)  1.654e+00        NaN     NaN      NaN
## age          1.503e-03        NaN     NaN      NaN
## temp        -5.693e-01        NaN     NaN      NaN
## moist       -1.108e-02        NaN     NaN      NaN
## fire1       -6.383e-01        NaN     NaN      NaN
## dry1         7.620e-01        NaN     NaN      NaN
## fenY         2.020e+02        NaN     NaN      NaN
## nutrient1   -1.840e-01        NaN     NaN      NaN
## age:fenY    -6.262e-02        NaN     NaN      NaN
## temp:fenY    5.433e+01        NaN     NaN      NaN
## moist:fenY   2.780e+02        NaN     NaN      NaN
## fire1:fenY   2.951e+02        NaN     NaN      NaN
## dry1:fenY   -4.504e+02        NaN     NaN      NaN
```

```
summary(mod_abund_Cuspidata_all_ints)
```

```
##  Family: beta  ( logit )
## Formula:
## Cuspidata_prop ~ (age + temp + moist + fire + dry) * fen + nutrient
## Zero inflation:                  ~.
## Data: data_peat
##
##      AIC      BIC   logLik deviance df.resid
##       NA       NA       NA       NA       61
##
##
## Dispersion parameter for beta family (): 5.68
##
## Conditional model:
##               Estimate Std. Error z value Pr(>|z|)
## (Intercept) -4.105e+00        NaN     NaN      NaN
## age         -6.525e-05        NaN     NaN      NaN
## temp         4.454e-01        NaN     NaN      NaN
## moist        8.771e-02        NaN     NaN      NaN
## fire1        1.105e-01        NaN     NaN      NaN
## dry1        -1.976e-01        NaN     NaN      NaN
## fenY        -1.746e-08        NaN     NaN      NaN
## nutrient1   -5.957e-01        NaN     NaN      NaN
## age:fenY    -1.492e-04        NaN     NaN      NaN
## temp:fenY   -1.599e-07        NaN     NaN      NaN
## moist:fenY   4.015e-09        NaN     NaN      NaN
## fire1:fenY   0.000e+00        NaN     NaN      NaN
## dry1:fenY    0.000e+00        NaN     NaN      NaN
##
```

```
## Zero-inflation model:
##               Estimate Std. Error z value Pr(>|z|)
## (Intercept)  1.369e-01        NaN     NaN      NaN
## age          6.564e-04        NaN     NaN      NaN
## temp        -3.200e-03        NaN     NaN      NaN
## moist       -1.425e+00        NaN     NaN      NaN
## fire1       -8.075e-01        NaN     NaN      NaN
## dry1         2.421e-01        NaN     NaN      NaN
## fenY         4.283e+02        NaN     NaN      NaN
## nutrient1   -1.477e+00        NaN     NaN      NaN
## age:fenY     3.516e-01        NaN     NaN      NaN
## temp:fenY   -3.387e+02        NaN     NaN      NaN
## moist:fenY   1.545e+03        NaN     NaN      NaN
## fire1:fenY   3.424e+02        NaN     NaN      NaN
## dry1:fenY    3.978e+02        NaN     NaN      NaN
```

And all the NaNs in the summaries.

I looked here https://cran.r-project.org/web/packages/glmmTMB/vignettes/troubleshooting.html but I am not sure how to solve this. It might be that the model is overparameterized (i.e. the data does not contain enough information to estimate the parameters reliably). So maybe here you should try to test the interactions one by one. Although then you do it in a different way for the plant groups and for the selected Sphagnum species. But I cannot think of a better solution!

Step 1 (alternative): Models testing interactions one by one (except fen*nutrient) Try to test each interaction separately (except with nutrient):

```
mod_abund_Medium_age_int<-glmmTMB(Medium_prop~age*fen+temp+moist+nutrient+
                            fire+dry,family="beta_family",
                          ziformula=~.,data=data_peat)
mod_abund_Medium_temp_int<-glmmTMB(Medium_prop~age+temp*fen+moist+nutrient+
                            fire+dry,family="beta_family",
                          ziformula=~.,data=data_peat)
mod_abund_Medium_moist_int<-glmmTMB(Medium_prop~age+temp+moist*fen+nutrient+
                            fire+dry,family="beta_family",
                          ziformula=~.,data=data_peat)
mod_abund_Medium_fire_int<-glmmTMB(Medium_prop~age+temp+moist+nutrient+
                            fire*fen+dry,family="beta_family",
                          ziformula=~.,data=data_peat)
mod_abund_Medium_dry_int<-glmmTMB(Medium_prop~age+temp+moist+nutrient+
                            fire+dry*fen,family="beta_family",
                          ziformula=~.,data=data_peat)
mod_abund_Fuscum_age_int<-glmmTMB(Fuscum_prop~age*fen+temp+moist+nutrient+
                            fire+dry,family="beta_family",
                          ziformula=~.,data=data_peat)
mod_abund_Fuscum_temp_int<-glmmTMB(Fuscum_prop~age+temp*fen+moist+nutrient+
                            fire+dry,family="beta_family",
                          ziformula=~.,data=data_peat)
mod_abund_Fuscum_moist_int<-glmmTMB(Fuscum_prop~age+temp+moist*fen+nutrient+
                            fire+dry,family="beta_family",
                          ziformula=~.,data=data_peat)
mod_abund_Fuscum_fire_int<-glmmTMB(Fuscum_prop~age+temp+moist+nutrient+
                            fire*fen+dry,family="beta_family",
                          ziformula=~.,data=data_peat)
```

