# 6. Worksheet: Among Site (Beta) Diversity – Part 1

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04 February, 2025

## OVERVIEW

In this worksheet, we move beyond the investigation of within-site $\alpha$-diversity. We will explore $\beta$-diversity, which is defined as the diversity that occurs among sites. This requires that we examine the compositional similarity of assemblages that vary in space or time.

After completing this exercise you will know how to:

1. formally quantify $\beta$-diversity
2. visualize $\beta$-diversity with heatmaps, cluster analysis, and ordination
3. test hypotheses about $\beta$-diversity using multivariate statistics

## Directions:

1. In the Markdown version of this document in your cloned repo, change "Student Name" on line 3 (above) with your name.
2. Complete as much of the worksheet as possible during class.
3. Use the handout as a guide; it contains a more complete description of data sets along with examples of proper scripting needed to carry out the exercises.
4. Answer questions in the worksheet. Space for your answers is provided in this document and is indicated by the ">" character. If you need a second paragraph be sure to start the first line with ">". You should notice that the answer is highlighted in green by RStudio (color may vary if you changed the editor theme).
5. Before you leave the classroom, **push** this file to your GitHub repo.
6. For the assignment portion of the worksheet, follow the directions at the bottom of this file.
7. When you are done, **Knit** the text and code into a PDF file.
8. After Knitting, submit the completed exercise by creating a **pull request** via GitHub. Your pull request should include this file (**6.BetaDiversity_1_Worksheet.Rmd**) with all code blocks filled out and questions answered) and the PDF output of `Knitr` (**6.BetaDiversity_1_Worksheet.pdf**).

The completed exercise is due on **Wednesday, February 5$^{th}$, 2025 before 12:00 PM (noon)**.

## 1) R SETUP

Typically, the first thing you will do in either an R script or an RMarkdown file is setup your environment. This includes things such as setting the working directory and loading any packages that you will need.

In the R code chunk below, please provide the code to:

1) Clear your R environment,
2) Print your current working directory,
3) Set your working directory to your `Week3-Beta/` folder folder, and
4) Load the `vegan` R package (be sure to install first if you have not already).

```r
rm(list = ls())
getwd()
```

```
## [1] "/cloud/project/QB2025_Guevara/Week3-Beta"
```

```r
setwd("/cloud/project/QB2025_Guevara/Week3-Beta")

#If we do ```{r, include = FALSE}, the whole R chunk will not be printed in the knitted file.
```

## 2) LOADING DATA

### Load dataset

In the R code chunk below, do the following:

1. load the **doubs** dataset from the **ade4** package, and
2. explore the structure of the dataset.

```r
# note, please do not print the dataset when submitting
package.list <- c('vegan', 'ade4', 'viridis', 'gplots', 'BiodiversityR', 'indicspecies')
for (package in package.list){
  if (!require(package, character.only = TRUE, quietly = TRUE)) {
    install.packages(package)
    library(package, character.only = TRUE)
  }
}
```

```
## This is vegan 2.6-8
```

```
##
## Attaching package: 'gplots'
```

```
## The following object is masked from 'package:stats':
##
##     lowess
```

```
## Warning in fun(libname, pkgname): couldn't connect to display ":0"
```

```
## BiodiversityR 2.17-1.1: Use command BiodiversityRGUI() to launch the Graphical User Interface;
## to see changes use BiodiversityRGUI(changeLog=TRUE, backward.compatibility.messages=TRUE)
```

```r
library(vegan)
data(doubs)
#doubs is our list, fish is our object in this case
doubs$fish
```

```
##    Cogo Satr Phph Neba Thth Teso Chna Chto Lele Lece Baba Spbi Gogo Eslu Pefl
## 1     0    3    0    0    0    0    0    0    0    0    0    0    0    0    0
## 2     0    5    4    3    0    0    0    0    0    0    0    0    0    0    0
## 3     0    5    5    5    0    0    0    0    0    0    0    0    0    1    0
## 4     0    4    5    5    0    0    0    0    0    1    0    0    1    2    2
## 5     0    2    3    2    0    0    0    0    5    2    0    0    2    4    4
## 6     0    3    4    5    0    0    0    0    1    2    0    0    1    1    1
## 7     0    5    4    5    0    0    0    0    1    1    0    0    0    0    0
## 8     0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
## 9     0    0    1    3    0    0    0    0    0    5    0    0    0    0    0
## 10    0    1    4    4    0    0    0    0    2    2    0    0    1    0    0
## 11    1    3    4    1    1    0    0    0    0    1    0    0    0    0    0
## 12    2    5    4    4    2    0    0    0    0    1    0    0    0    0    0
```

```
## 13    2    5    5    2    3    2    0    0    0    0    0    0    0    0    0
## 14    3    5    5    4    4    3    0    0    0    1    1    0    1    1    0
## 15    3    4    4    5    2    4    0    0    3    3    2    0    2    0    0
## 16    2    3    3    5    0    5    0    4    5    2    2    1    2    1    1
## 17    1    2    4    4    1    2    1    4    3    2    3    4    1    1    2
## 18    1    1    3    3    1    1    1    3    2    3    3    3    2    1    3
## 19    0    0    3    5    0    1    2    3    2    1    2    2    4    1    1
## 20    0    0    1    2    0    0    2    2    2    3    4    3    4    2    2
## 21    0    0    1    1    0    0    2    2    2    2    4    2    5    3    3
## 22    0    0    0    1    0    0    3    2    3    4    5    1    5    3    4
## 23    0    0    0    0    0    0    0    0    0    1    0    0    0    0    0
## 24    0    0    0    0    0    0    1    0    0    2    0    0    1    0    0
## 25    0    0    0    0    0    0    0    0    1    1    0    0    2    1    0
## 26    0    0    0    1    0    0    1    0    1    2    2    1    3    2    1
## 27    0    0    0    1    0    0    1    1    2    3    4    1    4    4    1
## 28    0    0    0    1    0    0    1    1    2    4    3    1    4    3    2
## 29    0    1    1    1    1    1    2    2    3    4    5    3    5    5    4
## 30    0    0    0    0    0    0    1    2    3    3    3    5    5    4    5
##    Rham Legi Scer Cyca Titi Abbr Icme Acce Ruru Blbj Alal Anan
## 1     0    0    0    0    0    0    0    0    0    0    0    0
## 2     0    0    0    0    0    0    0    0    0    0    0    0
## 3     0    0    0    0    0    0    0    0    0    0    0    0
## 4     0    0    0    0    1    0    0    0    0    0    0    0
## 5     0    0    2    0    3    0    0    0    5    0    0    0
## 6     0    0    0    0    2    0    0    0    1    0    0    0
## 7     0    0    0    0    0    0    0    0    0    0    0    0
## 8     0    0    0    0    0    0    0    0    0    0    0    0
## 9     0    0    0    0    1    0    0    0    4    0    0    0
## 10    0    0    0    0    0    0    0    0    0    0    0    0
## 11    0    0    0    0    0    0    0    0    0    0    0    0
## 12    0    0    0    0    0    0    0    0    0    0    0    0
## 13    0    0    0    0    0    0    0    0    0    0    0    0
## 14    0    0    0    0    0    0    0    0    0    0    0    0
## 15    0    0    0    0    1    0    0    0    0    0    0    0
## 16    0    1    0    1    1    0    0    0    1    0    0    0
## 17    1    1    0    1    1    0    0    0    2    0    2    1
## 18    2    1    0    1    1    0    0    1    2    0    2    1
## 19    2    1    1    1    2    1    0    1    5    1    3    1
## 20    3    2    2    1    4    1    0    2    5    2    5    2
## 21    3    2    2    2    4    3    1    3    5    3    5    2
## 22    3    3    2    3    4    4    2    4    5    4    5    2
## 23    0    0    0    0    0    0    0    0    1    0    2    0
## 24    0    1    0    0    0    0    0    2    2    1    5    0
## 25    0    0    1    0    0    0    0    1    1    0    3    0
## 26    2    2    1    1    3    2    1    4    4    2    5    2
## 27    3    3    1    2    5    3    2    5    5    4    5    3
## 28    4    4    2    4    4    3    3    5    5    5    5    4
## 29    5    5    2    3    3    4    4    5    5    4    5    4
## 30    5    3    5    5    5    5    5    5    5    5    5    5
```

```
str(doubs, max.level = 1)
```

```
## List of 4
##  $ env    :'data.frame': 30 obs. of  11 variables:
##  $ fish   :'data.frame': 30 obs. of  27 variables:
```

```
##  $ xy     :'data.frame': 30 obs. of  2 variables:
##  $ species:'data.frame': 27 obs. of  4 variables:
```

```
head(doubs$env)
```

```
##   dfs alt   slo flo pH har pho nit amm oxy bdo
## 1   3 934 6.176  84 79  45   1  20   0 122  27
## 2  22 932 3.434 100 80  40   2  20  10 103  19
## 3 102 914 3.638 180 83  52   5  22   5 105  35
## 4 185 854 3.497 253 80  72  10  21   0 110  13
## 5 215 849 3.178 264 81  84  38  52  20  80  62
## 6 324 846 3.497 286 79  60  20  15   0 102  53
```

```
head(doubs$fish)
```

```
##   Cogo Satr Phph Neba Thth Teso Chna Chto Lele Lece Baba Spbi Gogo Eslu Pefl
## 1    0    3    0    0    0    0    0    0    0    0    0    0    0    0    0
## 2    0    5    4    3    0    0    0    0    0    0    0    0    0    0    0
## 3    0    5    5    5    0    0    0    0    0    0    0    0    0    1    0
## 4    0    4    5    5    0    0    0    0    0    1    0    0    1    2    2
## 5    0    2    3    2    0    0    0    0    5    2    0    0    2    4    4
## 6    0    3    4    5    0    0    0    0    1    2    0    0    1    1    1
##   Rham Legi Scer Cyca Titi Abbr Icme Acce Ruru Blbj Alal Anan
## 1    0    0    0    0    0    0    0    0    0    0    0    0
## 2    0    0    0    0    0    0    0    0    0    0    0    0
## 3    0    0    0    0    0    0    0    0    0    0    0    0
## 4    0    0    0    0    1    0    0    0    0    0    0    0
## 5    0    0    2    0    3    0    0    0    5    0    0    0
## 6    0    0    0    0    2    0    0    0    1    0    0    0
```

```
? head
```

***Question 1***: Describe some of the attributes of the `doubs` dataset.

a. How many objects are in `doubs`?
b. How many fish species are there in the `doubs` dataset?
c. How many sites are in the `doubs` dataset?

***Answer 1a***: There are 4 objects in 'doubs', where each object is its own data.frame (fish, env, xy, and species). ***Answer 1b***: There are 27 species of fish in the doubs dataset ***Answer 1c***: There are 30 sites in the doubs dataset

### Visualizing the Doubs River Dataset

***Question 2***: Answer the following questions based on the spatial patterns of richness (i.e., $\alpha$-diversity) and Brown Trout (*Salmo trutta*) abundance in the Doubs River.

a. How does fish richness vary along the sampled reach of the Doubs River?
b. How does Brown Trout (*Salmo trutta*) abundance vary along the sampled reach of the Doubs River?
c. What do these patterns say about the limitations of using richness when examining patterns of biodiversity?

***Answer 2a***: Fish richness seems to be greatest downstream from Doubs River where it is less rich the further upstream ***Answer 2b***: Brown Trout seems to be the opposite of fish richness where there is less abundance of Brown Trout downstream and more Brown Trout upstream ***Answer 2c***: These patterns shows the limitation that using richness fails to account for evenness when examining patterns of biodiversity. It is most likely that Brown Trout dominate upstream of this river, which is why upstream fish richness is so low compared to downstream.

## 3) QUANTIFYING BETA-DIVERSITY

In the R code chunk below, do the following:

1. write a function (`beta.w()`) to calculate Whittaker's $\beta$-diversity (i.e., $\beta_w$) that accepts a site-by-species matrix with optional arguments to specify pairwise turnover between two sites, and
2. use this function to analyze various aspects of $\beta$-diversity in the Doubs River.

```
beta.w <- function(site.by.species = ""){
  SbyS.pa <- decostand(site.byspecies, method = "pa")
  #convert to presence-absence
  S <- ncol(SbyS.pa[,which(colSums(SbyS.pa) > 0 )])
  # number of species in the region
  a.bar <- mean(specnumber(SbyS.pa))
  #average richness at each site
  b.w <- round(S/a.bar, 3)
  #round to 3 decimal places
  return(b.w)
}

#Turnover between two sites
beta.w <- function(site.by.species = "", sitenum1 = "", sitenum2 = "", pairwise = FALSE){
  #Only if we specify pairwise as TRUE, do this:
  if (pairwise ==TRUE){
    #As a check, let's print an error if we do not provide needed arguments
    if (sitenum1 == "" | sitenum2 == ""){
      print("Error: please specify sites to compare")
      return(NA)}
    #If our function made it this far, let us calculate beta diversity
    site1 = site.by.species[sitenum1,]
    #Select site 1
    site2 = site.by.species[sitenum2,]
    #Select site 2
    site1 = subset(site1, select = site1 > 0)
    #Remove absences
    site2 = subset(site2, select = site2 > 0)
    #Removes absences
    gamma = union(colnames(site1), colnames(site2))
    #Gamma species pool
    s = length(gamma)
    #gamma richness
    a.bar = mean(c(specnumber(site1), specnumber(site2)))
    #Mean sample richness
    b.w = round(s/a.bar - 1, 3)
    return(b.w)
  }
  else{SbyS.pa <- decostand(site.by.species, method = "pa")
  #convert to presence-absence
  S <- ncol(SbyS.pa[,which(colSums(SbyS.pa) > 0)])
  #number of species in region
  a.bar <- mean(specnumber(SbyS.pa))
  #average richness at each site
  b.w <- round(S/a.bar, 3)
  return(b.w)
  }
```

```
}

#To answer 3b...We see that
beta.w(site.by.species = doubs$fish, sitenum1 = 1, sitenum2 = 2, pairwise = TRUE)
```

```
## [1] 0.5
```

```
beta.w(site.by.species = doubs$fish, sitenum1 = 1, sitenum2 = 10, pairwise = TRUE)
```

```
## [1] 0.714
```

***Question 3***: Using your `beta.w()` function above, answer the following questions:

a. Describe how local richness ($\alpha$) and turnover ($\beta$) contribute to regional ($\gamma$) fish diversity in the Doubs.
b. Is the fish assemblage at site 1 more similar to the one at site 2 or site 10?
c. Using your understanding of the equation $\beta_w = \gamma/\alpha$, how would your interpretation of $\beta$ change if we instead defined beta additively (i.e., $\beta = \gamma - \alpha$)?

> ***Answer 3a***: According to our beta function, the regional species pool is 2.16x more dense than the average richness at each site within the region (local richness or $\alpha$). In order to acquire our regional fish diversity in Doubs, we would need to mulitiply our alpha diversity and beta diversity since the equation is beta = gamma/alpha. ***Answer 3b***: Site 1 is more similar to site 2 as we see that the Whittaker's beta diversity value smaller indicating more shared species and less turnover. ***Answer 3c***: From what I understand, beta(w) is equal to the ratio of regional diversity over the average richness at each site within the specified region subtracted by one to provide the species turnover. If we were to convert this from being a ratio to a subtraction, our values of beta would not reveal how different the total diversity is from the mean site diversity by a given factor, but would instead reveal how mnay species in the regional pool are not found in the average local site. In sum, if beta was defined as additively rather than multiplicatively, beta would be an difference-based or absolute measure of diversity but would be more difficult to compare values across other regions since the values of diversity are no longer relative.

### The Resemblance Matrix

In order to quantify $\beta$-diversity for more than two samples, we need to introduce a new primary ecological data structure: the **Resemblance Matrix**.

***Question 4***: How do incidence- and abundance-based metrics differ in their treatment of rare species?

> ***Answer 4***: They differ in their treatment of rare species as incidence-based metrics treat rare species equally to more common/dominant species. Abundance-based metrics take into accountability the abundance (as in the name) of each species, weighing them based on relative abundance within a site. Dominant/common species would affect the similarity/dissimilarity between sites more so than a rare species when using an abundance-based analysis.

In the R code chunk below, do the following:

1. make a new object, `fish`, containing the fish abundance data for the Doubs River,
2. remove any sites where no fish were observed (i.e., rows with sum of zero),
3. construct a resemblance matrix based on Sørensen's Similarity ("fish.ds"), and
4. construct a resemblance matrix based on Bray-Curtis Distance ("fish.db").

```
fish <- doubs$fish
fish <- fish[-8, ] #Removes site 8 from data

#Calculate Jaccard
fish.dj <- vegdist(fish, method = "jaccard", binary = TRUE)
new.fish.dj <- vegdist(fish, method = "jaccard", binary = TRUE, upper = TRUE, diag = TRUE)
#Calculate Bray-Curtis
```

```r
fish.db <- vegdist(fish, method = "bray")

#Calculate Sørensen
fish.ds <- vegdist(fish, method = "bray", binary = TRUE)
full.fish.ds <- vegdist(fish, method = "bray", binary = TRUE, upper = TRUE, diag = TRUE)
#Printing the Bray-Curtis-based resemblance matrix in the console
fish.db
```

```
##             1          2          3          4          5          6          7
## 2  0.60000000
## 3  0.68421053 0.14285714
## 4  0.75000000 0.33333333 0.18918919
## 5  0.89189189 0.69565217 0.68000000 0.49090909
## 6  0.75000000 0.39393939 0.29729730 0.19047619 0.41818182
## 7  0.68421053 0.14285714 0.12500000 0.24324324 0.64000000 0.24324324
## 9  1.00000000 0.69230769 0.73333333 0.65714286 0.58333333 0.54285714 0.66666667
## 10 0.88235294 0.38461538 0.40000000 0.37142857 0.54166667 0.25714286 0.26666667
## 11 0.57142857 0.30434783 0.40740741 0.43750000 0.68888889 0.43750000 0.33333333
## 12 0.71428571 0.20000000 0.23529412 0.33333333 0.69230769 0.38461538 0.17647059
## 13 0.72727273 0.29032258 0.31428571 0.45000000 0.73584906 0.55000000 0.37142857
## 14 0.80645161 0.40000000 0.31818182 0.34693878 0.67741935 0.42857143 0.36363636
## 15 0.83333333 0.51111111 0.46938776 0.40740741 0.55223881 0.37037037 0.38775510
## 16 0.86046512 0.65384615 0.57142857 0.47540984 0.45945946 0.37704918 0.53571429
## 17 0.91489362 0.67857143 0.63333333 0.50769231 0.51282051 0.44615385 0.60000000
## 18 0.95555556 0.74074074 0.72413793 0.58730159 0.50000000 0.52380952 0.68965517
## 19 1.00000000 0.79310345 0.70967742 0.61194030 0.50000000 0.52238806 0.67741935
## 20 1.00000000 0.91176471 0.88888889 0.74025974 0.48888889 0.68831169 0.86111111
## 21 1.00000000 0.94594595 0.92307692 0.78313253 0.50000000 0.73493976 0.89743590
## 22 1.00000000 0.97619048 0.95454545 0.82795699 0.52830189 0.78494624 0.93181818
## 23 1.00000000 1.00000000 1.00000000 0.92000000 0.89473684 0.84000000 0.90000000
## 24 1.00000000 1.00000000 1.00000000 0.88888889 0.79591837 0.77777778 0.93548387
## 25 1.00000000 1.00000000 0.92592593 0.81250000 0.68888889 0.68750000 0.85185185
## 26 1.00000000 0.96363636 0.93220339 0.78125000 0.55844156 0.68750000 0.89830508
## 27 1.00000000 0.97333333 0.94936709 0.83333333 0.56701031 0.76190476 0.92405063
## 28 1.00000000 0.97560976 0.95348837 0.82417582 0.57692308 0.78021978 0.93023256
## 29 0.97777778 0.93939394 0.92233010 0.81481481 0.53719008 0.77777778 0.90291262
## 30 1.00000000 1.00000000 0.98095238 0.87272727 0.59349593 0.83636364 0.96190476
##             9         10         11         12         13         14         15
## 2
## 3
## 4
## 5
## 6
## 7
## 9
## 10 0.57142857
## 11 0.76000000 0.44000000
## 12 0.68750000 0.37500000 0.24137931
## 13 0.81818182 0.57575758 0.33333333 0.18918919
## 14 0.76190476 0.47619048 0.43589744 0.21739130 0.19148936
## 15 0.65957447 0.40425532 0.50000000 0.33333333 0.38461538 0.24590164
## 16 0.70370370 0.51851852 0.64705882 0.55172414 0.59322034 0.44117647 0.26027397
## 17 0.68965517 0.51724138 0.63636364 0.58064516 0.61904762 0.50000000 0.40259740
## 18 0.64285714 0.57142857 0.69811321 0.66666667 0.70491803 0.60000000 0.46666667
```

```
## 19 0.66666667 0.63333333 0.82456140 0.75000000 0.81538462 0.67567568 0.56962025
## 20 0.68571429 0.77142857 0.91044776 0.89189189 0.92000000 0.83333333 0.70786517
## 21 0.76315789 0.81578947 0.91780822 0.92500000 0.95061728 0.86666667 0.76842105
## 22 0.76744186 0.86046512 0.95180723 0.95555556 0.97802198 0.90000000 0.77142857
## 23 0.77777778 0.88888889 0.86666667 0.90909091 1.00000000 0.93750000 0.94594595
## 24 0.72413793 0.79310345 0.92307692 0.93939394 1.00000000 0.90697674 0.87500000
## 25 0.84000000 0.76000000 0.90909091 0.93103448 1.00000000 0.84615385 0.81818182
## 26 0.71929825 0.82456140 0.92592593 0.93442623 0.96774194 0.85915493 0.76315789
## 27 0.76623377 0.84415584 0.94594595 0.95061728 0.97560976 0.89010989 0.77083333
## 28 0.76190476 0.85714286 0.95061728 0.95454545 0.97752809 0.89795918 0.78640777
## 29 0.78217822 0.84158416 0.89795918 0.90476190 0.90566038 0.84347826 0.73333333
## 30 0.84466019 0.90291262 0.98000000 0.98130841 1.00000000 0.93162393 0.81967213
##            16         17         18         19         20         21         22
## 2
## 3
## 4
## 5
## 6
## 7
## 9
## 10
## 11
## 12
## 13
## 14
## 15
## 16
## 17 0.26190476
## 18 0.34146341 0.13953488
## 19 0.39534884 0.31111111 0.25000000
## 20 0.58333333 0.42000000 0.32653061 0.23529412
## 21 0.62745098 0.49056604 0.40384615 0.29629630 0.10169492
## 22 0.66071429 0.55172414 0.47368421 0.38983051 0.18750000 0.10447761
## 23 0.90909091 0.83333333 0.82608696 0.84000000 0.86666667 0.87878788 0.89473684
## 24 0.81818182 0.69491525 0.64912281 0.63934426 0.57746479 0.61038961 0.65517241
## 25 0.76470588 0.74545455 0.66037736 0.61403509 0.67164179 0.69863014 0.73493976
## 26 0.63855422 0.54022989 0.45882353 0.32584270 0.21212121 0.20000000 0.25217391
## 27 0.66990291 0.57009346 0.48571429 0.37614679 0.19327731 0.13600000 0.12592593
## 28 0.69090909 0.57894737 0.50000000 0.41379310 0.22222222 0.16666667 0.12676056
## 29 0.65354331 0.51145038 0.44186047 0.41353383 0.24475524 0.18120805 0.11949686
## 30 0.72093023 0.57894737 0.52671756 0.48148148 0.29655172 0.23178808 0.18012422
##            23         24         25         26         27         28         29
## 2
## 3
## 4
## 5
## 6
## 7
## 9
## 10
## 11
## 12
## 13
## 14
```

```
## 15
## 16
## 17
## 18
## 19
## 20
## 21
## 22
## 23
## 24 0.57894737
## 25 0.46666667 0.46153846
## 26 0.82978723 0.48275862 0.59259259
## 27 0.88059701 0.61538462 0.70270270 0.18867925
## 28 0.89189189 0.64705882 0.72839506 0.23893805 0.09774436
## 29 0.91208791 0.70588235 0.77551020 0.33846154 0.18666667 0.14649682
## 30 0.91397849 0.71153846 0.78000000 0.36363636 0.19736842 0.15723270 0.14772727
```

```
#Making fish.db into a square matrix from a large diagonal matrix. This doesn't really need to be done
fish.db <- vegdist(fish, method = "bray", upper = TRUE, diag = TRUE)
fish.db
```

```
##             1          2          3          4          5          6          7
## 1  0.00000000 0.60000000 0.68421053 0.75000000 0.89189189 0.75000000 0.68421053
## 2  0.60000000 0.00000000 0.14285714 0.33333333 0.69565217 0.39393939 0.14285714
## 3  0.68421053 0.14285714 0.00000000 0.18918919 0.68000000 0.29729730 0.12500000
## 4  0.75000000 0.33333333 0.18918919 0.00000000 0.49090909 0.19047619 0.24324324
## 5  0.89189189 0.69565217 0.68000000 0.49090909 0.00000000 0.41818182 0.64000000
## 6  0.75000000 0.39393939 0.29729730 0.19047619 0.41818182 0.00000000 0.24324324
## 7  0.68421053 0.14285714 0.12500000 0.24324324 0.64000000 0.24324324 0.00000000
## 9  1.00000000 0.69230769 0.73333333 0.65714286 0.58333333 0.54285714 0.66666667
## 10 0.88235294 0.38461538 0.40000000 0.37142857 0.54166667 0.25714286 0.26666667
## 11 0.57142857 0.30434783 0.40740741 0.43750000 0.68888889 0.43750000 0.33333333
## 12 0.71428571 0.20000000 0.23529412 0.33333333 0.69230769 0.38461538 0.17647059
## 13 0.72727273 0.29032258 0.31428571 0.45000000 0.73584906 0.55000000 0.37142857
## 14 0.80645161 0.40000000 0.31818182 0.34693878 0.67741935 0.42857143 0.36363636
## 15 0.83333333 0.51111111 0.46938776 0.40740741 0.55223881 0.37037037 0.38775510
## 16 0.86046512 0.65384615 0.57142857 0.47540984 0.45945946 0.37704918 0.53571429
## 17 0.91489362 0.67857143 0.63333333 0.50769231 0.51282051 0.44615385 0.60000000
## 18 0.95555556 0.74074074 0.72413793 0.58730159 0.50000000 0.52380952 0.68965517
## 19 1.00000000 0.79310345 0.70967742 0.61194030 0.50000000 0.52238806 0.67741935
## 20 1.00000000 0.91176471 0.88888889 0.74025974 0.48888889 0.68831169 0.86111111
## 21 1.00000000 0.94594595 0.92307692 0.78313253 0.50000000 0.73493976 0.89743590
## 22 1.00000000 0.97619048 0.95454545 0.82795699 0.52830189 0.78494624 0.93181818
## 23 1.00000000 1.00000000 1.00000000 0.92000000 0.89473684 0.84000000 0.90000000
## 24 1.00000000 1.00000000 1.00000000 0.88888889 0.79591837 0.77777778 0.93548387
## 25 1.00000000 1.00000000 0.92592593 0.81250000 0.68888889 0.68750000 0.85185185
## 26 1.00000000 0.96363636 0.93220339 0.78125000 0.55844156 0.68750000 0.89830508
## 27 1.00000000 0.97333333 0.94936709 0.83333333 0.56701031 0.76190476 0.92405063
## 28 1.00000000 0.97560976 0.95348837 0.82417582 0.57692308 0.78021978 0.93023256
## 29 0.97777778 0.93939394 0.92233010 0.81481481 0.53719008 0.77777778 0.90291262
## 30 1.00000000 1.00000000 0.98095238 0.87272727 0.59349593 0.83636364 0.96190476
##             9         10         11         12         13         14         15
## 1  1.00000000 0.88235294 0.57142857 0.71428571 0.72727273 0.80645161 0.83333333
## 2  0.69230769 0.38461538 0.30434783 0.20000000 0.29032258 0.40000000 0.51111111
## 3  0.73333333 0.40000000 0.40740741 0.23529412 0.31428571 0.31818182 0.46938776
```

```
## 4  0.65714286 0.37142857 0.43750000 0.33333333 0.45000000 0.34693878 0.40740741
## 5  0.58333333 0.54166667 0.68888889 0.69230769 0.73584906 0.67741935 0.55223881
## 6  0.54285714 0.25714286 0.43750000 0.38461538 0.55000000 0.42857143 0.37037037
## 7  0.66666667 0.26666667 0.33333333 0.17647059 0.37142857 0.36363636 0.38775510
## 9  0.00000000 0.57142857 0.76000000 0.68750000 0.81818182 0.76190476 0.65957447
## 10 0.57142857 0.00000000 0.44000000 0.37500000 0.57575758 0.47619048 0.40425532
## 11 0.76000000 0.44000000 0.00000000 0.24137931 0.33333333 0.43589744 0.50000000
## 12 0.68750000 0.37500000 0.24137931 0.00000000 0.18918919 0.21739130 0.33333333
## 13 0.81818182 0.57575758 0.33333333 0.18918919 0.00000000 0.19148936 0.38461538
## 14 0.76190476 0.47619048 0.43589744 0.21739130 0.19148936 0.00000000 0.24590164
## 15 0.65957447 0.40425532 0.50000000 0.33333333 0.38461538 0.24590164 0.00000000
## 16 0.70370370 0.51851852 0.64705882 0.55172414 0.59322034 0.44117647 0.26027397
## 17 0.68965517 0.51724138 0.63636364 0.58064516 0.61904762 0.50000000 0.40259740
## 18 0.64285714 0.57142857 0.69811321 0.66666667 0.70491803 0.60000000 0.46666667
## 19 0.66666667 0.63333333 0.82456140 0.75000000 0.81538462 0.67567568 0.56962025
## 20 0.68571429 0.77142857 0.91044776 0.89189189 0.92000000 0.83333333 0.70786517
## 21 0.76315789 0.81578947 0.91780822 0.92500000 0.95061728 0.86666667 0.76842105
## 22 0.76744186 0.86046512 0.95180723 0.95555556 0.97802198 0.90000000 0.77142857
## 23 0.77777778 0.88888889 0.86666667 0.90909091 1.00000000 0.93750000 0.94594595
## 24 0.72413793 0.79310345 0.92307692 0.93939394 1.00000000 0.90697674 0.87500000
## 25 0.84000000 0.76000000 0.90909091 0.93103448 1.00000000 0.84615385 0.81818182
## 26 0.71929825 0.82456140 0.92592593 0.93442623 0.96774194 0.85915493 0.76315789
## 27 0.76623377 0.84415584 0.94594595 0.95061728 0.97560976 0.89010989 0.77083333
## 28 0.76190476 0.85714286 0.95061728 0.95454545 0.97752809 0.89795918 0.78640777
## 29 0.78217822 0.84158416 0.89795918 0.90476190 0.90566038 0.84347826 0.73333333
## 30 0.84466019 0.90291262 0.98000000 0.98130841 1.00000000 0.93162393 0.81967213
##           16         17         18         19         20         21         22
## 1  0.86046512 0.91489362 0.95555556 1.00000000 1.00000000 1.00000000 1.00000000
## 2  0.65384615 0.67857143 0.74074074 0.79310345 0.91176471 0.94594595 0.97619048
## 3  0.57142857 0.63333333 0.72413793 0.70967742 0.88888889 0.92307692 0.95454545
## 4  0.47540984 0.50769231 0.58730159 0.61194030 0.74025974 0.78313253 0.82795699
## 5  0.45945946 0.51282051 0.50000000 0.50000000 0.48888889 0.50000000 0.52830189
## 6  0.37704918 0.44615385 0.52380952 0.52238806 0.68831169 0.73493976 0.78494624
## 7  0.53571429 0.60000000 0.68965517 0.67741935 0.86111111 0.89743590 0.93181818
## 9  0.70370370 0.68965517 0.64285714 0.66666667 0.68571429 0.76315789 0.76744186
## 10 0.51851852 0.51724138 0.57142857 0.63333333 0.77142857 0.81578947 0.86046512
## 11 0.64705882 0.63636364 0.69811321 0.82456140 0.91044776 0.91780822 0.95180723
## 12 0.55172414 0.58064516 0.66666667 0.75000000 0.89189189 0.92500000 0.95555556
## 13 0.59322034 0.61904762 0.70491803 0.81538462 0.92000000 0.95061728 0.97802198
## 14 0.44117647 0.50000000 0.60000000 0.67567568 0.83333333 0.86666667 0.90000000
## 15 0.26027397 0.40259740 0.46666667 0.56962025 0.70786517 0.76842105 0.77142857
## 16 0.00000000 0.26190476 0.34146341 0.39534884 0.58333333 0.62745098 0.66071429
## 17 0.26190476 0.00000000 0.13953488 0.31111111 0.42000000 0.49056604 0.55172414
## 18 0.34146341 0.13953488 0.00000000 0.25000000 0.32653061 0.40384615 0.47368421
## 19 0.39534884 0.31111111 0.25000000 0.00000000 0.23529412 0.29629630 0.38983051
## 20 0.58333333 0.42000000 0.32653061 0.23529412 0.00000000 0.10169492 0.18750000
## 21 0.62745098 0.49056604 0.40384615 0.29629630 0.10169492 0.00000000 0.10447761
## 22 0.66071429 0.55172414 0.47368421 0.38983051 0.18750000 0.10447761 0.00000000
## 23 0.90909091 0.83333333 0.82608696 0.84000000 0.86666667 0.87878788 0.89473684
## 24 0.81818182 0.69491525 0.64912281 0.63934426 0.57746479 0.61038961 0.65517241
## 25 0.76470588 0.74545455 0.66037736 0.61403509 0.67164179 0.69863014 0.73493976
## 26 0.63855422 0.54022989 0.45882353 0.32584270 0.21212121 0.20000000 0.25217391
## 27 0.66990291 0.57009346 0.48571429 0.37614679 0.19327731 0.13600000 0.12592593
## 28 0.69090909 0.57894737 0.50000000 0.41379310 0.22222222 0.16666667 0.12676056
```

```
## 29 0.65354331 0.51145038 0.44186047 0.41353383 0.24475524 0.18120805 0.11949686
## 30 0.72093023 0.57894737 0.52671756 0.48148148 0.29655172 0.23178808 0.18012422
##            23         24         25         26         27         28         29
## 1  1.00000000 1.00000000 1.00000000 1.00000000 1.00000000 1.00000000 0.97777778
## 2  1.00000000 1.00000000 1.00000000 0.96363636 0.97333333 0.97560976 0.93939394
## 3  1.00000000 1.00000000 0.92592593 0.93220339 0.94936709 0.95348837 0.92233010
## 4  0.92000000 0.88888889 0.81250000 0.78125000 0.83333333 0.82417582 0.81481481
## 5  0.89473684 0.79591837 0.68888889 0.55844156 0.56701031 0.57692308 0.53719008
## 6  0.84000000 0.77777778 0.68750000 0.68750000 0.76190476 0.78021978 0.77777778
## 7  0.90000000 0.93548387 0.85185185 0.89830508 0.92405063 0.93023256 0.90291262
## 9  0.77777778 0.72413793 0.84000000 0.71929825 0.76623377 0.76190476 0.78217822
## 10 0.88888889 0.79310345 0.76000000 0.82456140 0.84415584 0.85714286 0.84158416
## 11 0.86666667 0.92307692 0.90909091 0.92592593 0.94594595 0.95061728 0.89795918
## 12 0.90909091 0.93939394 0.93103448 0.93442623 0.95061728 0.95454545 0.90476190
## 13 1.00000000 1.00000000 1.00000000 0.96774194 0.97560976 0.97752809 0.90566038
## 14 0.93750000 0.90697674 0.84615385 0.85915493 0.89010989 0.89795918 0.84347826
## 15 0.94594595 0.87500000 0.81818182 0.76315789 0.77083333 0.78640777 0.73333333
## 16 0.90909091 0.81818182 0.76470588 0.63855422 0.66990291 0.69090909 0.65354331
## 17 0.83333333 0.69491525 0.74545455 0.54022989 0.57009346 0.57894737 0.51145038
## 18 0.82608696 0.64912281 0.66037736 0.45882353 0.48571429 0.50000000 0.44186047
## 19 0.84000000 0.63934426 0.61403509 0.32584270 0.37614679 0.41379310 0.41353383
## 20 0.86666667 0.57746479 0.67164179 0.21212121 0.19327731 0.22222222 0.24475524
## 21 0.87878788 0.61038961 0.69863014 0.20000000 0.13600000 0.16666667 0.18120805
## 22 0.89473684 0.65517241 0.73493976 0.25217391 0.12592593 0.12676056 0.11949686
## 23 0.00000000 0.57894737 0.46666667 0.82978723 0.88059701 0.89189189 0.91208791
## 24 0.57894737 0.00000000 0.46153846 0.48275862 0.61538462 0.64705882 0.70588235
## 25 0.46666667 0.46153846 0.00000000 0.59259259 0.70270270 0.72839506 0.77551020
## 26 0.82978723 0.48275862 0.59259259 0.00000000 0.18867925 0.23893805 0.33846154
## 27 0.88059701 0.61538462 0.70270270 0.18867925 0.00000000 0.09774436 0.18666667
## 28 0.89189189 0.64705882 0.72839506 0.23893805 0.09774436 0.00000000 0.14649682
## 29 0.91208791 0.70588235 0.77551020 0.33846154 0.18666667 0.14649682 0.00000000
## 30 0.91397849 0.71153846 0.78000000 0.36363636 0.19736842 0.15723270 0.14772727
##            30
## 1  1.00000000
## 2  1.00000000
## 3  0.98095238
## 4  0.87272727
## 5  0.59349593
## 6  0.83636364
## 7  0.96190476
## 9  0.84466019
## 10 0.90291262
## 11 0.98000000
## 12 0.98130841
## 13 1.00000000
## 14 0.93162393
## 15 0.81967213
## 16 0.72093023
## 17 0.57894737
## 18 0.52671756
## 19 0.48148148
## 20 0.29655172
## 21 0.23178808
## 22 0.18012422
```

```
## 23 0.91397849
## 24 0.71153846
## 25 0.78000000
## 26 0.36363636
## 27 0.19736842
## 28 0.15723270
## 29 0.14772727
## 30 0.00000000
```