```
mod_abund_Fuscum_dry_int<-glmmTMB(Fuscum_prop~age+temp+moist+nutrient+
                            fire+dry*fen,family="beta_family",
                          ziformula=~.,data=data_peat)
mod_abund_Rubellum_age_int<-glmmTMB(Rubellum_prop~age*fen+temp+moist+nutrient+
                            fire+dry,family="beta_family",
                          ziformula=~.,data=data_peat)
mod_abund_Rubellum_temp_int<-glmmTMB(Rubellum_prop~age+temp*fen+moist+nutrient+
                            fire+dry,family="beta_family",
                          ziformula=~.,data=data_peat)
mod_abund_Rubellum_moist_int<-glmmTMB(Rubellum_prop~age+temp+moist*fen+nutrient+
                            fire+dry,family="beta_family",
                          ziformula=~.,data=data_peat)
mod_abund_Rubellum_fire_int<-glmmTMB(Rubellum_prop~age+temp+moist+nutrient+
                            fire*fen+dry,family="beta_family",
                          ziformula=~.,data=data_peat)
mod_abund_Rubellum_dry_int<-glmmTMB(Rubellum_prop~age+temp+moist+nutrient+
                            fire+dry*fen,family="beta_family",
                          ziformula=~.,data=data_peat)
mod_abund_Balticum_age_int<-glmmTMB(Balticum_prop~age*fen+temp+moist+nutrient+
                            fire+dry,family="beta_family",
                          ziformula=~.,data=data_peat)
mod_abund_Balticum_temp_int<-glmmTMB(Balticum_prop~age+temp*fen+moist+nutrient+
                            fire+dry,family="beta_family",
                          ziformula=~.,data=data_peat)
mod_abund_Balticum_moist_int<-glmmTMB(Balticum_prop~age+temp+moist*fen+nutrient+
                            fire+dry,family="beta_family",
                          ziformula=~.,data=data_peat)
mod_abund_Balticum_fire_int<-glmmTMB(Balticum_prop~age+temp+moist+nutrient+
                            fire*fen+dry,family="beta_family",
                          ziformula=~.,data=data_peat)
mod_abund_Balticum_dry_int<-glmmTMB(Balticum_prop~age+temp+moist+nutrient+
                            fire+dry*fen,family="beta_family",
                          ziformula=~.,data=data_peat)
mod_abund_Cuspidata_age_int<-glmmTMB(Cuspidata_prop~age*fen+temp+moist+nutrient+
                            fire+dry,family="beta_family",
                          ziformula=~.,data=data_peat)
mod_abund_Cuspidata_temp_int<-glmmTMB(Cuspidata_prop~age+temp*fen+moist+nutrient+
                            fire+dry,family="beta_family",
                          ziformula=~.,data=data_peat)
mod_abund_Cuspidata_moist_int<-glmmTMB(Cuspidata_prop~age+temp+moist*fen+nutrient+
                            fire+dry,family="beta_family",
                          ziformula=~.,data=data_peat)
mod_abund_Cuspidata_fire_int<-glmmTMB(Cuspidata_prop~age+temp+moist+nutrient+
                            fire*fen+dry,family="beta_family",
                          ziformula=~.,data=data_peat)
mod_abund_Cuspidata_dry_int<-glmmTMB(Cuspidata_prop~age+temp+moist+nutrient+
                            fire+dry*fen,family="beta_family",
                          ziformula=~.,data=data_peat)
```

```
summary(mod_abund_Medium_age_int) # Model OK, interaction NS
```

```
##  Family: beta  ( logit )
## Formula:
```

```
## Medium_prop ~ age * fen + temp + moist + nutrient + fire + dry
## Zero inflation:               ~.
## Data: data_peat
##
##      AIC      BIC   logLik deviance df.resid
##     89.2    136.2    -25.6     51.2       69
##
##
## Dispersion parameter for beta family (): 2.62
##
## Conditional model:
##               Estimate Std. Error z value Pr(>|z|)
## (Intercept)  2.828e+00  2.062e+00   1.371  0.17033
## age          1.574e-05  1.890e-04   0.083  0.93365
## fenY         5.173e+00  6.061e+00   0.853  0.39340
## temp        -2.690e-01  3.095e-01  -0.869  0.38479
## moist        4.748e-01  4.311e-01   1.101  0.27074
## nutrient1   -1.385e+00  4.379e-01  -3.162  0.00156 **
## fire1       -1.779e+00  6.505e-01  -2.735  0.00625 **
## dry1         7.113e-01  4.675e-01   1.522  0.12809
## age:fenY    -7.364e-04  8.918e-04  -0.826  0.40895
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Zero-inflation model:
##               Estimate Std. Error z value Pr(>|z|)
## (Intercept) -1.4135333  3.9238953  -0.360   0.7187
## age          0.0007839  0.0003286   2.386   0.0171 *
## fenY         2.9284331  7.6580950   0.382   0.7022
## temp        -0.1887657  0.5944084  -0.318   0.7508
## moist       -0.6475030  0.7064990  -0.916   0.3594
## nutrient1    0.6693750  0.6767250   0.989   0.3226
## fire1       -1.6619150  0.9533872  -1.743   0.0813 .
## dry1         0.8839507  0.6560802   1.347   0.1779
## age:fenY    -0.0004300  0.0010992  -0.391   0.6957
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
summary(mod_abund_Medium_temp_int) # Model OK, interaction NS
```

```
##  Family: beta  ( logit )
## Formula:
## Medium_prop ~ age + temp * fen + moist + nutrient + fire + dry
## Zero inflation:               ~.
## Data: data_peat
##
##      AIC      BIC   logLik deviance df.resid
##     86.2    133.3    -24.1     48.2       69
##
##
## Dispersion parameter for beta family (): 2.62
##
## Conditional model:
##               Estimate Std. Error z value Pr(>|z|)
```

```
## (Intercept)  2.828e+00  2.062e+00   1.371  0.17033
## age          1.574e-05  1.890e-04   0.083  0.93365
## temp        -2.690e-01  3.095e-01  -0.869  0.38479
## fenY        -9.799e+00  1.220e+01  -0.803  0.42169
## moist        4.748e-01  4.311e-01   1.101  0.27074
## nutrient1   -1.385e+00  4.379e-01  -3.162  0.00156 **
## fire1       -1.779e+00  6.505e-01  -2.735  0.00625 **
## dry1         7.113e-01  4.675e-01   1.522  0.12809
## temp:fenY    1.150e+00  1.393e+00   0.826  0.40895
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Zero-inflation model:
##               Estimate Std. Error z value Pr(>|z|)
## (Intercept)  2.353e+00  4.263e+00   0.552  0.58089
## age          1.086e-03  3.737e-04   2.907  0.00365 **
## temp        -7.816e-01  6.667e-01  -1.172  0.24102
## fenY        -2.513e+01  1.532e+01  -1.641  0.10087
## moist       -6.293e-01  7.265e-01  -0.866  0.38634
## nutrient1    8.141e-01  6.901e-01   1.180  0.23817
## fire1       -1.631e+00  9.202e-01  -1.773  0.07627 .
## dry1         7.350e-01  6.619e-01   1.110  0.26679
## temp:fenY    2.757e+00  1.701e+00   1.621  0.10509
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
summary(mod_abund_Medium_moist_int) # Model OK, interaction NS
```

```
##  Family: beta  ( logit )
## Formula:
## Medium_prop ~ age + temp + moist * fen + nutrient + fire + dry
## Zero inflation:               ~.
## Data: data_peat
##
##      AIC      BIC   logLik deviance df.resid
##     89.2    136.3    -25.6     51.2       69
##
##
## Dispersion parameter for beta family (): 2.62
##
## Conditional model:
##               Estimate Std. Error z value Pr(>|z|)
## (Intercept)  2.828e+00  2.062e+00   1.371  0.17033
## age          1.574e-05  1.890e-04   0.083  0.93366
## temp        -2.690e-01  3.095e-01  -0.869  0.38479
## moist        4.748e-01  4.311e-01   1.101  0.27074
## fenY        -1.755e+01  2.156e+01  -0.814  0.41573
## nutrient1   -1.385e+00  4.379e-01  -3.162  0.00156 **
## fire1       -1.779e+00  6.505e-01  -2.735  0.00625 **
## dry1         7.113e-01  4.675e-01   1.522  0.12809
## moist:fenY   3.905e+01  4.729e+01   0.826  0.40895
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
```