***Question 5***: Using the distance matrices from above, answer the following questions:

a. Does the resemblance matrix (`fish.db`) represent similarity or dissimilarity? What information in the resemblance matrix led you to arrive at your answer?
b. Compare the resemblance matrices (`fish.db` or `fish.ds`) you just created. How does the choice of the Sørensen or Bray-Curtis distance influence your interpretation of site (dis)similarity?

***Answer 5a***: fish.db represents dissimilarity as it uses the Bray-Curtis Dissimilarity Abundance-based metric. When comparing each site to itself (diagonal line of zeros), we see that the value is zero indicating that there is no dissimilarity between the sites (makes sense because they are same site). ***Answer 5b***: The choice of using Sørensen or Bray-Curtis method differ in their influence on our interpretation of site (dis)similarity as Sørensen is a incidence-based metric so sites will appear more similar if they share lots of species rather than focusing on the abundance of those shared species as does the Bray-Curtis method.

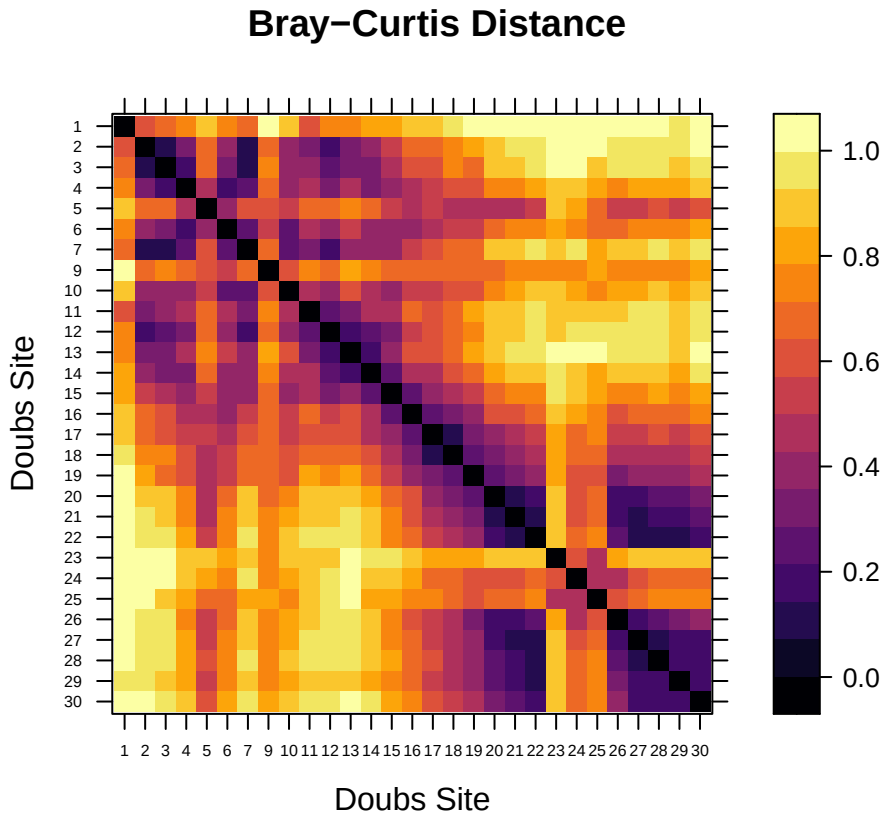
# 4) VISUALIZING BETA-DIVERSITY

### A. Heatmaps

In the R code chunk below, do the following:

1. define a color palette,
2. define the order of sites in the Doubs River, and
3. use the `levelplot()` function to create a heatmap of fish abundances in the Doubs River.

```
#Define Order of Sites
order <- rev(attr(fish.db, "Labels"))
#Plot Heatmap
levelplot(as.matrix(fish.db)[,order], aspect = "iso", col.regions = inferno,
          xlab = "Doubs Site", ylab = "Doubs Site", scales = list(cex = 0.5),
          main = "Bray-Curtis Distance")
```

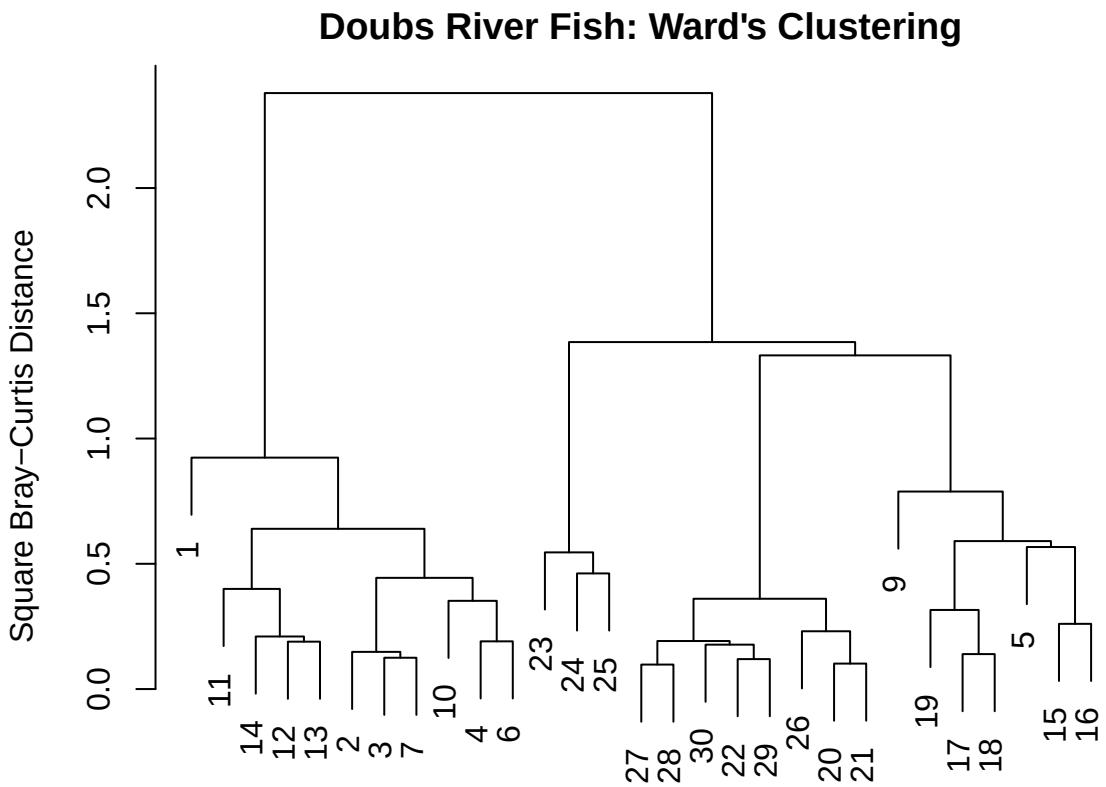



**B. Cluster Analysis**

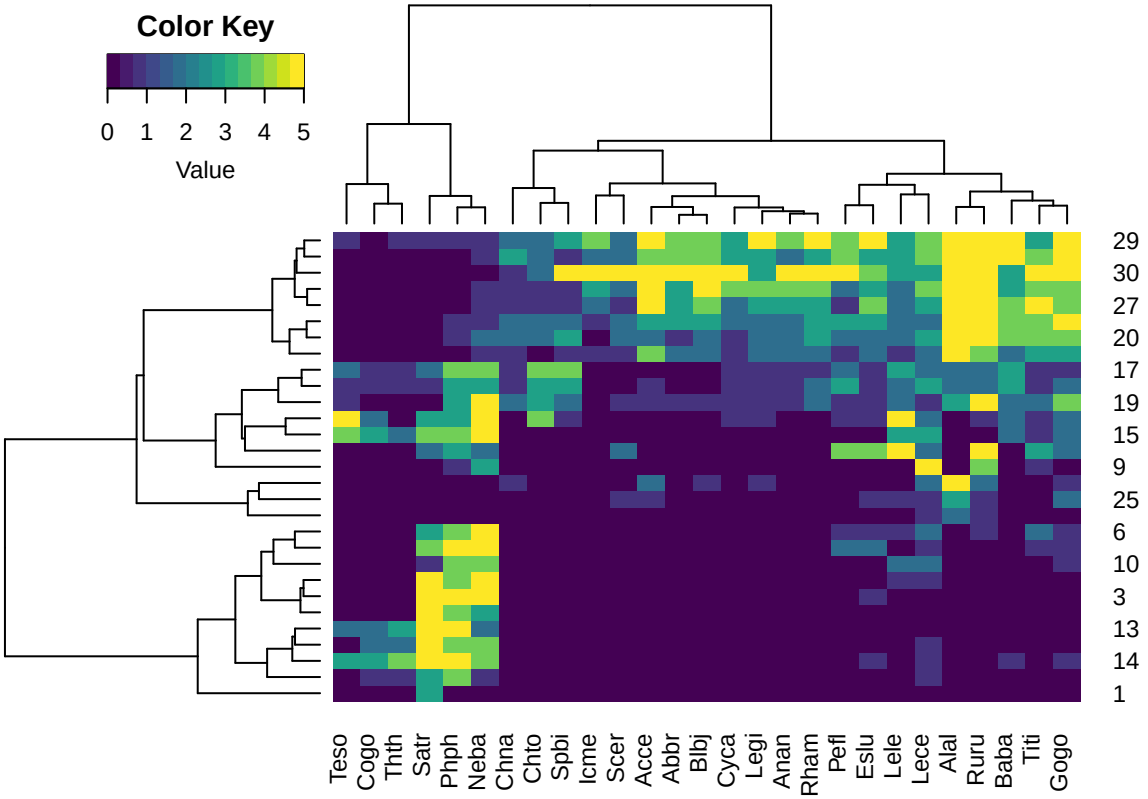
In the R code chunk below, do the following:

1. perform a cluster analysis using Ward's Clustering, and
2. plot your cluster analysis (use either `hclust` or `heatmap.2`).

```
#Perform Cluster Analysis
fish.ward <- hclust(fish.db, method = "ward.D2")
#Plot Cluster
par(mar = c(1,5,2,2) + 0.1)
plot(fish.ward, main = "Doubs River Fish: Ward's Clustering", ylab = "Square Bray-Curtis Distance")
```




```
gplots::heatmap.2(as.matrix(fish),
                  distfun = function(x) vegdist(x, method = "bray"),
                  hclustfun = function(x) hclust(x, method = "ward.D2"),
                  col = viridis, trace = "none", density.info = "none")
```




***Question 6***: Based on cluster analyses and the introductory plots that we generated after loading the data, develop an ecological hypothesis for fish diversity the `doubs` data set?

> ***Answer 6***: Based off of what we are seeing, I am inclined to hypothesized that sites 15 - 30 are close in proximity and sites 1 - 14 are closer in proximity. This could imply that there is a downstream/upstream component in terms of how the fish are being measured where certain species of fish reside either downstream or upstream, or are capable of moving between them. For example, site 5 shows relatively similar similarity across almost all sites. I would hypothesize that sites 1-14 are either downstream/upstream and sites 15 - 30 are the opposite.

### C. Ordination

### Principal Coordinates Analysis (PCoA)

In the R code chunk below, do the following:

1. perform a Principal Coordinates Analysis to visualize beta-diversity
2. calculate the variation explained by the first three axes in your ordination
3. plot the PCoA ordination,
4. label the sites as points using the Doubs River site number, and
5. identify influential species and add species coordinates to PCoA plot.

```
fish.pcoa <- cmdscale(fish.db, eig = TRUE, k = 3)
explainvar1 <- round(fish.pcoa$eig[1]/sum(fish.pcoa$eig), 3) * 100
explainvar2 <- round(fish.pcoa$eig[2]/sum(fish.pcoa$eig), 3) * 100
explainvar3 <- round(fish.pcoa$eig[3]/sum(fish.pcoa$eig), 3) * 100
sum.eig <- sum(explainvar1, explainvar2, explainvar3)

#Define Plot Parameters
par(mar = c(5, 5, 1, 2) + 0.1)
#Initiate Plot
```

```
plot(fish.pcoa$points[,1], fish.pcoa$points[,2], ylim = c(-0.2, 0.7),
     xlab = paste("PCoA 1 (", explainvar1, "%)", sep = ""),
     ylab = paste("PCoA 2 (", explainvar2, "%)", sep = ""),
     pch = 16, cex = 2.0, type = "n", cex.lab = 1.5,
     cex.axis = 1.2, axes = FALSE)

#Add Axes
axis(side = 1, labels = T, lwd.ticks = 2, cex.axis = 1.2, las = 1)
axis(side = 2, labels = T, lwd.ticks = 2, cex.axis = 1.2, las = 1)
abline(h = 0, v = 0, lty = 3)
box(lwd = 2)

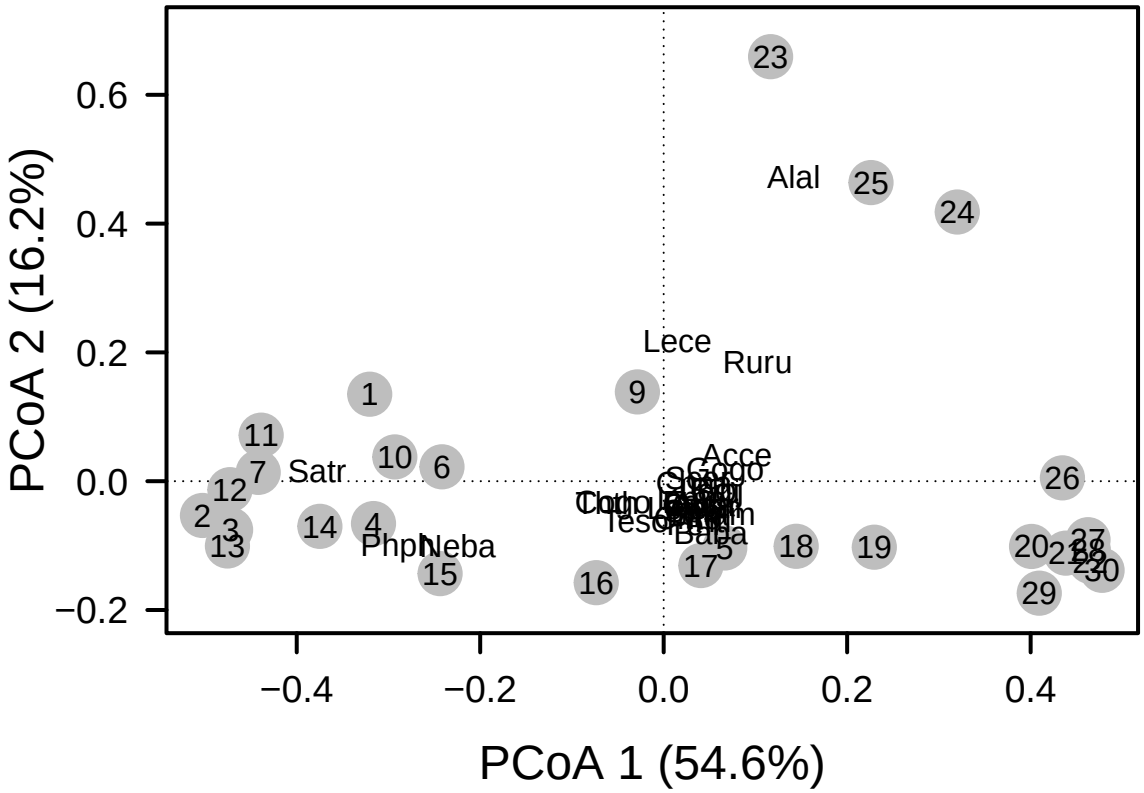
#Add Points and Labels
points(fish.pcoa$points[,1], fish.pcoa$points[,2],
       pch = 19, cex = 3, bg = "gray", col = "gray")
text(fish.pcoa$points[,1], fish.pcoa$points[,2],
     labels = row.names(fish.pcoa$points))

#First we calculate the relative abundances of each species at each site
fishREL <- fish
for(i in 1:nrow(fish)){
  fishREL[i, ] =fish[i, ] / sum(fish[i, ])
}

add.spec.scores.class <- function(ordi,comm,method="cor.scores",multi=1,Rscale=F,scaling="1") {
    ordiscores <- scores(ordi,display="sites")
    n <- ncol(comm)
    p <- ncol(ordiscores)
    specscores <- array(NA,dim=c(n,p))
    rownames(specscores) <- colnames(comm)
    colnames(specscores) <- colnames(ordiscores)
    if (method == "cor.scores") {
      for (i in 1:n) {
        for (j in 1:p) {specscores[i,j] <- cor(comm[,i],ordiscores[,j],method="pearson")}
      }
    }
    if (method == "wa.scores") {specscores <- wascores(ordiscores,comm)}
    if (method == "pcoa.scores") {
      rownames(ordiscores) <- rownames(comm)
      eigenv <- ordi$eig
      accounted <- sum(eigenv)
      tot <- 2*(accounted/ordi$GOF[2])-(accounted/ordi$GOF[1])
      eigen.var <- eigenv/(nrow(comm)-1)
      neg <- length(eigenv[eigenv<0])
      pos <- length(eigenv[eigenv>0])
      tot <- tot/(nrow(comm)-1)
      eigen.percen <- 100*eigen.var/tot
      eigen.cumpercen <- cumsum(eigen.percen)
      constant <- ((nrow(comm)-1)*tot)^0.25
      ordiscores <- ordiscores * (nrow(comm)-1)^-0.5 * tot^-0.5 * constant
      p1 <- min(p, pos)
      for (i in 1:n) {
        for (j in 1:p1) {
```

```
          specscores[i,j] <- cor(comm[,i],ordiscores[,j])*sd(comm[,i])/sd(ordiscores[,j])
          if(is.na(specscores[i,j])) {specscores[i,j]<-0}
        }
      }
      if (Rscale==T && scaling=="2") {
        percen <- eigen.var/tot
        percen <- percen^0.5
        ordiscores <- sweep(ordiscores,2,percen,"/")
        specscores <- sweep(specscores,2,percen,"*")
      }
      if (Rscale==F) {
        specscores <- specscores / constant
        ordiscores <- ordi$points
      }
      ordi$points <- ordiscores
      ordi$eig <- eigen.var
      ordi$eig.percen <- eigen.percen
      ordi$eig.cumpercen <- eigen.cumpercen
      ordi$eigen.total <- tot
      ordi$R.constant <- constant
      ordi$Rscale <- Rscale
      ordi$scaling <- scaling
    }
    specscores <- specscores * multi
    ordi$cproj <- specscores
    return(ordi)
  }


#Now we will use the relative abundances of each species at each site to calcualte and add species scor
library(vegan)
fish.pcoa <- add.spec.scores.class(fish.pcoa,fishREL, method = "pcoa.scores")
text(fish.pcoa$cproj[,1], fish.pcoa$cproj[,2],
     labels = row.names(fish.pcoa$cproj), col = "black")
```




In the R code chunk below, do the following:

1. identify influential species based on correlations along each PCoA axis (use a cutoff of 0.70), and
2. use a permutation test (999 permutations) to test the correlations of each species along each axis.

```
spe.corr <- add.spec.scores.class(fish.pcoa, fishREL, method = "cor.scores")$cproj
corrcut <- 0.7 #user defined cutoff
imp.spp <- spe.corr[abs(spe.corr[,1]) >= corrcut | abs(spe.corr[,2]) >= corrcut, ]

#Permutation test for Spcies Abundances Acros Axes
fit <- envfit(fish.pcoa, fishREL, perm = 999)


#Create "Factors" vector
quality <- c(rep("HQ", 13), rep("MQ", 5), rep("LQ", 6), rep("MQ", 5))
#Run PERMANOVA with adonis function
adonis2(fish ~ quality, method = "bray", permutations = 999)
```

```
## Permutation test for adonis under reduced model
## Permutation: free
## Number of permutations: 999
##
## adonis2(formula = fish ~ quality, permutations = 999, method = "bray")
##          Df SumOfSqs      R2     F Pr(>F)
## Model     2   3.0947 0.45765 10.97  0.001 ***
## Residual 26   3.6674 0.54235
## Total    28   6.7621 1.00000
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

***Question 7***: Address the following questions about the ordination results of the `doubs` data set:

a. Describe the grouping of sites in the Doubs River based on fish community composition.
b. Generate a hypothesis about which fish species are potential indicators of river quality.

***Answer 7a***: Looking at fish community composition, we see a clear break between almost all of sites 1 - 14 and 15-30 with the exception 5, 17, and 16 with a wider distribution of variance across the latter half of the total sites as explained by PCoA 2. ***Answer 7b***: I hypothesize that species Alal, Lece, and Ruru are indicators of river quality as they seem to appear quite distinguished from the rest of the species clustering.

## SYNTHESIS

Load the dataset from that you and your partner are using for the team project. Use one of the tools introduced in the beta diversity module to visualize your data. Describe any interesting patterns and identify a hypothesis is relevant to the principles of biodiversity.

```
Projdata <- read.csv("/cloud/project/QB2025_Guevara/Week2-Alpha/MAT_fungal_abundances.csv")
str(Projdata)
```

```
## 'data.frame':    704 obs. of  12 variables:
##  $ Plot              : chr  "MAT.B1.C" "MAT.B1.C" "MAT.B1.C" "MAT.B1.C" ...
##  $ Block             : chr  "B1" "B1" "B1" "B1" ...
##  $ Treatment         : chr  "Control" "Control" "Control" "Control" ...
##  $ OTU               : chr  "X1" "X2" "X3" "X4" ...
##  $ Species           : chr  "Alternaria_alternata" "Articulospora_tetracladia" "Cadophora_finlandica
##  $ Genus             : chr  "Alternaria" "Articulospora" "Cadophora" "Cenococcum" ...
##  $ Family            : chr  "Pleosporaceae" "Helotiaceae" "Helotiaceae" "Gloniaceae" ...
##  $ Order             : chr  "Pleosporales" "Helotiales" "Helotiales" "Mytilinidiales" ...
##  $ Phylum            : chr  "Ascomycota" "Ascomycota" "Ascomycota" "Ascomycota" ...
##  $ Relative.Abundance: num  0.0345 0 0 0.0345 0 ...
##  $ EcM.density       : num  0.679 0.679 0.679 0.679 0.679 ...
##  $ Absolute.Abundance: num  0.0234 0 0 0.0234 0 ...
```

```
#To slim down the data to only columns I will need
library(dplyr)
```

```
##
## Attaching package: 'dplyr'
```

```
## The following objects are masked from 'package:stats':
##
##     filter, lag
```

```
## The following objects are masked from 'package:base':
##
##     intersect, setdiff, setequal, union
```

```
slim <- Projdata %>%
  select(Plot, Treatment, Species, Relative.Abundance)
slim
```

```
##          Plot         Treatment                   Species Relative.Abundance
## 1    MAT.B1.C           Control       Alternaria_alternata         0.03448276
## 2    MAT.B1.C           Control  Articulospora_tetracladia         0.00000000
## 3    MAT.B1.C           Control       Cadophora_finlandica         0.00000000
## 4    MAT.B1.C           Control       Cenococcum_geophilum         0.03448276
## 5    MAT.B1.C           Control              Chalara_sp._1         0.00000000
## 6    MAT.B1.C           Control          Cortinarius_sp._1         0.37931034
```

```
## 7    MAT.B1.C          Control      Cortinarius_croceus_1         0.03448276
## 8    MAT.B1.C          Control    Cortinarius_glandicolor         0.03448276
## 9    MAT.B1.C          Control       Cortinarius_casimiri         0.00000000
## 10   MAT.B1.C          Control      Cortinarius_croceus_2         0.00000000
## 11   MAT.B1.C          Control     Cortinarius_herpeticus         0.00000000
## 12   MAT.B1.C          Control      Cortinarius_tabularis         0.00000000
## 13   MAT.B1.C          Control      Cortinarius_delibutus         0.00000000
## 14   MAT.B1.C          Control          Cortinarius_sp._2         0.00000000
## 15   MAT.B1.C          Control     Cortinarius_paragaudis         0.00000000
## 16   MAT.B1.C          Control          Cortinarius_sp._3         0.00000000
## 17   MAT.B1.C          Control           Helotiales_sp._1         0.00000000
## 18   MAT.B1.C          Control           Laccaria_laccata         0.00000000
## 19   MAT.B1.C          Control         Lactarius_vietus_1         0.10344828
## 20   MAT.B1.C          Control       Lactarius_glyciosmus         0.00000000
## 21   MAT.B1.C          Control         Lactarius_vietus_2         0.00000000
## 22   MAT.B1.C          Control           Leccinum_holopus         0.00000000
## 23   MAT.B1.C          Control           Leccinum_scabrum         0.00000000
## 24   MAT.B1.C          Control      Leccinum_variicolor_1         0.00000000
## 25   MAT.B1.C          Control      Leccinum_variicolor_2         0.00000000
## 26   MAT.B1.C          Control      Leccinum_variicolor_3         0.00000000
## 27   MAT.B1.C          Control     Leptodontidium_elatius         0.00000000
## 28   MAT.B1.C          Control    Meliniomyces_variabilis         0.00000000
## 29   MAT.B1.C          Control       Meliniomyces_bicolor         0.00000000
## 30   MAT.B1.C          Control     Phialocephala_fortinii         0.00000000
## 31   MAT.B1.C          Control     Pseudotomentella_sp._1         0.00000000
## 32   MAT.B1.C          Control        Rhizoscyphus_ericae         0.00000000
## 33   MAT.B1.C          Control      Thelephora_terrestris         0.00000000
## 34   MAT.B1.C          Control     Tomentella_sublilacina         0.00000000
## 35   MAT.B1.C          Control           Tomentella_sp._1         0.00000000
## 36   MAT.B1.C          Control   Tomentellopsis_submollis         0.00000000
## 37   MAT.B1.C          Control          Russula_chamiteae         0.00000000
## 38   MAT.B1.C          Control         Russula_decolorans         0.00000000
## 39   MAT.B1.C          Control Russula_nitida/sphagnicola         0.00000000
## 40   MAT.B1.C          Control              Russula_sp._1         0.00000000
## 41   MAT.B1.C          Control              Russula_sp._2         0.00000000
## 42   MAT.B1.C          Control              Russula_sp._3         0.37931034
## 43   MAT.B1.C          Control              Russula_sp._4         0.00000000
## 44   MAT.B1.C          Control             Russula_vinosa         0.00000000
## 45   MAT.B1.F       Fertilized       Alternaria_alternata         0.00000000
## 46   MAT.B1.F       Fertilized  Articulospora_tetracladia         0.00000000
## 47   MAT.B1.F       Fertilized       Cadophora_finlandica         0.00000000
## 48   MAT.B1.F       Fertilized       Cenococcum_geophilum         0.00000000
## 49   MAT.B1.F       Fertilized              Chalara_sp._1         0.00000000
## 50   MAT.B1.F       Fertilized          Cortinarius_sp._1         0.00000000
## 51   MAT.B1.F       Fertilized      Cortinarius_croceus_1         0.00000000
## 52   MAT.B1.F       Fertilized    Cortinarius_glandicolor         0.00000000
## 53   MAT.B1.F       Fertilized       Cortinarius_casimiri         0.00000000
## 54   MAT.B1.F       Fertilized      Cortinarius_croceus_2         0.00000000
## 55   MAT.B1.F       Fertilized     Cortinarius_herpeticus         0.00000000
## 56   MAT.B1.F       Fertilized      Cortinarius_tabularis         0.00000000
## 57   MAT.B1.F       Fertilized      Cortinarius_delibutus         0.00000000
## 58   MAT.B1.F       Fertilized          Cortinarius_sp._2         0.00000000
## 59   MAT.B1.F       Fertilized     Cortinarius_paragaudis         0.00000000
## 60   MAT.B1.F       Fertilized          Cortinarius_sp._3         0.00000000
```