```
## Zero-inflation model:
##               Estimate Std. Error z value Pr(>|z|)
## (Intercept) -1.9462317  3.5489825  -0.548   0.5834
## age          0.0007370  0.0002896   2.545   0.0109 *
## temp        -0.1055723  0.5325141  -0.198   0.8428
## moist       -0.6876450  0.7158145  -0.961   0.3367
## fenY        -0.3799067  1.8566279  -0.205   0.8379
## nutrient1    0.6509970  0.6774534   0.961   0.3366
## fire1       -1.6180499  0.9434642  -1.715   0.0863 .
## dry1         0.9272115  0.6417740   1.445   0.1485
## moist:fenY   0.8247042  3.1162849   0.265   0.7913
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
summary(mod_abund_Medium_fire_int) # Model OK, interaction NS
```

```
##  Family: beta  ( logit )
## Formula:
## Medium_prop ~ age + temp + moist + nutrient + fire * fen + dry
## Zero inflation:                ~.
## Data: data_peat
##
##      AIC      BIC   logLik deviance df.resid
##     89.0    136.0    -25.5     51.0       69
##
##
## Dispersion parameter for beta family (): 2.62
##
## Conditional model:
##               Estimate Std. Error z value Pr(>|z|)
## (Intercept)  2.828e+00  2.062e+00   1.371  0.17033
## age          1.574e-05  1.890e-04   0.083  0.93365
## temp        -2.690e-01  3.095e-01  -0.869  0.38479
## moist        4.748e-01  4.311e-01   1.101  0.27074
## nutrient1   -1.385e+00  4.379e-01  -3.162  0.00156 **
## fire1       -1.779e+00  6.505e-01  -2.735  0.00625 **
## fenY         8.055e-01  1.218e+00   0.661  0.50835
## dry1         7.113e-01  4.675e-01   1.522  0.12809
## fire1:fenY  -1.562e+00  1.892e+00  -0.826  0.40895
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Zero-inflation model:
##               Estimate Std. Error z value Pr(>|z|)
## (Intercept) -1.9670895  3.4012149  -0.578  0.56303
## age          0.0007369  0.0002786   2.645  0.00817 **
## temp        -0.0966376  0.5094610  -0.190  0.84956
## moist       -0.6685442  0.7097105  -0.942  0.34619
## nutrient1    0.6149666  0.6840187   0.899  0.36863
## fire1       -1.9265485  1.1669302  -1.651  0.09875 .
## fenY        -0.5142454  1.4592305  -0.352  0.72453
## dry1         0.9262137  0.6398419   1.448  0.14774
## fire1:fenY   1.1609835  1.9764061   0.587  0.55692
## ---
```

```
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
summary(mod_abund_Medium_dry_int) # Model OK, interaction NS
```

```
##  Family: beta  ( logit )
## Formula:
## Medium_prop ~ age + temp + moist + nutrient + fire + dry * fen
## Zero inflation:               ~.
## Data: data_peat
##
##      AIC      BIC   logLik deviance df.resid
##     88.9    136.0    -25.4     50.9       69
##
##
## Dispersion parameter for beta family (): 2.62
##
## Conditional model:
##               Estimate Std. Error z value Pr(>|z|)
## (Intercept)  2.828e+00  2.062e+00   1.371  0.17033
## age          1.574e-05  1.890e-04   0.083  0.93365
## temp        -2.690e-01  3.095e-01  -0.869  0.38479
## moist        4.748e-01  4.311e-01   1.101  0.27074
## nutrient1   -1.385e+00  4.379e-01  -3.162  0.00156 **
## fire1       -1.779e+00  6.505e-01  -2.735  0.00625 **
## dry1         7.113e-01  4.675e-01   1.522  0.12809
## fenY        -7.564e-01  1.568e+00  -0.482  0.62946
## dry1:fenY    1.562e+00  1.892e+00   0.826  0.40895
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Zero-inflation model:
##               Estimate Std. Error z value Pr(>|z|)
## (Intercept) -1.1750974  3.6404959  -0.323  0.74686
## age          0.0008029  0.0003045   2.637  0.00837 **
## temp        -0.2207095  0.5466516  -0.404  0.68640
## moist       -0.6597724  0.7091249  -0.930  0.35216
## nutrient1    0.6498826  0.6752716   0.962  0.33585
## fire1       -1.7316227  0.9746402  -1.777  0.07562 .
## dry1         0.8169093  0.6666689   1.225  0.22044
## fenY        -0.7897658  1.6858374  -0.469  0.63945
## dry1:fenY    1.2978607  1.9983288   0.649  0.51603
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
summary(mod_abund_Fuscum_age_int) # NaNs produced
```

```
##  Family: beta  ( logit )
## Formula:
## Fuscum_prop ~ age * fen + temp + moist + nutrient + fire + dry
## Zero inflation:               ~.
## Data: data_peat
##
##      AIC      BIC   logLik deviance df.resid
```

```
##       NA       NA       NA       NA       69
##
##
## Dispersion parameter for beta family (): 6.28
##
## Conditional model:
##              Estimate Std. Error z value Pr(>|z|)
## (Intercept)  1.058775        NaN     NaN      NaN
## age          0.000797        NaN     NaN      NaN
## fenY         0.000000        NaN     NaN      NaN
## temp        -0.478576        NaN     NaN      NaN
## moist       -0.021484        NaN     NaN      NaN
## nutrient1    0.406631        NaN     NaN      NaN
## fire1        0.070453        NaN     NaN      NaN
## dry1        -1.309663        NaN     NaN      NaN
## age:fenY     0.000000        NaN     NaN      NaN
##
## Zero-inflation model:
##              Estimate Std. Error z value Pr(>|z|)
## (Intercept) -7.178285        NaN     NaN      NaN
## age         -0.001256        NaN     NaN      NaN
## fenY        -0.006417        NaN     NaN      NaN
## temp         1.492428        NaN     NaN      NaN
## moist        2.549153        NaN     NaN      NaN
## nutrient1   -1.336956        NaN     NaN      NaN
## fire1        1.141551        NaN     NaN      NaN
## dry1        -0.551846        NaN     NaN      NaN
## age:fenY     0.003508        NaN     NaN      NaN
```

```
summary(mod_abund_Fuscum_temp_int) # NaNs produced
```

```
##  Family: beta  ( logit )
## Formula:
## Fuscum_prop ~ age + temp * fen + moist + nutrient + fire + dry
## Zero inflation:                ~.
## Data: data_peat
##
##      AIC      BIC   logLik deviance df.resid
##       NA       NA       NA       NA       69
##
##
## Dispersion parameter for beta family (): 6.28
##
## Conditional model:
##              Estimate Std. Error z value Pr(>|z|)
## (Intercept)  1.058769        NaN     NaN      NaN
## age          0.000797        NaN     NaN      NaN
## temp        -0.478576        NaN     NaN      NaN
## fenY         0.000000        NaN     NaN      NaN
## moist       -0.021485        NaN     NaN      NaN
## nutrient1    0.406631        NaN     NaN      NaN
## fire1        0.070450        NaN     NaN      NaN
## dry1        -1.309664        NaN     NaN      NaN
## temp:fenY    0.000000        NaN     NaN      NaN
```