```
## 61   MAT.B1.F       Fertilized          Helotiales_sp._1        0.00000000
## 62   MAT.B1.F       Fertilized          Laccaria_laccata        0.00000000
## 63   MAT.B1.F       Fertilized        Lactarius_vietus_1        0.00000000
## 64   MAT.B1.F       Fertilized       Lactarius_glyciosmus       0.00000000
## 65   MAT.B1.F       Fertilized        Lactarius_vietus_2        0.00000000
## 66   MAT.B1.F       Fertilized          Leccinum_holopus        0.00000000
## 67   MAT.B1.F       Fertilized          Leccinum_scabrum        0.00000000
## 68   MAT.B1.F       Fertilized     Leccinum_variicolor_1        0.00000000
## 69   MAT.B1.F       Fertilized     Leccinum_variicolor_2        0.00000000
## 70   MAT.B1.F       Fertilized     Leccinum_variicolor_3        0.00000000
## 71   MAT.B1.F       Fertilized    Leptodontidium_elatius        0.00000000
## 72   MAT.B1.F       Fertilized   Meliniomyces_variabilis        0.00000000
## 73   MAT.B1.F       Fertilized      Meliniomyces_bicolor        0.00000000
## 74   MAT.B1.F       Fertilized    Phialocephala_fortinii        0.00000000
## 75   MAT.B1.F       Fertilized    Pseudotomentella_sp._1        0.00000000
## 76   MAT.B1.F       Fertilized       Rhizoscyphus_ericae        0.00000000
## 77   MAT.B1.F       Fertilized     Thelephora_terrestris        0.00000000
## 78   MAT.B1.F       Fertilized    Tomentella_sublilacina        0.00000000
## 79   MAT.B1.F       Fertilized          Tomentella_sp._1        0.00000000
## 80   MAT.B1.F       Fertilized   Tomentellopsis_submollis        0.02777778
## 81   MAT.B1.F       Fertilized         Russula_chamiteae        0.08333333
## 82   MAT.B1.F       Fertilized        Russula_decolorans        0.08333333
## 83   MAT.B1.F       Fertilized Russula_nitida/sphagnicola        0.77777778
## 84   MAT.B1.F       Fertilized             Russula_sp._1        0.02777778
## 85   MAT.B1.F       Fertilized             Russula_sp._2        0.00000000
## 86   MAT.B1.F       Fertilized             Russula_sp._3        0.00000000
## 87   MAT.B1.F       Fertilized             Russula_sp._4        0.00000000
## 88   MAT.B1.F       Fertilized            Russula_vinosa        0.00000000
## 89   MAT.B1.W           Warmed       Alternaria_alternata        0.00000000
## 90   MAT.B1.W           Warmed  Articulospora_tetracladia        0.00000000
## 91   MAT.B1.W           Warmed       Cadophora_finlandica        0.00000000
## 92   MAT.B1.W           Warmed       Cenococcum_geophilum        0.00000000
## 93   MAT.B1.W           Warmed             Chalara_sp._1        0.00000000
## 94   MAT.B1.W           Warmed          Cortinarius_sp._1        0.00000000
## 95   MAT.B1.W           Warmed      Cortinarius_croceus_1        0.00000000
## 96   MAT.B1.W           Warmed    Cortinarius_glandicolor        0.00000000
## 97   MAT.B1.W           Warmed       Cortinarius_casimiri        0.00000000
## 98   MAT.B1.W           Warmed      Cortinarius_croceus_2        0.00000000
## 99   MAT.B1.W           Warmed     Cortinarius_herpeticus        0.00000000
## 100  MAT.B1.W           Warmed      Cortinarius_tabularis        0.00000000
## 101  MAT.B1.W           Warmed      Cortinarius_delibutus        0.00000000
## 102  MAT.B1.W           Warmed          Cortinarius_sp._2        0.00000000
## 103  MAT.B1.W           Warmed     Cortinarius_paragaudis        0.00000000
## 104  MAT.B1.W           Warmed          Cortinarius_sp._3        0.00000000
## 105  MAT.B1.W           Warmed           Helotiales_sp._1        0.00000000
## 106  MAT.B1.W           Warmed           Laccaria_laccata        0.00000000
## 107  MAT.B1.W           Warmed         Lactarius_vietus_1        0.00000000
## 108  MAT.B1.W           Warmed       Lactarius_glyciosmus        0.03225807
## 109  MAT.B1.W           Warmed         Lactarius_vietus_2        0.00000000
## 110  MAT.B1.W           Warmed           Leccinum_holopus        0.00000000
## 111  MAT.B1.W           Warmed           Leccinum_scabrum        0.00000000
## 112  MAT.B1.W           Warmed      Leccinum_variicolor_1        0.00000000
## 113  MAT.B1.W           Warmed      Leccinum_variicolor_2        0.00000000
## 114  MAT.B1.W           Warmed      Leccinum_variicolor_3        0.00000000
```

```
## 115  MAT.B1.W            Warmed     Leptodontidium_elatius         0.00000000
## 116  MAT.B1.W            Warmed    Meliniomyces_variabilis         0.00000000
## 117  MAT.B1.W            Warmed       Meliniomyces_bicolor         0.00000000
## 118  MAT.B1.W            Warmed     Phialocephala_fortinii         0.00000000
## 119  MAT.B1.W            Warmed     Pseudotomentella_sp._1         0.00000000
## 120  MAT.B1.W            Warmed        Rhizoscyphus_ericae         0.00000000
## 121  MAT.B1.W            Warmed      Thelephora_terrestris         0.00000000
## 122  MAT.B1.W            Warmed     Tomentella_sublilacina         0.00000000
## 123  MAT.B1.W            Warmed           Tomentella_sp._1         0.00000000
## 124  MAT.B1.W            Warmed   Tomentellopsis_submollis         0.06451613
## 125  MAT.B1.W            Warmed          Russula_chamiteae         0.16129032
## 126  MAT.B1.W            Warmed         Russula_decolorans         0.38709677
## 127  MAT.B1.W            Warmed Russula_nitida/sphagnicola         0.16129032
## 128  MAT.B1.W            Warmed              Russula_sp._1         0.09677419
## 129  MAT.B1.W            Warmed              Russula_sp._2         0.00000000
## 130  MAT.B1.W            Warmed              Russula_sp._3         0.09677419
## 131  MAT.B1.W            Warmed              Russula_sp._4         0.00000000
## 132  MAT.B1.W            Warmed             Russula_vinosa         0.00000000
## 133 MAT.B1.WF Warmed.Fertilized       Alternaria_alternata         0.00000000
## 134 MAT.B1.WF Warmed.Fertilized  Articulospora_tetracladia         0.00000000
## 135 MAT.B1.WF Warmed.Fertilized       Cadophora_finlandica         0.00000000
## 136 MAT.B1.WF Warmed.Fertilized       Cenococcum_geophilum         0.00000000
## 137 MAT.B1.WF Warmed.Fertilized              Chalara_sp._1         0.02857143
## 138 MAT.B1.WF Warmed.Fertilized         Cortinarius_sp._1         0.00000000
## 139 MAT.B1.WF Warmed.Fertilized      Cortinarius_croceus_1         0.00000000
## 140 MAT.B1.WF Warmed.Fertilized    Cortinarius_glandicolor         0.00000000
## 141 MAT.B1.WF Warmed.Fertilized       Cortinarius_casimiri         0.00000000
## 142 MAT.B1.WF Warmed.Fertilized      Cortinarius_croceus_2         0.00000000
## 143 MAT.B1.WF Warmed.Fertilized     Cortinarius_herpeticus         0.00000000
## 144 MAT.B1.WF Warmed.Fertilized      Cortinarius_tabularis         0.00000000
## 145 MAT.B1.WF Warmed.Fertilized      Cortinarius_delibutus         0.00000000
## 146 MAT.B1.WF Warmed.Fertilized          Cortinarius_sp._2         0.00000000
## 147 MAT.B1.WF Warmed.Fertilized     Cortinarius_paragaudis         0.00000000
## 148 MAT.B1.WF Warmed.Fertilized          Cortinarius_sp._3         0.00000000
## 149 MAT.B1.WF Warmed.Fertilized           Helotiales_sp._1         0.02857143
## 150 MAT.B1.WF Warmed.Fertilized           Laccaria_laccata         0.40000000
## 151 MAT.B1.WF Warmed.Fertilized         Lactarius_vietus_1         0.00000000
## 152 MAT.B1.WF Warmed.Fertilized       Lactarius_glyciosmus         0.00000000
## 153 MAT.B1.WF Warmed.Fertilized         Lactarius_vietus_2         0.00000000
## 154 MAT.B1.WF Warmed.Fertilized           Leccinum_holopus         0.00000000
## 155 MAT.B1.WF Warmed.Fertilized           Leccinum_scabrum         0.00000000
## 156 MAT.B1.WF Warmed.Fertilized      Leccinum_variicolor_1         0.00000000
## 157 MAT.B1.WF Warmed.Fertilized      Leccinum_variicolor_2         0.00000000
## 158 MAT.B1.WF Warmed.Fertilized      Leccinum_variicolor_3         0.00000000
## 159 MAT.B1.WF Warmed.Fertilized     Leptodontidium_elatius         0.00000000
## 160 MAT.B1.WF Warmed.Fertilized    Meliniomyces_variabilis         0.00000000
## 161 MAT.B1.WF Warmed.Fertilized       Meliniomyces_bicolor         0.00000000
## 162 MAT.B1.WF Warmed.Fertilized     Phialocephala_fortinii         0.00000000
## 163 MAT.B1.WF Warmed.Fertilized     Pseudotomentella_sp._1         0.00000000
## 164 MAT.B1.WF Warmed.Fertilized        Rhizoscyphus_ericae         0.00000000
## 165 MAT.B1.WF Warmed.Fertilized      Thelephora_terrestris         0.14285714
## 166 MAT.B1.WF Warmed.Fertilized     Tomentella_sublilacina         0.00000000
## 167 MAT.B1.WF Warmed.Fertilized           Tomentella_sp._1         0.00000000
## 168 MAT.B1.WF Warmed.Fertilized   Tomentellopsis_submollis         0.20000000
```

```
## 169 MAT.B1.WF Warmed.Fertilized          Russula_chamiteae         0.00000000
## 170 MAT.B1.WF Warmed.Fertilized         Russula_decolorans         0.00000000
## 171 MAT.B1.WF Warmed.Fertilized Russula_nitida/sphagnicola         0.20000000
## 172 MAT.B1.WF Warmed.Fertilized              Russula_sp._1         0.00000000
## 173 MAT.B1.WF Warmed.Fertilized              Russula_sp._2         0.00000000
## 174 MAT.B1.WF Warmed.Fertilized              Russula_sp._3         0.00000000
## 175 MAT.B1.WF Warmed.Fertilized              Russula_sp._4         0.00000000
## 176 MAT.B1.WF Warmed.Fertilized             Russula_vinosa         0.00000000
## 177  MAT.B2.C           Control       Alternaria_alternata         0.00000000
## 178  MAT.B2.C           Control  Articulospora_tetracladia         0.00000000
## 179  MAT.B2.C           Control       Cadophora_finlandica         0.00000000
## 180  MAT.B2.C           Control       Cenococcum_geophilum         0.09677419
## 181  MAT.B2.C           Control              Chalara_sp._1         0.00000000
## 182  MAT.B2.C           Control          Cortinarius_sp._1         0.00000000
## 183  MAT.B2.C           Control      Cortinarius_croceus_1         0.00000000
## 184  MAT.B2.C           Control    Cortinarius_glandicolor         0.00000000
## 185  MAT.B2.C           Control       Cortinarius_casimiri         0.00000000
## 186  MAT.B2.C           Control      Cortinarius_croceus_2         0.00000000
## 187  MAT.B2.C           Control     Cortinarius_herpeticus         0.00000000
## 188  MAT.B2.C           Control      Cortinarius_tabularis         0.00000000
## 189  MAT.B2.C           Control      Cortinarius_delibutus         0.00000000
## 190  MAT.B2.C           Control          Cortinarius_sp._2         0.00000000
## 191  MAT.B2.C           Control     Cortinarius_paragaudis         0.00000000
## 192  MAT.B2.C           Control          Cortinarius_sp._3         0.00000000
## 193  MAT.B2.C           Control           Helotiales_sp._1         0.00000000
## 194  MAT.B2.C           Control           Laccaria_laccata         0.00000000
## 195  MAT.B2.C           Control         Lactarius_vietus_1         0.29032258
## 196  MAT.B2.C           Control       Lactarius_glyciosmus         0.06451613
## 197  MAT.B2.C           Control         Lactarius_vietus_2         0.00000000
## 198  MAT.B2.C           Control           Leccinum_holopus         0.03225807
## 199  MAT.B2.C           Control           Leccinum_scabrum         0.00000000
## 200  MAT.B2.C           Control      Leccinum_variicolor_1         0.03225807
## 201  MAT.B2.C           Control      Leccinum_variicolor_2         0.00000000
## 202  MAT.B2.C           Control      Leccinum_variicolor_3         0.03225807
## 203  MAT.B2.C           Control     Leptodontidium_elatius         0.00000000
## 204  MAT.B2.C           Control    Meliniomyces_variabilis         0.03225807
## 205  MAT.B2.C           Control       Meliniomyces_bicolor         0.00000000
## 206  MAT.B2.C           Control     Phialocephala_fortinii         0.03225807
## 207  MAT.B2.C           Control     Pseudotomentella_sp._1         0.03225807
## 208  MAT.B2.C           Control        Rhizoscyphus_ericae         0.00000000
## 209  MAT.B2.C           Control      Thelephora_terrestris         0.00000000
## 210  MAT.B2.C           Control     Tomentella_sublilacina         0.00000000
## 211  MAT.B2.C           Control           Tomentella_sp._1         0.00000000
## 212  MAT.B2.C           Control   Tomentellopsis_submollis         0.00000000
## 213  MAT.B2.C           Control          Russula_chamiteae         0.03225807
## 214  MAT.B2.C           Control         Russula_decolorans         0.25806452
## 215  MAT.B2.C           Control Russula_nitida/sphagnicola         0.00000000
## 216  MAT.B2.C           Control              Russula_sp._1         0.00000000
## 217  MAT.B2.C           Control              Russula_sp._2         0.00000000
## 218  MAT.B2.C           Control              Russula_sp._3         0.06451613
## 219  MAT.B2.C           Control              Russula_sp._4         0.00000000
## 220  MAT.B2.C           Control             Russula_vinosa         0.00000000
## 221  MAT.B2.F        Fertilized       Alternaria_alternata         0.00000000
## 222  MAT.B2.F        Fertilized  Articulospora_tetracladia         0.03571429
```