```
##
## Zero-inflation model:
##              Estimate Std. Error z value Pr(>|z|)
## (Intercept) -7.178294        NaN     NaN      NaN
## age         -0.001256        NaN     NaN      NaN
## temp         1.492431        NaN     NaN      NaN
## fenY         2.252187        NaN     NaN      NaN
## moist        2.549165        NaN     NaN      NaN
## nutrient1   -1.336959        NaN     NaN      NaN
## fire1        1.141553        NaN     NaN      NaN
## dry1        -0.551848        NaN     NaN      NaN
## temp:fenY    3.199996        NaN     NaN      NaN
```

```
summary(mod_abund_Fuscum_moist_int) # NaNs produced
```

```
##  Family: beta  ( logit )
## Formula:
## Fuscum_prop ~ age + temp + moist * fen + nutrient + fire + dry
## Zero inflation:               ~.
## Data: data_peat
##
##      AIC      BIC   logLik deviance df.resid
##       NA       NA       NA       NA       69
##
##
## Dispersion parameter for beta family (): 6.28
##
## Conditional model:
##              Estimate Std. Error z value Pr(>|z|)
## (Intercept)  1.058762        NaN     NaN      NaN
## age          0.000797        NaN     NaN      NaN
## temp        -0.478575        NaN     NaN      NaN
## moist       -0.021485        NaN     NaN      NaN
## fenY         0.000000        NaN     NaN      NaN
## nutrient1    0.406631        NaN     NaN      NaN
## fire1        0.070451        NaN     NaN      NaN
## dry1        -1.309663        NaN     NaN      NaN
## moist:fenY   0.000000        NaN     NaN      NaN
##
## Zero-inflation model:
##              Estimate Std. Error z value Pr(>|z|)
## (Intercept) -7.178272        NaN     NaN      NaN
## age         -0.001256        NaN     NaN      NaN
## temp         1.492427        NaN     NaN      NaN
## moist        2.549159        NaN     NaN      NaN
## fenY        28.974406        NaN     NaN      NaN
## nutrient1   -1.336957        NaN     NaN      NaN
## fire1        1.141550        NaN     NaN      NaN
## dry1        -0.551847        NaN     NaN      NaN
## moist:fenY  -7.066961        NaN     NaN      NaN
```

```
summary(mod_abund_Fuscum_fire_int) # NaNs produced
```

```
##  Family: beta  ( logit )
## Formula:
## Fuscum_prop ~ age + temp + moist + nutrient + fire * fen + dry
## Zero inflation:               ~.
## Data: data_peat
##
##      AIC      BIC   logLik deviance df.resid
##       NA       NA       NA       NA       69
##
##
## Dispersion parameter for beta family (): 6.28
##
## Conditional model:
##              Estimate Std. Error z value Pr(>|z|)
## (Intercept)  1.058762        NaN     NaN      NaN
## age          0.000797        NaN     NaN      NaN
## temp        -0.478575        NaN     NaN      NaN
## moist       -0.021485        NaN     NaN      NaN
## nutrient1    0.406631        NaN     NaN      NaN
## fire1        0.070453        NaN     NaN      NaN
## fenY         0.000000        NaN     NaN      NaN
## dry1        -1.309663        NaN     NaN      NaN
## fire1:fenY   0.000000        NaN     NaN      NaN
##
## Zero-inflation model:
##              Estimate Std. Error z value Pr(>|z|)
## (Intercept) -7.178302        NaN     NaN      NaN
## age         -0.001256        NaN     NaN      NaN
## temp         1.492433        NaN     NaN      NaN
## moist        2.549169        NaN     NaN      NaN
## nutrient1   -1.336961        NaN     NaN      NaN
## fire1        1.141555        NaN     NaN      NaN
## fenY        28.329500        NaN     NaN      NaN
## dry1        -0.551845        NaN     NaN      NaN
## fire1:fenY  -4.173372        NaN     NaN      NaN
```

```
summary(mod_abund_Fuscum_dry_int) # NaNs produced
```

```
##  Family: beta  ( logit )
## Formula:
## Fuscum_prop ~ age + temp + moist + nutrient + fire + dry * fen
## Zero inflation:               ~.
## Data: data_peat
##
##      AIC      BIC   logLik deviance df.resid
##       NA       NA       NA       NA       69
##
##
## Dispersion parameter for beta family (): 6.28
##
## Conditional model:
##              Estimate Std. Error z value Pr(>|z|)
## (Intercept)  1.058772        NaN     NaN      NaN
## age          0.000797        NaN     NaN      NaN
```

```
## temp        -0.478576        NaN     NaN      NaN
## moist       -0.021485        NaN     NaN      NaN
## nutrient1    0.406631        NaN     NaN      NaN
## fire1        0.070450        NaN     NaN      NaN
## dry1        -1.309664        NaN     NaN      NaN
## fenY         0.000000        NaN     NaN      NaN
## dry1:fenY    0.000000        NaN     NaN      NaN
##
## Zero-inflation model:
##              Estimate Std. Error z value Pr(>|z|)
## (Intercept) -7.178310        NaN     NaN      NaN
## age         -0.001256        NaN     NaN      NaN
## temp         1.492434        NaN     NaN      NaN
## moist        2.549170        NaN     NaN      NaN
## nutrient1   -1.336963        NaN     NaN      NaN
## fire1        1.141556        NaN     NaN      NaN
## dry1        -0.551850        NaN     NaN      NaN
## fenY        27.519190        NaN     NaN      NaN
## dry1:fenY   -2.201093        NaN     NaN      NaN
```

```
summary(mod_abund_Rubellum_age_int) # NaNs produced
```

```
##  Family: beta  ( logit )
## Formula:          Rubellum_prop ~ age * fen + temp + moist + nutrient + fire +
##     dry
## Zero inflation:                 ~.
## Data: data_peat
##
##      AIC      BIC   logLik deviance df.resid
##     81.8    128.9    -21.9     43.8       69
##
##
## Dispersion parameter for beta family (): 8.62
##
## Conditional model:
##               Estimate Std. Error z value Pr(>|z|)
## (Intercept) -2.845e+00  1.561e+00  -1.823  0.06834 .
## age          1.404e-04        NaN     NaN      NaN
## fenY        -2.961e-08        NaN     NaN      NaN
## temp         2.429e-01  1.820e-01   1.335  0.18202
## moist       -3.119e-01  3.239e-01  -0.963  0.33545
## nutrient1   -6.738e-01  3.699e-01  -1.822  0.06851 .
## fire1        1.744e+00  6.573e-01   2.653  0.00798 **
## dry1         1.179e-01  2.875e-01   0.410  0.68166
## age:fenY    -2.530e-04        NaN     NaN      NaN
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Zero-inflation model:
##               Estimate Std. Error z value Pr(>|z|)
## (Intercept) -0.1002828        NaN     NaN      NaN
## age         -0.0007854        NaN     NaN      NaN
## fenY        69.9654654        NaN     NaN      NaN
## temp         0.5478435        NaN     NaN      NaN
```

```
## moist        1.0152614  0.6399478   1.586   0.1126
## nutrient1   -1.5115831  0.6743465  -2.242   0.0250 *
## fire1       -0.4192099  0.8909836  -0.470   0.6380
## dry1        -1.1301769  0.4921143  -2.297   0.0216 *
## age:fenY    -0.0077825        NaN     NaN      NaN
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
summary(mod_abund_Rubellum_temp_int) # NaNs produced
```

```
##  Family: beta  ( logit )
## Formula:          Rubellum_prop ~ age + temp * fen + moist + nutrient + fire +
##     dry
## Zero inflation:                 ~.
## Data: data_peat
##
##      AIC      BIC   logLik deviance df.resid
##       NA       NA       NA       NA       69
##
##
## Dispersion parameter for beta family (): 8.62
##
## Conditional model:
##               Estimate Std. Error z value Pr(>|z|)
## (Intercept) -2.8449171        NaN     NaN      NaN
## age          0.0001404        NaN     NaN      NaN
## temp         0.2429268        NaN     NaN      NaN
## fenY        -0.0254638        NaN     NaN      NaN
## moist       -0.3119388        NaN     NaN      NaN
## nutrient1   -0.6738322        NaN     NaN      NaN
## fire1        1.7436209        NaN     NaN      NaN
## dry1         0.1179176        NaN     NaN      NaN
## temp:fenY   -0.2332688        NaN     NaN      NaN
##
## Zero-inflation model:
##              Estimate Std. Error z value Pr(>|z|)
## (Intercept) -4.077000        NaN     NaN      NaN
## age         -0.001132        NaN     NaN      NaN
## temp         1.181369        NaN     NaN      NaN
## fenY        26.176090        NaN     NaN      NaN
## moist        1.197068        NaN     NaN      NaN
## nutrient1   -1.606874        NaN     NaN      NaN
## fire1       -0.264263        NaN     NaN      NaN
## dry1        -0.986026        NaN     NaN      NaN
## temp:fenY   -2.366361        NaN     NaN      NaN
```

```
summary(mod_abund_Rubellum_moist_int) # NaNs produced
```

```
##  Family: beta  ( logit )
## Formula:          Rubellum_prop ~ age + temp + moist * fen + nutrient + fire +
##     dry
## Zero inflation:                 ~.
## Data: data_peat
```

```
##
##      AIC      BIC   logLik deviance df.resid
##       NA       NA       NA       NA       69
##
##
## Dispersion parameter for beta family (): 8.62
##
## Conditional model:
##               Estimate Std. Error z value Pr(>|z|)
## (Intercept) -2.8449153        NaN     NaN      NaN
## age          0.0001404        NaN     NaN      NaN
## temp         0.2429265        NaN     NaN      NaN
## moist       -0.3119392        NaN     NaN      NaN
## fenY        -2.0537487        NaN     NaN      NaN
## nutrient1   -0.6738317        NaN     NaN      NaN
## fire1        1.7436215        NaN     NaN      NaN
## dry1         0.1179181        NaN     NaN      NaN
## moist:fenY   0.4723622        NaN     NaN      NaN
##
## Zero-inflation model:
##               Estimate Std. Error z value Pr(>|z|)
## (Intercept) -0.2934621        NaN     NaN      NaN
## age         -0.0008007        NaN     NaN      NaN
## temp         0.5776468        NaN     NaN      NaN
## moist        1.0121215        NaN     NaN      NaN
## fenY         4.5759818        NaN     NaN      NaN
## nutrient1   -1.5156453        NaN     NaN      NaN
## fire1       -0.4026938        NaN     NaN      NaN
## dry1        -1.1224719        NaN     NaN      NaN
## moist:fenY   4.2961463        NaN     NaN      NaN
```

```
summary(mod_abund_Rubellum_fire_int) # NaNs produced
```

```
##  Family: beta  ( logit )
## Formula:          Rubellum_prop ~ age + temp + moist + nutrient + fire * fen +
##     dry
## Zero inflation:                 ~.
## Data: data_peat
##
##      AIC      BIC   logLik deviance df.resid
##       NA       NA       NA       NA       69
##
##
## Dispersion parameter for beta family (): 8.62
##
## Conditional model:
##               Estimate Std. Error z value Pr(>|z|)
## (Intercept) -2.8449153        NaN     NaN      NaN
## age          0.0001404        NaN     NaN      NaN
## temp         0.2429265        NaN     NaN      NaN
## moist       -0.3119390        NaN     NaN      NaN
## nutrient1   -0.6738322        NaN     NaN      NaN
## fire1        1.7436218        NaN     NaN      NaN
## fenY        -2.1623940        NaN     NaN      NaN
```

```
## dry1         0.1179176        NaN     NaN      NaN
## fire1:fenY   0.0000000        NaN     NaN      NaN
##
## Zero-inflation model:
##               Estimate Std. Error z value Pr(>|z|)
## (Intercept) -0.5297667        NaN     NaN      NaN
## age         -0.0008315        NaN     NaN      NaN
## temp         0.6183178        NaN     NaN      NaN
## moist        1.1294972        NaN     NaN      NaN
## nutrient1   -1.5005695        NaN     NaN      NaN
## fire1       -0.4319395        NaN     NaN      NaN
## fenY         4.1882182        NaN     NaN      NaN
## dry1        -1.1085862        NaN     NaN      NaN
## fire1:fenY  18.2487631        NaN     NaN      NaN
```

```
summary(mod_abund_Rubellum_dry_int) # NaNs produced
```

```
##  Family: beta  ( logit )
## Formula:          Rubellum_prop ~ age + temp + moist + nutrient + fire + dry *
##     fen
## Zero inflation:                 ~.
## Data: data_peat
##
##      AIC      BIC   logLik deviance df.resid
##       NA       NA       NA       NA       69
##
##
## Dispersion parameter for beta family (): 8.62
##
## Conditional model:
##               Estimate Std. Error z value Pr(>|z|)
## (Intercept) -2.8449137        NaN     NaN      NaN
## age          0.0001404        NaN     NaN      NaN
## temp         0.2429263        NaN     NaN      NaN
## moist       -0.3119390        NaN     NaN      NaN
## nutrient1   -0.6738314        NaN     NaN      NaN
## fire1        1.7436214        NaN     NaN      NaN
## dry1         0.1179176        NaN     NaN      NaN
## fenY        -2.1623918        NaN     NaN      NaN
## dry1:fenY    0.0000000        NaN     NaN      NaN
##
## Zero-inflation model:
##               Estimate Std. Error z value Pr(>|z|)
## (Intercept) -0.0134603        NaN     NaN      NaN
## age         -0.0007847        NaN     NaN      NaN
## temp         0.5332318        NaN     NaN      NaN
## moist        1.1358541        NaN     NaN      NaN
## nutrient1   -1.4645054        NaN     NaN      NaN
## fire1       -0.3527860        NaN     NaN      NaN
## dry1        -1.1562221        NaN     NaN      NaN
## fenY         4.0441157        NaN     NaN      NaN
## dry1:fenY   18.0237806        NaN     NaN      NaN
```