```
## 223  MAT.B2.F       Fertilized       Cadophora_finlandica        0.00000000
## 224  MAT.B2.F       Fertilized       Cenococcum_geophilum        0.00000000
## 225  MAT.B2.F       Fertilized             Chalara_sp._1         0.00000000
## 226  MAT.B2.F       Fertilized          Cortinarius_sp._1        0.00000000
## 227  MAT.B2.F       Fertilized      Cortinarius_croceus_1        0.00000000
## 228  MAT.B2.F       Fertilized    Cortinarius_glandicolor        0.00000000
## 229  MAT.B2.F       Fertilized       Cortinarius_casimiri        0.00000000
## 230  MAT.B2.F       Fertilized      Cortinarius_croceus_2        0.00000000
## 231  MAT.B2.F       Fertilized     Cortinarius_herpeticus        0.00000000
## 232  MAT.B2.F       Fertilized      Cortinarius_tabularis        0.00000000
## 233  MAT.B2.F       Fertilized      Cortinarius_delibutus        0.00000000
## 234  MAT.B2.F       Fertilized          Cortinarius_sp._2        0.00000000
## 235  MAT.B2.F       Fertilized     Cortinarius_paragaudis        0.00000000
## 236  MAT.B2.F       Fertilized          Cortinarius_sp._3        0.00000000
## 237  MAT.B2.F       Fertilized           Helotiales_sp._1        0.00000000
## 238  MAT.B2.F       Fertilized           Laccaria_laccata        0.00000000
## 239  MAT.B2.F       Fertilized         Lactarius_vietus_1        0.03571429
## 240  MAT.B2.F       Fertilized       Lactarius_glyciosmus        0.00000000
## 241  MAT.B2.F       Fertilized         Lactarius_vietus_2        0.00000000
## 242  MAT.B2.F       Fertilized           Leccinum_holopus        0.00000000
## 243  MAT.B2.F       Fertilized           Leccinum_scabrum        0.00000000
## 244  MAT.B2.F       Fertilized      Leccinum_variicolor_1        0.00000000
## 245  MAT.B2.F       Fertilized      Leccinum_variicolor_2        0.00000000
## 246  MAT.B2.F       Fertilized      Leccinum_variicolor_3        0.00000000
## 247  MAT.B2.F       Fertilized     Leptodontidium_elatius        0.00000000
## 248  MAT.B2.F       Fertilized    Meliniomyces_variabilis        0.03571429
## 249  MAT.B2.F       Fertilized       Meliniomyces_bicolor        0.00000000
## 250  MAT.B2.F       Fertilized     Phialocephala_fortinii        0.00000000
## 251  MAT.B2.F       Fertilized     Pseudotomentella_sp._1        0.03571429
## 252  MAT.B2.F       Fertilized         Rhizoscyphus_ericae        0.03571429
## 253  MAT.B2.F       Fertilized      Thelephora_terrestris        0.67857143
## 254  MAT.B2.F       Fertilized     Tomentella_sublilacina        0.00000000
## 255  MAT.B2.F       Fertilized           Tomentella_sp._1        0.00000000
## 256  MAT.B2.F       Fertilized   Tomentellopsis_submollis        0.14285714
## 257  MAT.B2.F       Fertilized          Russula_chamiteae        0.00000000
## 258  MAT.B2.F       Fertilized         Russula_decolorans        0.00000000
## 259  MAT.B2.F       Fertilized Russula_nitida/sphagnicola        0.00000000
## 260  MAT.B2.F       Fertilized              Russula_sp._1        0.00000000
## 261  MAT.B2.F       Fertilized              Russula_sp._2        0.00000000
## 262  MAT.B2.F       Fertilized              Russula_sp._3        0.00000000
## 263  MAT.B2.F       Fertilized              Russula_sp._4        0.00000000
## 264  MAT.B2.F       Fertilized             Russula_vinosa        0.00000000
## 265  MAT.B2.W           Warmed       Alternaria_alternata        0.00000000
## 266  MAT.B2.W           Warmed  Articulospora_tetracladia        0.00000000
## 267  MAT.B2.W           Warmed       Cadophora_finlandica        0.00000000
## 268  MAT.B2.W           Warmed       Cenococcum_geophilum        0.15151515
## 269  MAT.B2.W           Warmed             Chalara_sp._1         0.00000000
## 270  MAT.B2.W           Warmed          Cortinarius_sp._1        0.00000000
## 271  MAT.B2.W           Warmed      Cortinarius_croceus_1        0.03030303
## 272  MAT.B2.W           Warmed    Cortinarius_glandicolor        0.00000000
## 273  MAT.B2.W           Warmed       Cortinarius_casimiri        0.00000000
## 274  MAT.B2.W           Warmed      Cortinarius_croceus_2        0.00000000
## 275  MAT.B2.W           Warmed     Cortinarius_herpeticus        0.00000000
## 276  MAT.B2.W           Warmed      Cortinarius_tabularis        0.00000000
```

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## 277  MAT.B2.W            Warmed      Cortinarius_delibutus         0.00000000
## 278  MAT.B2.W            Warmed          Cortinarius_sp._2         0.00000000
## 279  MAT.B2.W            Warmed     Cortinarius_paragaudis         0.00000000
## 280  MAT.B2.W            Warmed          Cortinarius_sp._3         0.00000000
## 281  MAT.B2.W            Warmed           Helotiales_sp._1         0.00000000
## 282  MAT.B2.W            Warmed           Laccaria_laccata         0.00000000
## 283  MAT.B2.W            Warmed         Lactarius_vietus_1         0.03030303
## 284  MAT.B2.W            Warmed       Lactarius_glyciosmus         0.03030303
## 285  MAT.B2.W            Warmed         Lactarius_vietus_2         0.00000000
## 286  MAT.B2.W            Warmed           Leccinum_holopus         0.00000000
## 287  MAT.B2.W            Warmed           Leccinum_scabrum         0.00000000
## 288  MAT.B2.W            Warmed      Leccinum_variicolor_1         0.00000000
## 289  MAT.B2.W            Warmed      Leccinum_variicolor_2         0.00000000
## 290  MAT.B2.W            Warmed      Leccinum_variicolor_3         0.00000000
## 291  MAT.B2.W            Warmed     Leptodontidium_elatius         0.00000000
## 292  MAT.B2.W            Warmed    Meliniomyces_variabilis         0.03030303
## 293  MAT.B2.W            Warmed       Meliniomyces_bicolor         0.00000000
## 294  MAT.B2.W            Warmed     Phialocephala_fortinii         0.00000000
## 295  MAT.B2.W            Warmed     Pseudotomentella_sp._1         0.00000000
## 296  MAT.B2.W            Warmed        Rhizoscyphus_ericae         0.03030303
## 297  MAT.B2.W            Warmed      Thelephora_terrestris         0.00000000
## 298  MAT.B2.W            Warmed     Tomentella_sublilacina         0.00000000
## 299  MAT.B2.W            Warmed           Tomentella_sp._1         0.00000000
## 300  MAT.B2.W            Warmed   Tomentellopsis_submollis         0.00000000
## 301  MAT.B2.W            Warmed          Russula_chamiteae         0.00000000
## 302  MAT.B2.W            Warmed         Russula_decolorans         0.42424242
## 303  MAT.B2.W            Warmed Russula_nitida/sphagnicola         0.03030303
## 304  MAT.B2.W            Warmed              Russula_sp._1         0.00000000
## 305  MAT.B2.W            Warmed              Russula_sp._2         0.00000000
## 306  MAT.B2.W            Warmed              Russula_sp._3         0.24242424
## 307  MAT.B2.W            Warmed              Russula_sp._4         0.00000000
## 308  MAT.B2.W            Warmed             Russula_vinosa         0.00000000
## 309 MAT.B2.WF Warmed.Fertilized       Alternaria_alternata         0.00000000
## 310 MAT.B2.WF Warmed.Fertilized  Articulospora_tetracladia         0.00000000
## 311 MAT.B2.WF Warmed.Fertilized       Cadophora_finlandica         0.04761905
## 312 MAT.B2.WF Warmed.Fertilized       Cenococcum_geophilum         0.00000000
## 313 MAT.B2.WF Warmed.Fertilized              Chalara_sp._1         0.04761905
## 314 MAT.B2.WF Warmed.Fertilized          Cortinarius_sp._1         0.00000000
## 315 MAT.B2.WF Warmed.Fertilized      Cortinarius_croceus_1         0.00000000
## 316 MAT.B2.WF Warmed.Fertilized    Cortinarius_glandicolor         0.00000000
## 317 MAT.B2.WF Warmed.Fertilized       Cortinarius_casimiri         0.04761905
## 318 MAT.B2.WF Warmed.Fertilized      Cortinarius_croceus_2         0.00000000
## 319 MAT.B2.WF Warmed.Fertilized     Cortinarius_herpeticus         0.00000000
## 320 MAT.B2.WF Warmed.Fertilized      Cortinarius_tabularis         0.00000000
## 321 MAT.B2.WF Warmed.Fertilized      Cortinarius_delibutus         0.00000000
## 322 MAT.B2.WF Warmed.Fertilized          Cortinarius_sp._2         0.00000000
## 323 MAT.B2.WF Warmed.Fertilized     Cortinarius_paragaudis         0.00000000
## 324 MAT.B2.WF Warmed.Fertilized          Cortinarius_sp._3         0.00000000
## 325 MAT.B2.WF Warmed.Fertilized           Helotiales_sp._1         0.04761905
## 326 MAT.B2.WF Warmed.Fertilized           Laccaria_laccata         0.04761905
## 327 MAT.B2.WF Warmed.Fertilized         Lactarius_vietus_1         0.04761905
## 328 MAT.B2.WF Warmed.Fertilized       Lactarius_glyciosmus         0.14285714
## 329 MAT.B2.WF Warmed.Fertilized         Lactarius_vietus_2         0.00000000
## 330 MAT.B2.WF Warmed.Fertilized           Leccinum_holopus         0.00000000
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## 331 MAT.B2.WF Warmed.Fertilized          Leccinum_scabrum         0.00000000
## 332 MAT.B2.WF Warmed.Fertilized      Leccinum_variicolor_1        0.00000000
## 333 MAT.B2.WF Warmed.Fertilized      Leccinum_variicolor_2        0.00000000
## 334 MAT.B2.WF Warmed.Fertilized      Leccinum_variicolor_3        0.00000000
## 335 MAT.B2.WF Warmed.Fertilized     Leptodontidium_elatius        0.00000000
## 336 MAT.B2.WF Warmed.Fertilized    Meliniomyces_variabilis        0.00000000
## 337 MAT.B2.WF Warmed.Fertilized       Meliniomyces_bicolor        0.04761905
## 338 MAT.B2.WF Warmed.Fertilized     Phialocephala_fortinii        0.00000000
## 339 MAT.B2.WF Warmed.Fertilized     Pseudotomentella_sp._1        0.14285714
## 340 MAT.B2.WF Warmed.Fertilized        Rhizoscyphus_ericae        0.04761905
## 341 MAT.B2.WF Warmed.Fertilized      Thelephora_terrestris        0.09523809
## 342 MAT.B2.WF Warmed.Fertilized     Tomentella_sublilacina        0.00000000
## 343 MAT.B2.WF Warmed.Fertilized           Tomentella_sp._1        0.00000000
## 344 MAT.B2.WF Warmed.Fertilized   Tomentellopsis_submollis        0.09523809
## 345 MAT.B2.WF Warmed.Fertilized          Russula_chamiteae        0.00000000
## 346 MAT.B2.WF Warmed.Fertilized         Russula_decolorans        0.04761905
## 347 MAT.B2.WF Warmed.Fertilized Russula_nitida/sphagnicola        0.09523809
## 348 MAT.B2.WF Warmed.Fertilized              Russula_sp._1        0.00000000
## 349 MAT.B2.WF Warmed.Fertilized              Russula_sp._2        0.00000000
## 350 MAT.B2.WF Warmed.Fertilized              Russula_sp._3        0.00000000
## 351 MAT.B2.WF Warmed.Fertilized              Russula_sp._4        0.00000000
## 352 MAT.B2.WF Warmed.Fertilized             Russula_vinosa        0.00000000
## 353  MAT.B3.C           Control       Alternaria_alternata        0.00000000
## 354  MAT.B3.C           Control  Articulospora_tetracladia        0.00000000
## 355  MAT.B3.C           Control       Cadophora_finlandica        0.00000000
## 356  MAT.B3.C           Control       Cenococcum_geophilum        0.00000000
## 357  MAT.B3.C           Control             Chalara_sp._1        0.00000000
## 358  MAT.B3.C           Control          Cortinarius_sp._1        0.11764706
## 359  MAT.B3.C           Control      Cortinarius_croceus_1        0.00000000
## 360  MAT.B3.C           Control    Cortinarius_glandicolor        0.00000000
## 361  MAT.B3.C           Control       Cortinarius_casimiri        0.00000000
## 362  MAT.B3.C           Control      Cortinarius_croceus_2        0.17647059
## 363  MAT.B3.C           Control     Cortinarius_herpeticus        0.00000000
## 364  MAT.B3.C           Control      Cortinarius_tabularis        0.00000000
## 365  MAT.B3.C           Control      Cortinarius_delibutus        0.00000000
## 366  MAT.B3.C           Control          Cortinarius_sp._2        0.00000000
## 367  MAT.B3.C           Control     Cortinarius_paragaudis        0.00000000
## 368  MAT.B3.C           Control          Cortinarius_sp._3        0.00000000
## 369  MAT.B3.C           Control           Helotiales_sp._1        0.00000000
## 370  MAT.B3.C           Control           Laccaria_laccata        0.00000000
## 371  MAT.B3.C           Control         Lactarius_vietus_1        0.17647059
## 372  MAT.B3.C           Control       Lactarius_glyciosmus        0.00000000
## 373  MAT.B3.C           Control         Lactarius_vietus_2        0.00000000
## 374  MAT.B3.C           Control           Leccinum_holopus        0.00000000
## 375  MAT.B3.C           Control           Leccinum_scabrum        0.00000000
## 376  MAT.B3.C           Control      Leccinum_variicolor_1        0.00000000
## 377  MAT.B3.C           Control      Leccinum_variicolor_2        0.00000000
## 378  MAT.B3.C           Control      Leccinum_variicolor_3        0.00000000
## 379  MAT.B3.C           Control     Leptodontidium_elatius        0.00000000
## 380  MAT.B3.C           Control    Meliniomyces_variabilis        0.00000000
## 381  MAT.B3.C           Control       Meliniomyces_bicolor        0.00000000
## 382  MAT.B3.C           Control     Phialocephala_fortinii        0.00000000
## 383  MAT.B3.C           Control     Pseudotomentella_sp._1        0.00000000
## 384  MAT.B3.C           Control        Rhizoscyphus_ericae        0.00000000
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## 385  MAT.B3.C          Control      Thelephora_terrestris         0.00000000
## 386  MAT.B3.C          Control     Tomentella_sublilacina         0.00000000
## 387  MAT.B3.C          Control           Tomentella_sp._1         0.00000000
## 388  MAT.B3.C          Control   Tomentellopsis_submollis         0.00000000
## 389  MAT.B3.C          Control          Russula_chamiteae         0.00000000
## 390  MAT.B3.C          Control         Russula_decolorans         0.29411765
## 391  MAT.B3.C          Control Russula_nitida/sphagnicola         0.05882353
## 392  MAT.B3.C          Control              Russula_sp._1         0.17647059
## 393  MAT.B3.C          Control              Russula_sp._2         0.00000000
## 394  MAT.B3.C          Control              Russula_sp._3         0.00000000
## 395  MAT.B3.C          Control              Russula_sp._4         0.00000000
## 396  MAT.B3.C          Control             Russula_vinosa         0.00000000
## 397  MAT.B3.F       Fertilized       Alternaria_alternata         0.00000000
## 398  MAT.B3.F       Fertilized  Articulospora_tetracladia         0.00000000
## 399  MAT.B3.F       Fertilized       Cadophora_finlandica         0.00000000
## 400  MAT.B3.F       Fertilized       Cenococcum_geophilum         0.00000000
## 401  MAT.B3.F       Fertilized              Chalara_sp._1         0.00000000
## 402  MAT.B3.F       Fertilized          Cortinarius_sp._1         0.00000000
## 403  MAT.B3.F       Fertilized      Cortinarius_croceus_1         0.00000000
## 404  MAT.B3.F       Fertilized    Cortinarius_glandicolor         0.00000000
## 405  MAT.B3.F       Fertilized       Cortinarius_casimiri         0.00000000
## 406  MAT.B3.F       Fertilized      Cortinarius_croceus_2         0.00000000
## 407  MAT.B3.F       Fertilized     Cortinarius_herpeticus         0.00000000
## 408  MAT.B3.F       Fertilized      Cortinarius_tabularis         0.00000000
## 409  MAT.B3.F       Fertilized      Cortinarius_delibutus         0.00000000
## 410  MAT.B3.F       Fertilized          Cortinarius_sp._2         0.00000000
## 411  MAT.B3.F       Fertilized     Cortinarius_paragaudis         0.00000000
## 412  MAT.B3.F       Fertilized          Cortinarius_sp._3         0.00000000
## 413  MAT.B3.F       Fertilized           Helotiales_sp._1         0.00000000
## 414  MAT.B3.F       Fertilized           Laccaria_laccata         0.06666667
## 415  MAT.B3.F       Fertilized         Lactarius_vietus_1         0.06666667
## 416  MAT.B3.F       Fertilized       Lactarius_glyciosmus         0.13333333
## 417  MAT.B3.F       Fertilized         Lactarius_vietus_2         0.00000000
## 418  MAT.B3.F       Fertilized           Leccinum_holopus         0.00000000
## 419  MAT.B3.F       Fertilized           Leccinum_scabrum         0.00000000
## 420  MAT.B3.F       Fertilized      Leccinum_variicolor_1         0.00000000
## 421  MAT.B3.F       Fertilized      Leccinum_variicolor_2         0.00000000
## 422  MAT.B3.F       Fertilized      Leccinum_variicolor_3         0.00000000
## 423  MAT.B3.F       Fertilized     Leptodontidium_elatius         0.00000000
## 424  MAT.B3.F       Fertilized    Meliniomyces_variabilis         0.00000000
## 425  MAT.B3.F       Fertilized       Meliniomyces_bicolor         0.00000000
## 426  MAT.B3.F       Fertilized     Phialocephala_fortinii         0.00000000
## 427  MAT.B3.F       Fertilized     Pseudotomentella_sp._1         0.00000000
## 428  MAT.B3.F       Fertilized        Rhizoscyphus_ericae         0.00000000
## 429  MAT.B3.F       Fertilized      Thelephora_terrestris         0.00000000
## 430  MAT.B3.F       Fertilized     Tomentella_sublilacina         0.00000000
## 431  MAT.B3.F       Fertilized           Tomentella_sp._1         0.00000000
## 432  MAT.B3.F       Fertilized   Tomentellopsis_submollis         0.06666667
## 433  MAT.B3.F       Fertilized          Russula_chamiteae         0.00000000
## 434  MAT.B3.F       Fertilized         Russula_decolorans         0.00000000
## 435  MAT.B3.F       Fertilized Russula_nitida/sphagnicola         0.66666667
## 436  MAT.B3.F       Fertilized              Russula_sp._1         0.00000000
## 437  MAT.B3.F       Fertilized              Russula_sp._2         0.00000000
## 438  MAT.B3.F       Fertilized              Russula_sp._3         0.00000000
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## 439  MAT.B3.F        Fertilized             Russula_sp._4         0.00000000