```r
summary(mod_abund_Balticum_age_int) # NaNs produced
```

```
##  Family: beta  ( logit )
## Formula:          Balticum_prop ~ age * fen + temp + moist + nutrient + fire +
##     dry
## Zero inflation:                ~.
## Data: data_peat
##
##      AIC      BIC   logLik deviance df.resid
##       NA       NA       NA       NA       69
##
##
## Dispersion parameter for beta family (): 10.7
##
## Conditional model:
##               Estimate Std. Error z value Pr(>|z|)
## (Intercept) -5.741e+00  1.796e+00  -3.197 0.001391 **
## age          2.697e-04        NaN     NaN      NaN
## fenY        -5.271e-08        NaN     NaN      NaN
## temp         5.914e-01  2.202e-01   2.686 0.007234 **
## moist        1.945e+00  5.458e-01   3.564 0.000366 ***
## nutrient1    9.672e-01  3.969e-01   2.437 0.014823 *
## fire1        1.196e+00  6.478e-01   1.847 0.064778 .
## dry1        -1.930e+00  6.517e-01  -2.961 0.003068 **
## age:fenY    -3.668e-04        NaN     NaN      NaN
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Zero-inflation model:
##               Estimate Std. Error z value Pr(>|z|)
## (Intercept)  2.9794245 11.3995204   0.261  0.79381
## age          0.0016241  0.0005954   2.728  0.00638 **
## fenY         3.7252081 13.5308624   0.275  0.78308
## temp        -0.7741142  1.6800513  -0.461  0.64496
## moist        0.0887609  0.9309699   0.095  0.92404
## nutrient1   -0.1208410  0.7714424  -0.157  0.87553
## fire1       -0.2987166  1.1451319  -0.261  0.79420
## dry1         0.4009667  0.9256097   0.433  0.66488
## age:fenY    -0.0012186  0.0017269  -0.706  0.48040
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```r
summary(mod_abund_Balticum_temp_int) # NaNs produced
```

```
##  Family: beta  ( logit )
## Formula:          Balticum_prop ~ age + temp * fen + moist + nutrient + fire +
##     dry
## Zero inflation:                ~.
## Data: data_peat
##
##      AIC      BIC   logLik deviance df.resid
##       NA       NA       NA       NA       69
```

```
##
##
## Dispersion parameter for beta family (): 10.7
##
## Conditional model:
##               Estimate Std. Error z value Pr(>|z|)
## (Intercept) -5.7411448        NaN     NaN      NaN
## age          0.0002697        NaN     NaN      NaN
## temp         0.5913520        NaN     NaN      NaN
## fenY        -0.0256939        NaN     NaN      NaN
## moist        1.9450446        NaN     NaN      NaN
## nutrient1    0.9671606        NaN     NaN      NaN
## fire1        1.1962959        NaN     NaN      NaN
## dry1        -1.9297110        NaN     NaN      NaN
## temp:fenY   -0.2548086        NaN     NaN      NaN
##
## Zero-inflation model:
##              Estimate Std. Error z value Pr(>|z|)
## (Intercept)  1.240417        NaN     NaN      NaN
## age          0.001444        NaN     NaN      NaN
## temp        -0.485660        NaN     NaN      NaN
## fenY        22.431199        NaN     NaN      NaN
## moist        0.093437        NaN     NaN      NaN
## nutrient1   -0.219735        NaN     NaN      NaN
## fire1       -0.258313        NaN     NaN      NaN
## dry1         0.403929        NaN     NaN      NaN
## temp:fenY   -2.765786        NaN     NaN      NaN
```

```
summary(mod_abund_Balticum_moist_int) # NaNs produced
```

```
##  Family: beta  ( logit )
## Formula:          Balticum_prop ~ age + temp + moist * fen + nutrient + fire +
##     dry
## Zero inflation:                 ~.
## Data: data_peat
##
##      AIC      BIC   logLik deviance df.resid
##       NA       NA       NA       NA       69
##
##
## Dispersion parameter for beta family (): 10.7
##
## Conditional model:
##               Estimate Std. Error z value Pr(>|z|)
## (Intercept) -5.7411444        NaN     NaN      NaN
## age          0.0002697        NaN     NaN      NaN
## temp         0.5913519        NaN     NaN      NaN
## moist        1.9450451        NaN     NaN      NaN
## fenY        -2.2005624        NaN     NaN      NaN
## nutrient1    0.9671616        NaN     NaN      NaN
## fire1        1.1962954        NaN     NaN      NaN
## dry1        -1.9297101        NaN     NaN      NaN
## moist:fenY  -0.8802249        NaN     NaN      NaN
##
```

```
## Zero-inflation model:
##              Estimate Std. Error z value Pr(>|z|)
## (Intercept)  2.318668        NaN     NaN      NaN
## age          0.001517        NaN     NaN      NaN
## temp        -0.660293        NaN     NaN      NaN
## moist        0.010382        NaN     NaN      NaN
## fenY        -5.296227        NaN     NaN      NaN
## nutrient1   -0.170125        NaN     NaN      NaN
## fire1       -0.195522        NaN     NaN      NaN
## dry1         0.478653        NaN     NaN      NaN
## moist:fenY   2.451429        NaN     NaN      NaN
```

```
summary(mod_abund_Balticum_fire_int) # NaNs produced
```

```
##  Family: beta  ( logit )
## Formula:          Balticum_prop ~ age + temp + moist + nutrient + fire * fen +
##     dry
## Zero inflation:                 ~.
## Data: data_peat
##
##      AIC      BIC   logLik deviance df.resid
##       NA       NA       NA       NA       69
##
##
## Dispersion parameter for beta family (): 10.7
##
## Conditional model:
##               Estimate Std. Error z value Pr(>|z|)
## (Intercept) -5.7411443        NaN     NaN      NaN
## age          0.0002697        NaN     NaN      NaN
## temp         0.5913519        NaN     NaN      NaN
## moist        1.9450445        NaN     NaN      NaN
## nutrient1    0.9671610        NaN     NaN      NaN
## fire1        1.1962958        NaN     NaN      NaN
## fenY        -2.5526529        NaN     NaN      NaN
## dry1        -1.9297103        NaN     NaN      NaN
## fire1:fenY   0.0000000        NaN     NaN      NaN
##
## Zero-inflation model:
##             Estimate Std. Error z value Pr(>|z|)
## (Intercept)  2.51998        NaN     NaN      NaN
## age          0.00155        NaN     NaN      NaN
## temp        -0.68729        NaN     NaN      NaN
## moist        0.11173        NaN     NaN      NaN
## nutrient1   -0.17589        NaN     NaN      NaN
## fire1       -0.60698        NaN     NaN      NaN
## fenY        -5.27246        NaN     NaN      NaN
## dry1         0.50430        NaN     NaN      NaN
## fire1:fenY  21.09780        NaN     NaN      NaN
```

```
summary(mod_abund_Balticum_dry_int) # NaNs produced
```

```
##  Family: beta  ( logit )
```

```
## Formula:          Balticum_prop ~ age + temp + moist + nutrient + fire + dry *
##     fen
## Zero inflation:                 ~.
## Data: data_peat
##
##      AIC      BIC   logLik deviance df.resid
##       NA       NA       NA       NA       69
##
##
## Dispersion parameter for beta family (): 10.7
##
## Conditional model:
##               Estimate Std. Error z value Pr(>|z|)
## (Intercept) -5.7411409        NaN     NaN      NaN
## age          0.0002697        NaN     NaN      NaN
## temp         0.5913516        NaN     NaN      NaN
## moist        1.9450443        NaN     NaN      NaN
## nutrient1    0.9671599        NaN     NaN      NaN
## fire1        1.1962947        NaN     NaN      NaN
## dry1        -1.9297099        NaN     NaN      NaN
## fenY        -1.2763258        NaN     NaN      NaN
## dry1:fenY   -1.2763258        NaN     NaN      NaN
##
## Zero-inflation model:
##              Estimate Std. Error z value Pr(>|z|)
## (Intercept)   1.49579        NaN     NaN      NaN
## age           0.00141        NaN     NaN      NaN
## temp         -0.53206        NaN     NaN      NaN
## moist         0.03065        NaN     NaN      NaN
## nutrient1    -0.16474        NaN     NaN      NaN
## fire1        -0.08019        NaN     NaN      NaN
## dry1          0.61844        NaN     NaN      NaN
## fenY         15.16912        NaN     NaN      NaN
## dry1:fenY   -19.54223        NaN     NaN      NaN
```

```
summary(mod_abund_Cuspidata_age_int) # NaNs produced
```

```
##  Family: beta  ( logit )
## Formula:
## Cuspidata_prop ~ age * fen + temp + moist + nutrient + fire +      dry
## Zero inflation:                   ~.
## Data: data_peat
##
##      AIC      BIC   logLik deviance df.resid
##     76.8    123.9    -19.4     38.8       69
##
##
## Dispersion parameter for beta family (): 5.68
##
## Conditional model:
##               Estimate Std. Error z value Pr(>|z|)
## (Intercept) -4.105e+00  1.963e+00  -2.091  0.03653 *
## age         -6.526e-05        NaN     NaN      NaN
## fenY        -1.746e-08  7.119e-01   0.000  1.00000
```

```
## temp         4.454e-01  1.657e-01   2.688  0.00719 **
## moist        8.771e-02  6.082e-01   0.144  0.88534
## nutrient1   -5.957e-01  1.022e+00  -0.583  0.55993
## fire1        1.106e-01  5.947e-01   0.186  0.85252
## dry1        -1.976e-01  1.053e+00  -0.188  0.85121
## age:fenY    -1.492e-04        NaN     NaN      NaN
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Zero-inflation model:
##               Estimate Std. Error z value Pr(>|z|)
## (Intercept)  1.649e+00  4.128e+00   0.400    0.690
## age          7.611e-04  3.219e-04   2.365    0.018 *
## fenY         1.059e+02        NaN     NaN      NaN
## temp        -2.380e-01  6.265e-01  -0.380    0.704
## moist       -1.370e+00  8.562e-01  -1.601    0.109
## nutrient1   -1.391e+00  8.516e-01  -1.634    0.102
## fire1       -8.817e-01  9.335e-01  -0.945    0.345
## dry1         2.311e-01  7.617e-01   0.303    0.762
## age:fenY    -1.302e-02        NaN     NaN      NaN
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
summary(mod_abund_Cuspidata_temp_int) # NaNs produced
```

```
##  Family: beta  ( logit )
## Formula:
## Cuspidata_prop ~ age + temp * fen + moist + nutrient + fire +      dry
## Zero inflation:                   ~.
## Data: data_peat
##
##      AIC      BIC   logLik deviance df.resid
##       NA       NA       NA       NA       69
##
##
## Dispersion parameter for beta family (): 5.68
##
## Conditional model:
##               Estimate Std. Error z value Pr(>|z|)
## (Intercept) -4.105e+00        NaN     NaN      NaN
## age         -6.526e-05        NaN     NaN      NaN
## temp         4.454e-01        NaN     NaN      NaN
## fenY        -1.501e-02        NaN     NaN      NaN
## moist        8.771e-02        NaN     NaN      NaN
## nutrient1   -5.957e-01        NaN     NaN      NaN
## fire1        1.106e-01        NaN     NaN      NaN
## dry1        -1.976e-01        NaN     NaN      NaN
## temp:fenY   -1.375e-01        NaN     NaN      NaN
##
## Zero-inflation model:
##               Estimate Std. Error z value Pr(>|z|)
## (Intercept) -1.7770365        NaN     NaN      NaN
## age          0.0004619        NaN     NaN      NaN
## temp         0.2696131        NaN     NaN      NaN
```

```
## fenY         1.1351952        NaN     NaN      NaN
## moist       -1.0779475        NaN     NaN      NaN
## nutrient1   -1.2619378        NaN     NaN      NaN
## fire1       -0.4951280        NaN     NaN      NaN
## dry1         0.4517894        NaN     NaN      NaN
## temp:fenY   -0.2325140        NaN     NaN      NaN
```

```
summary(mod_abund_Cuspidata_moist_int) # NaNs produced
```

```
##  Family: beta  ( logit )
## Formula:
## Cuspidata_prop ~ age + temp + moist * fen + nutrient + fire +      dry
## Zero inflation:                   ~.
## Data: data_peat
##
##      AIC      BIC   logLik deviance df.resid
##       NA       NA       NA       NA       69
##
##
## Dispersion parameter for beta family (): 5.68
##
## Conditional model:
##               Estimate Std. Error z value Pr(>|z|)
## (Intercept) -4.105e+00        NaN     NaN      NaN
## age         -6.526e-05        NaN     NaN      NaN
## temp         4.454e-01        NaN     NaN      NaN
## moist        8.771e-02        NaN     NaN      NaN
## fenY        -1.211e+00        NaN     NaN      NaN
## nutrient1   -5.957e-01        NaN     NaN      NaN
## fire1        1.106e-01        NaN     NaN      NaN
## dry1        -1.976e-01        NaN     NaN      NaN
## moist:fenY   2.785e-01        NaN     NaN      NaN
##
## Zero-inflation model:
##               Estimate Std. Error z value Pr(>|z|)
## (Intercept)  1.1960580        NaN     NaN      NaN
## age          0.0007247        NaN     NaN      NaN
## temp        -0.1685793        NaN     NaN      NaN
## moist       -1.3920477        NaN     NaN      NaN
## fenY        -2.9191226        NaN     NaN      NaN
## nutrient1   -1.4054175        NaN     NaN      NaN
## fire1       -0.8390185        NaN     NaN      NaN
## dry1         0.2551322        NaN     NaN      NaN
## moist:fenY   9.0698474        NaN     NaN      NaN
```

```
summary(mod_abund_Cuspidata_fire_int) # NaNs produced
```

```
##  Family: beta  ( logit )
## Formula:
## Cuspidata_prop ~ age + temp + moist + nutrient + fire * fen +      dry
## Zero inflation:                   ~.
## Data: data_peat
##
```