## 440  MAT.B3.F        Fertilized            Russula_vinosa         0.00000000
## 441  MAT.B3.W            Warmed       Alternaria_alternata         0.00000000
## 442  MAT.B3.W            Warmed  Articulospora_tetracladia         0.00000000
## 443  MAT.B3.W            Warmed       Cadophora_finlandica         0.00000000
## 444  MAT.B3.W            Warmed       Cenococcum_geophilum         0.00000000
## 445  MAT.B3.W            Warmed             Chalara_sp._1         0.00000000
## 446  MAT.B3.W            Warmed          Cortinarius_sp._1         0.00000000
## 447  MAT.B3.W            Warmed      Cortinarius_croceus_1         0.00000000
## 448  MAT.B3.W            Warmed    Cortinarius_glandicolor         0.00000000
## 449  MAT.B3.W            Warmed       Cortinarius_casimiri         0.00000000
## 450  MAT.B3.W            Warmed      Cortinarius_croceus_2         0.00000000
## 451  MAT.B3.W            Warmed     Cortinarius_herpeticus         0.00000000
## 452  MAT.B3.W            Warmed      Cortinarius_tabularis         0.00000000
## 453  MAT.B3.W            Warmed      Cortinarius_delibutus         0.00000000
## 454  MAT.B3.W            Warmed          Cortinarius_sp._2         0.00000000
## 455  MAT.B3.W            Warmed     Cortinarius_paragaudis         0.00000000
## 456  MAT.B3.W            Warmed          Cortinarius_sp._3         0.00000000
## 457  MAT.B3.W            Warmed           Helotiales_sp._1         0.00000000
## 458  MAT.B3.W            Warmed           Laccaria_laccata         0.00000000
## 459  MAT.B3.W            Warmed         Lactarius_vietus_1         0.00000000
## 460  MAT.B3.W            Warmed       Lactarius_glyciosmus         0.11111111
## 461  MAT.B3.W            Warmed         Lactarius_vietus_2         0.00000000
## 462  MAT.B3.W            Warmed           Leccinum_holopus         0.00000000
## 463  MAT.B3.W            Warmed           Leccinum_scabrum         0.03703704
## 464  MAT.B3.W            Warmed      Leccinum_variicolor_1         0.00000000
## 465  MAT.B3.W            Warmed      Leccinum_variicolor_2         0.00000000
## 466  MAT.B3.W            Warmed      Leccinum_variicolor_3         0.00000000
## 467  MAT.B3.W            Warmed     Leptodontidium_elatius         0.07407407
## 468  MAT.B3.W            Warmed    Meliniomyces_variabilis         0.00000000
## 469  MAT.B3.W            Warmed       Meliniomyces_bicolor         0.07407407
## 470  MAT.B3.W            Warmed     Phialocephala_fortinii         0.00000000
## 471  MAT.B3.W            Warmed     Pseudotomentella_sp._1         0.00000000
## 472  MAT.B3.W            Warmed        Rhizoscyphus_ericae         0.00000000
## 473  MAT.B3.W            Warmed      Thelephora_terrestris         0.00000000
## 474  MAT.B3.W            Warmed     Tomentella_sublilacina         0.00000000
## 475  MAT.B3.W            Warmed           Tomentella_sp._1         0.00000000
## 476  MAT.B3.W            Warmed   Tomentellopsis_submollis         0.03703704
## 477  MAT.B3.W            Warmed          Russula_chamiteae         0.00000000
## 478  MAT.B3.W            Warmed         Russula_decolorans         0.00000000
## 479  MAT.B3.W            Warmed Russula_nitida/sphagnicola         0.62962963
## 480  MAT.B3.W            Warmed             Russula_sp._1         0.00000000
## 481  MAT.B3.W            Warmed             Russula_sp._2         0.00000000
## 482  MAT.B3.W            Warmed             Russula_sp._3         0.00000000
## 483  MAT.B3.W            Warmed             Russula_sp._4         0.00000000
## 484  MAT.B3.W            Warmed            Russula_vinosa         0.03703704
## 485 MAT.B3.WF Warmed.Fertilized       Alternaria_alternata         0.00000000
## 486 MAT.B3.WF Warmed.Fertilized  Articulospora_tetracladia         0.00000000
## 487 MAT.B3.WF Warmed.Fertilized       Cadophora_finlandica         0.00000000
## 488 MAT.B3.WF Warmed.Fertilized       Cenococcum_geophilum         0.00000000
## 489 MAT.B3.WF Warmed.Fertilized             Chalara_sp._1         0.00000000
## 490 MAT.B3.WF Warmed.Fertilized          Cortinarius_sp._1         0.00000000
## 491 MAT.B3.WF Warmed.Fertilized      Cortinarius_croceus_1         0.00000000
## 492 MAT.B3.WF Warmed.Fertilized    Cortinarius_glandicolor         0.00000000
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## 493 MAT.B3.WF Warmed.Fertilized       Cortinarius_casimiri         0.00000000
## 494 MAT.B3.WF Warmed.Fertilized      Cortinarius_croceus_2         0.00000000
## 495 MAT.B3.WF Warmed.Fertilized     Cortinarius_herpeticus         0.00000000
## 496 MAT.B3.WF Warmed.Fertilized      Cortinarius_tabularis         0.00000000
## 497 MAT.B3.WF Warmed.Fertilized      Cortinarius_delibutus         0.00000000
## 498 MAT.B3.WF Warmed.Fertilized          Cortinarius_sp._2         0.00000000
## 499 MAT.B3.WF Warmed.Fertilized     Cortinarius_paragaudis         0.00000000
## 500 MAT.B3.WF Warmed.Fertilized          Cortinarius_sp._3         0.00000000
## 501 MAT.B3.WF Warmed.Fertilized           Helotiales_sp._1         0.00000000
## 502 MAT.B3.WF Warmed.Fertilized           Laccaria_laccata         0.14285714
## 503 MAT.B3.WF Warmed.Fertilized         Lactarius_vietus_1         0.00000000
## 504 MAT.B3.WF Warmed.Fertilized       Lactarius_glyciosmus         0.25000000
## 505 MAT.B3.WF Warmed.Fertilized         Lactarius_vietus_2         0.00000000
## 506 MAT.B3.WF Warmed.Fertilized           Leccinum_holopus         0.00000000
## 507 MAT.B3.WF Warmed.Fertilized           Leccinum_scabrum         0.00000000
## 508 MAT.B3.WF Warmed.Fertilized      Leccinum_variicolor_1         0.00000000
## 509 MAT.B3.WF Warmed.Fertilized      Leccinum_variicolor_2         0.00000000
## 510 MAT.B3.WF Warmed.Fertilized      Leccinum_variicolor_3         0.00000000
## 511 MAT.B3.WF Warmed.Fertilized     Leptodontidium_elatius         0.00000000
## 512 MAT.B3.WF Warmed.Fertilized    Meliniomyces_variabilis         0.00000000
## 513 MAT.B3.WF Warmed.Fertilized       Meliniomyces_bicolor         0.00000000
## 514 MAT.B3.WF Warmed.Fertilized     Phialocephala_fortinii         0.00000000
## 515 MAT.B3.WF Warmed.Fertilized     Pseudotomentella_sp._1         0.00000000
## 516 MAT.B3.WF Warmed.Fertilized        Rhizoscyphus_ericae         0.00000000
## 517 MAT.B3.WF Warmed.Fertilized      Thelephora_terrestris         0.00000000
## 518 MAT.B3.WF Warmed.Fertilized     Tomentella_sublilacina         0.00000000
## 519 MAT.B3.WF Warmed.Fertilized           Tomentella_sp._1         0.00000000
## 520 MAT.B3.WF Warmed.Fertilized   Tomentellopsis_submollis         0.07142857
## 521 MAT.B3.WF Warmed.Fertilized          Russula_chamiteae         0.00000000
## 522 MAT.B3.WF Warmed.Fertilized         Russula_decolorans         0.00000000
## 523 MAT.B3.WF Warmed.Fertilized Russula_nitida/sphagnicola         0.17857143
## 524 MAT.B3.WF Warmed.Fertilized              Russula_sp._1         0.03571429
## 525 MAT.B3.WF Warmed.Fertilized              Russula_sp._2         0.07142857
## 526 MAT.B3.WF Warmed.Fertilized              Russula_sp._3         0.25000000
## 527 MAT.B3.WF Warmed.Fertilized              Russula_sp._4         0.00000000
## 528 MAT.B3.WF Warmed.Fertilized             Russula_vinosa         0.00000000
## 529  MAT.B4.C           Control       Alternaria_alternata         0.00000000
## 530  MAT.B4.C           Control  Articulospora_tetracladia         0.00000000
## 531  MAT.B4.C           Control       Cadophora_finlandica         0.00000000
## 532  MAT.B4.C           Control       Cenococcum_geophilum         0.10000000
## 533  MAT.B4.C           Control              Chalara_sp._1         0.00000000
## 534  MAT.B4.C           Control          Cortinarius_sp._1         0.16666667
## 535  MAT.B4.C           Control      Cortinarius_croceus_1         0.00000000
## 536  MAT.B4.C           Control    Cortinarius_glandicolor         0.00000000
## 537  MAT.B4.C           Control       Cortinarius_casimiri         0.00000000
## 538  MAT.B4.C           Control      Cortinarius_croceus_2         0.00000000
## 539  MAT.B4.C           Control     Cortinarius_herpeticus         0.10000000
## 540  MAT.B4.C           Control      Cortinarius_tabularis         0.03333333
## 541  MAT.B4.C           Control      Cortinarius_delibutus         0.00000000
## 542  MAT.B4.C           Control          Cortinarius_sp._2         0.00000000
## 543  MAT.B4.C           Control     Cortinarius_paragaudis         0.00000000
## 544  MAT.B4.C           Control          Cortinarius_sp._3         0.00000000
## 545  MAT.B4.C           Control           Helotiales_sp._1         0.00000000
## 546  MAT.B4.C           Control           Laccaria_laccata         0.03333333
```

```
## 547  MAT.B4.C          Control         Lactarius_vietus_1         0.00000000
## 548  MAT.B4.C          Control       Lactarius_glyciosmus         0.03333333
## 549  MAT.B4.C          Control         Lactarius_vietus_2         0.00000000
## 550  MAT.B4.C          Control           Leccinum_holopus         0.00000000
## 551  MAT.B4.C          Control           Leccinum_scabrum         0.00000000
## 552  MAT.B4.C          Control      Leccinum_variicolor_1         0.00000000
## 553  MAT.B4.C          Control      Leccinum_variicolor_2         0.03333333
## 554  MAT.B4.C          Control      Leccinum_variicolor_3         0.00000000
## 555  MAT.B4.C          Control     Leptodontidium_elatius         0.00000000
## 556  MAT.B4.C          Control    Meliniomyces_variabilis         0.00000000
## 557  MAT.B4.C          Control       Meliniomyces_bicolor         0.00000000
## 558  MAT.B4.C          Control     Phialocephala_fortinii         0.00000000
## 559  MAT.B4.C          Control     Pseudotomentella_sp._1         0.00000000
## 560  MAT.B4.C          Control        Rhizoscyphus_ericae         0.00000000
## 561  MAT.B4.C          Control      Thelephora_terrestris         0.00000000
## 562  MAT.B4.C          Control     Tomentella_sublilacina         0.00000000
## 563  MAT.B4.C          Control           Tomentella_sp._1         0.00000000
## 564  MAT.B4.C          Control   Tomentellopsis_submollis         0.03333333
## 565  MAT.B4.C          Control          Russula_chamiteae         0.13333333
## 566  MAT.B4.C          Control         Russula_decolorans         0.23333333
## 567  MAT.B4.C          Control Russula_nitida/sphagnicola         0.03333333
## 568  MAT.B4.C          Control              Russula_sp._1         0.06666667
## 569  MAT.B4.C          Control              Russula_sp._2         0.00000000
## 570  MAT.B4.C          Control              Russula_sp._3         0.00000000
## 571  MAT.B4.C          Control              Russula_sp._4         0.00000000
## 572  MAT.B4.C          Control             Russula_vinosa         0.00000000
## 573  MAT.B4.F       Fertilized       Alternaria_alternata         0.00000000
## 574  MAT.B4.F       Fertilized  Articulospora_tetracladia         0.00000000
## 575  MAT.B4.F       Fertilized       Cadophora_finlandica         0.00000000
## 576  MAT.B4.F       Fertilized       Cenococcum_geophilum         0.00000000
## 577  MAT.B4.F       Fertilized              Chalara_sp._1         0.00000000
## 578  MAT.B4.F       Fertilized         Cortinarius_sp._1         0.00000000
## 579  MAT.B4.F       Fertilized      Cortinarius_croceus_1         0.00000000
## 580  MAT.B4.F       Fertilized    Cortinarius_glandicolor         0.00000000
## 581  MAT.B4.F       Fertilized       Cortinarius_casimiri         0.00000000
## 582  MAT.B4.F       Fertilized      Cortinarius_croceus_2         0.00000000
## 583  MAT.B4.F       Fertilized     Cortinarius_herpeticus         0.00000000
## 584  MAT.B4.F       Fertilized      Cortinarius_tabularis         0.00000000
## 585  MAT.B4.F       Fertilized      Cortinarius_delibutus         0.10000000
## 586  MAT.B4.F       Fertilized          Cortinarius_sp._2         0.00000000
## 587  MAT.B4.F       Fertilized     Cortinarius_paragaudis         0.00000000
## 588  MAT.B4.F       Fertilized          Cortinarius_sp._3         0.00000000
## 589  MAT.B4.F       Fertilized           Helotiales_sp._1         0.00000000
## 590  MAT.B4.F       Fertilized           Laccaria_laccata         0.26666667
## 591  MAT.B4.F       Fertilized         Lactarius_vietus_1         0.00000000
## 592  MAT.B4.F       Fertilized       Lactarius_glyciosmus         0.06666667
## 593  MAT.B4.F       Fertilized         Lactarius_vietus_2         0.03333333
## 594  MAT.B4.F       Fertilized           Leccinum_holopus         0.00000000
## 595  MAT.B4.F       Fertilized           Leccinum_scabrum         0.00000000
## 596  MAT.B4.F       Fertilized      Leccinum_variicolor_1         0.00000000
## 597  MAT.B4.F       Fertilized      Leccinum_variicolor_2         0.00000000
## 598  MAT.B4.F       Fertilized      Leccinum_variicolor_3         0.00000000
## 599  MAT.B4.F       Fertilized     Leptodontidium_elatius         0.00000000
## 600  MAT.B4.F       Fertilized    Meliniomyces_variabilis         0.00000000
```

```
## 601  MAT.B4.F       Fertilized       Meliniomyces_bicolor         0.00000000
## 602  MAT.B4.F       Fertilized     Phialocephala_fortinii         0.00000000
## 603  MAT.B4.F       Fertilized     Pseudotomentella_sp._1         0.00000000
## 604  MAT.B4.F       Fertilized        Rhizoscyphus_ericae         0.03333333
## 605  MAT.B4.F       Fertilized      Thelephora_terrestris         0.10000000
## 606  MAT.B4.F       Fertilized     Tomentella_sublilacina         0.00000000
## 607  MAT.B4.F       Fertilized           Tomentella_sp._1         0.00000000
## 608  MAT.B4.F       Fertilized   Tomentellopsis_submollis         0.00000000
## 609  MAT.B4.F       Fertilized          Russula_chamiteae         0.00000000
## 610  MAT.B4.F       Fertilized         Russula_decolorans         0.00000000
## 611  MAT.B4.F       Fertilized Russula_nitida/sphagnicola         0.40000000
## 612  MAT.B4.F       Fertilized              Russula_sp._1         0.00000000
## 613  MAT.B4.F       Fertilized              Russula_sp._2         0.00000000
## 614  MAT.B4.F       Fertilized              Russula_sp._3         0.00000000
## 615  MAT.B4.F       Fertilized              Russula_sp._4         0.00000000
## 616  MAT.B4.F       Fertilized             Russula_vinosa         0.00000000
## 617  MAT.B4.W           Warmed       Alternaria_alternata         0.00000000
## 618  MAT.B4.W           Warmed  Articulospora_tetracladia         0.00000000
## 619  MAT.B4.W           Warmed       Cadophora_finlandica         0.00000000
## 620  MAT.B4.W           Warmed       Cenococcum_geophilum         0.03389830
## 621  MAT.B4.W           Warmed              Chalara_sp._1         0.00000000
## 622  MAT.B4.W           Warmed          Cortinarius_sp._1         0.00000000
## 623  MAT.B4.W           Warmed      Cortinarius_croceus_1         0.00000000
## 624  MAT.B4.W           Warmed    Cortinarius_glandicolor         0.00000000
## 625  MAT.B4.W           Warmed       Cortinarius_casimiri         0.00000000
## 626  MAT.B4.W           Warmed      Cortinarius_croceus_2         0.01694915
## 627  MAT.B4.W           Warmed     Cortinarius_herpeticus         0.00000000
## 628  MAT.B4.W           Warmed      Cortinarius_tabularis         0.00000000
## 629  MAT.B4.W           Warmed      Cortinarius_delibutus         0.00000000
## 630  MAT.B4.W           Warmed          Cortinarius_sp._2         0.08474576
## 631  MAT.B4.W           Warmed     Cortinarius_paragaudis         0.01694915
## 632  MAT.B4.W           Warmed          Cortinarius_sp._3         0.00000000
## 633  MAT.B4.W           Warmed           Helotiales_sp._1         0.00000000
## 634  MAT.B4.W           Warmed           Laccaria_laccata         0.00000000
## 635  MAT.B4.W           Warmed         Lactarius_vietus_1         0.10169491
## 636  MAT.B4.W           Warmed       Lactarius_glyciosmus         0.01694915
## 637  MAT.B4.W           Warmed         Lactarius_vietus_2         0.00000000
## 638  MAT.B4.W           Warmed           Leccinum_holopus         0.00000000
## 639  MAT.B4.W           Warmed           Leccinum_scabrum         0.00000000
## 640  MAT.B4.W           Warmed      Leccinum_variicolor_1         0.00000000
## 641  MAT.B4.W           Warmed      Leccinum_variicolor_2         0.00000000
## 642  MAT.B4.W           Warmed      Leccinum_variicolor_3         0.00000000
## 643  MAT.B4.W           Warmed     Leptodontidium_elatius         0.00000000
## 644  MAT.B4.W           Warmed    Meliniomyces_variabilis         0.00000000
## 645  MAT.B4.W           Warmed       Meliniomyces_bicolor         0.00000000
## 646  MAT.B4.W           Warmed     Phialocephala_fortinii         0.00000000
## 647  MAT.B4.W           Warmed     Pseudotomentella_sp._1         0.00000000
## 648  MAT.B4.W           Warmed        Rhizoscyphus_ericae         0.00000000
## 649  MAT.B4.W           Warmed      Thelephora_terrestris         0.00000000
## 650  MAT.B4.W           Warmed     Tomentella_sublilacina         0.08474576
## 651  MAT.B4.W           Warmed           Tomentella_sp._1         0.05084746
## 652  MAT.B4.W           Warmed   Tomentellopsis_submollis         0.00000000
## 653  MAT.B4.W           Warmed          Russula_chamiteae         0.08474576
## 654  MAT.B4.W           Warmed         Russula_decolorans         0.49152542
```

```
## 655  MAT.B4.W            Warmed Russula_nitida/sphagnicola         0.00000000
## 656  MAT.B4.W            Warmed              Russula_sp._1         0.00000000
## 657  MAT.B4.W            Warmed              Russula_sp._2         0.00000000
## 658  MAT.B4.W            Warmed              Russula_sp._3         0.00000000
## 659  MAT.B4.W            Warmed              Russula_sp._4         0.01694915
## 660  MAT.B4.W            Warmed             Russula_vinosa         0.00000000
## 661 MAT.B4.WF Warmed.Fertilized       Alternaria_alternata         0.00000000
## 662 MAT.B4.WF Warmed.Fertilized  Articulospora_tetracladia         0.00000000
## 663 MAT.B4.WF Warmed.Fertilized       Cadophora_finlandica         0.00000000
## 664 MAT.B4.WF Warmed.Fertilized       Cenococcum_geophilum         0.25000000
## 665 MAT.B4.WF Warmed.Fertilized              Chalara_sp._1         0.00000000
## 666 MAT.B4.WF Warmed.Fertilized          Cortinarius_sp._1         0.00000000
## 667 MAT.B4.WF Warmed.Fertilized      Cortinarius_croceus_1         0.00000000
## 668 MAT.B4.WF Warmed.Fertilized    Cortinarius_glandicolor         0.00000000
## 669 MAT.B4.WF Warmed.Fertilized       Cortinarius_casimiri         0.06250000
## 670 MAT.B4.WF Warmed.Fertilized      Cortinarius_croceus_2         0.00000000
## 671 MAT.B4.WF Warmed.Fertilized     Cortinarius_herpeticus         0.00000000
## 672 MAT.B4.WF Warmed.Fertilized      Cortinarius_tabularis         0.00000000
## 673 MAT.B4.WF Warmed.Fertilized      Cortinarius_delibutus         0.00000000
## 674 MAT.B4.WF Warmed.Fertilized          Cortinarius_sp._2         0.00000000
## 675 MAT.B4.WF Warmed.Fertilized     Cortinarius_paragaudis         0.00000000
## 676 MAT.B4.WF Warmed.Fertilized          Cortinarius_sp._3         0.09375000
## 677 MAT.B4.WF Warmed.Fertilized           Helotiales_sp._1         0.00000000
## 678 MAT.B4.WF Warmed.Fertilized           Laccaria_laccata         0.00000000
## 679 MAT.B4.WF Warmed.Fertilized         Lactarius_vietus_1         0.25000000
## 680 MAT.B4.WF Warmed.Fertilized       Lactarius_glyciosmus         0.06250000
## 681 MAT.B4.WF Warmed.Fertilized         Lactarius_vietus_2         0.00000000
## 682 MAT.B4.WF Warmed.Fertilized           Leccinum_holopus         0.00000000
## 683 MAT.B4.WF Warmed.Fertilized           Leccinum_scabrum         0.00000000
## 684 MAT.B4.WF Warmed.Fertilized      Leccinum_variicolor_1         0.00000000
## 685 MAT.B4.WF Warmed.Fertilized      Leccinum_variicolor_2         0.00000000
## 686 MAT.B4.WF Warmed.Fertilized      Leccinum_variicolor_3         0.00000000
## 687 MAT.B4.WF Warmed.Fertilized     Leptodontidium_elatius         0.00000000
## 688 MAT.B4.WF Warmed.Fertilized    Meliniomyces_variabilis         0.00000000
## 689 MAT.B4.WF Warmed.Fertilized       Meliniomyces_bicolor         0.06250000
## 690 MAT.B4.WF Warmed.Fertilized     Phialocephala_fortinii         0.00000000
## 691 MAT.B4.WF Warmed.Fertilized     Pseudotomentella_sp._1         0.00000000
## 692 MAT.B4.WF Warmed.Fertilized        Rhizoscyphus_ericae         0.00000000
## 693 MAT.B4.WF Warmed.Fertilized      Thelephora_terrestris         0.00000000
## 694 MAT.B4.WF Warmed.Fertilized     Tomentella_sublilacina         0.00000000
## 695 MAT.B4.WF Warmed.Fertilized           Tomentella_sp._1         0.00000000
## 696 MAT.B4.WF Warmed.Fertilized   Tomentellopsis_submollis         0.03125000
## 697 MAT.B4.WF Warmed.Fertilized          Russula_chamiteae         0.03125000
## 698 MAT.B4.WF Warmed.Fertilized         Russula_decolorans         0.00000000
## 699 MAT.B4.WF Warmed.Fertilized Russula_nitida/sphagnicola         0.12500000
## 700 MAT.B4.WF Warmed.Fertilized              Russula_sp._1         0.00000000
## 701 MAT.B4.WF Warmed.Fertilized              Russula_sp._2         0.00000000
## 702 MAT.B4.WF Warmed.Fertilized              Russula_sp._3         0.03125000
## 703 MAT.B4.WF Warmed.Fertilized              Russula_sp._4         0.00000000
## 704 MAT.B4.WF Warmed.Fertilized             Russula_vinosa         0.00000000
```