```
##      AIC      BIC   logLik deviance df.resid
##       NA       NA       NA       NA       69
##
##
## Dispersion parameter for beta family (): 5.68
##
## Conditional model:
##               Estimate Std. Error z value Pr(>|z|)
## (Intercept) -4.105e+00        NaN     NaN      NaN
## age         -6.526e-05        NaN     NaN      NaN
## temp         4.454e-01        NaN     NaN      NaN
## moist        8.771e-02        NaN     NaN      NaN
## nutrient1   -5.957e-01        NaN     NaN      NaN
## fire1        1.106e-01        NaN     NaN      NaN
## fenY        -1.275e+00        NaN     NaN      NaN
## dry1        -1.976e-01        NaN     NaN      NaN
## fire1:fenY   0.000e+00        NaN     NaN      NaN
##
## Zero-inflation model:
##               Estimate Std. Error z value Pr(>|z|)
## (Intercept) -0.9012948        NaN     NaN      NaN
## age          0.0005272        NaN     NaN      NaN
## temp         0.1494182        NaN     NaN      NaN
## moist       -1.0819701        NaN     NaN      NaN
## nutrient1   -1.3254927        NaN     NaN      NaN
## fire1       -0.8822987        NaN     NaN      NaN
## fenY        -1.9544447        NaN     NaN      NaN
## dry1         0.4349800        NaN     NaN      NaN
## fire1:fenY  20.1109620        NaN     NaN      NaN
```

```
summary(mod_abund_Cuspidata_dry_int) # NaNs produced
```

```
##  Family: beta  ( logit )
## Formula:
## Cuspidata_prop ~ age + temp + moist + nutrient + fire + dry *      fen
## Zero inflation:                   ~.
## Data: data_peat
##
##      AIC      BIC   logLik deviance df.resid
##       NA       NA       NA       NA       69
##
##
## Dispersion parameter for beta family (): 5.68
##
## Conditional model:
##               Estimate Std. Error z value Pr(>|z|)
## (Intercept) -4.105e+00        NaN     NaN      NaN
## age         -6.526e-05        NaN     NaN      NaN
## temp         4.454e-01        NaN     NaN      NaN
## moist        8.771e-02        NaN     NaN      NaN
## nutrient1   -5.957e-01        NaN     NaN      NaN
## fire1        1.106e-01        NaN     NaN      NaN
## dry1        -1.976e-01        NaN     NaN      NaN
## fenY        -1.275e+00        NaN     NaN      NaN
```

```
## dry1:fenY    0.000e+00        NaN     NaN      NaN
##
## Zero-inflation model:
##               Estimate Std. Error z value Pr(>|z|)
## (Intercept)  0.3776870        NaN     NaN      NaN
## age          0.0006445        NaN     NaN      NaN
## temp        -0.0488889        NaN     NaN      NaN
## moist       -1.1027016        NaN     NaN      NaN
## nutrient1   -1.2885898        NaN     NaN      NaN
## fire1       -0.6778077        NaN     NaN      NaN
## dry1         0.1778433        NaN     NaN      NaN
## fenY        -2.7296537        NaN     NaN      NaN
## dry1:fenY   21.0314174        NaN     NaN      NaN
```

I am not sure why the models for Medium work OK, but not the models for the other species. I guess it might also be a problem of sample size - maybe there is not enough data to estimate so many parameters in the model. These models have 88 observations, while the moddels for the plant groups have 108 observations, and this might make a difference (although still not sure why it worked in the case of Medium). Anyway, I think it might be better to only test the interactions for the plant groups (i.e. total Sphagnum, Erio, Erica, Carex),but not for the Sphagnum species. You can say in the text that you did not test the interactions for Sphagnum species because of the reduced sample size.

R session info

```
sessionInfo()
```

```
## R version 4.3.0 (2023-04-21 ucrt)
## Platform: x86_64-w64-mingw32/x64 (64-bit)
## Running under: Windows 11 x64 (build 22621)
##
## Matrix products: default
##
##
## locale:
## [1] LC_COLLATE=English_United States.utf8
## [2] LC_CTYPE=English_United States.utf8
## [3] LC_MONETARY=English_United States.utf8
## [4] LC_NUMERIC=C
## [5] LC_TIME=English_United States.utf8
##
## time zone: Europe/Madrid
## tzcode source: internal
##
## attached base packages:
## [1] stats     graphics  grDevices utils     datasets  methods   base
##
## other attached packages:
##  [1] ggord_1.1.7     ggthemes_4.2.4  gridExtra_2.3   rdacca.hp_1.1-0
##  [5] vegan_2.6-4     lattice_0.21-8  permute_0.9-7   glmmTMB_1.1.7
##  [9] car_3.1-2       carData_3.0-5   ggeffects_1.2.2 knitr_1.43
## [13] readxl_1.4.2    lubridate_1.9.2 forcats_1.0.0   stringr_1.5.0
```

```
## [17] dplyr_1.1.2     purrr_1.0.1     readr_2.1.4     tidyr_1.3.0
## [21] tibble_3.2.1    ggplot2_3.4.2   tidyverse_2.0.0
##
## loaded via a namespace (and not attached):
##  [1] sjlabelled_1.2.0    tidyselect_1.2.0    farver_2.1.1
##  [4] fastmap_1.1.1       TH.data_1.1-2       digest_0.6.31
##  [7] estimability_1.4.1  timechange_0.2.0    lifecycle_1.0.3
## [10] cluster_2.1.4       survival_3.5-5      magrittr_2.0.3
## [13] compiler_4.3.0      rlang_1.1.1         tools_4.3.0
## [16] utf8_1.2.3          yaml_2.3.7          labeling_0.4.2
## [19] plyr_1.8.8          multcomp_1.4-25     abind_1.4-5
## [22] withr_2.5.0         numDeriv_2016.8-1.1 grid_4.3.0
## [25] fansi_1.0.4         xtable_1.8-4        colorspace_2.1-0
## [28] emmeans_1.8.8       scales_1.2.1        MASS_7.3-58.4
## [31] insight_0.19.4      cli_3.6.1           mvtnorm_1.1-3
## [34] rmarkdown_2.24      ragg_1.2.5          generics_0.1.3
## [37] rstudioapi_0.15.0   tzdb_0.4.0          minqa_1.2.5
## [40] splines_4.3.0       parallel_4.3.0      cellranger_1.1.0
## [43] vctrs_0.6.2         boot_1.3-28.1       Matrix_1.5-4
## [46] sandwich_3.0-2      hms_1.1.3           ggrepel_0.9.3
## [49] systemfonts_1.0.4   glue_1.6.2          nloptr_2.0.3
## [52] codetools_0.2-19    stringi_1.7.12      gtable_0.3.4
## [55] lme4_1.1-33         munsell_0.5.0       pillar_1.9.0
## [58] htmltools_0.5.5     R6_2.5.1            TMB_1.9.4
## [61] textshaping_0.3.6   evaluate_0.21       haven_2.5.2
## [64] highr_0.10          Rcpp_1.0.10         coda_0.19-4
## [67] nlme_3.1-162        mgcv_1.8-42         xfun_0.39
## [70] zoo_1.8-12          pkgconfig_2.0.3
```