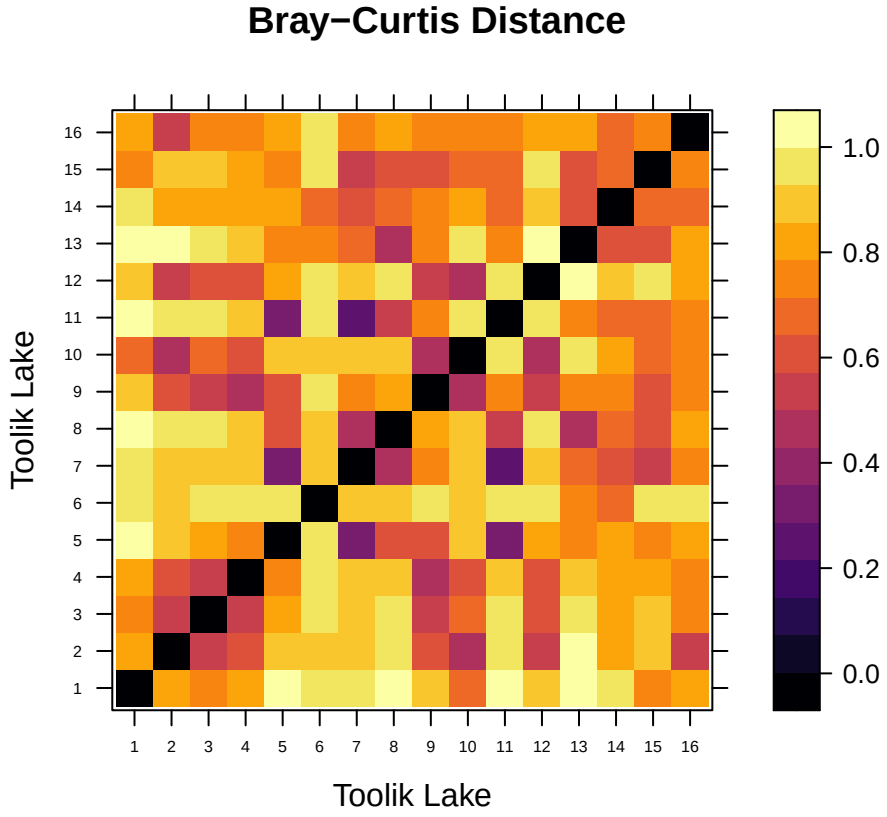
```
#Changing data so that each species is a column, values are the relative.abundance, and rows are each p
library(tidyr)
ExpandProjdata <- slim %>%
```

```
  pivot_wider(names_from = Species, values_from = Relative.Abundance, values_fill = 0)
Sorted_ExpandProjdata <- ExpandProjdata %>%
  arrange(Treatment)
ExpandProjdata.db <- vegdist(Sorted_ExpandProjdata[, -c(1,2)], method = "bray", upper = TRUE, diag = TRU
#Define Order of Sites
order.projdata <- rev(attr(ExpandProjdata.db, "Labels"))


heatmap_matrix <- as.matrix(ExpandProjdata.db)

# Ensure rows and columns match the order
if (!is.null(order.projdata)) {
  heatmap_matrix <- heatmap_matrix[order.projdata, order.projdata]
}

# Now plot
levelplot(heatmap_matrix, aspect = "iso", col.regions = inferno,
          xlab = "Toolik Lake", ylab = "Toolik Lake", scales = list(cex = 0.5),
          main = "Bray-Curtis Distance")
```




```
#After having reorganized my data so that sites are sorted by treatment group, it is difficult to detec
```