Phasmid_morphospace - Habitat

Romain Boisseau

2024-07-24

Load Packages and data

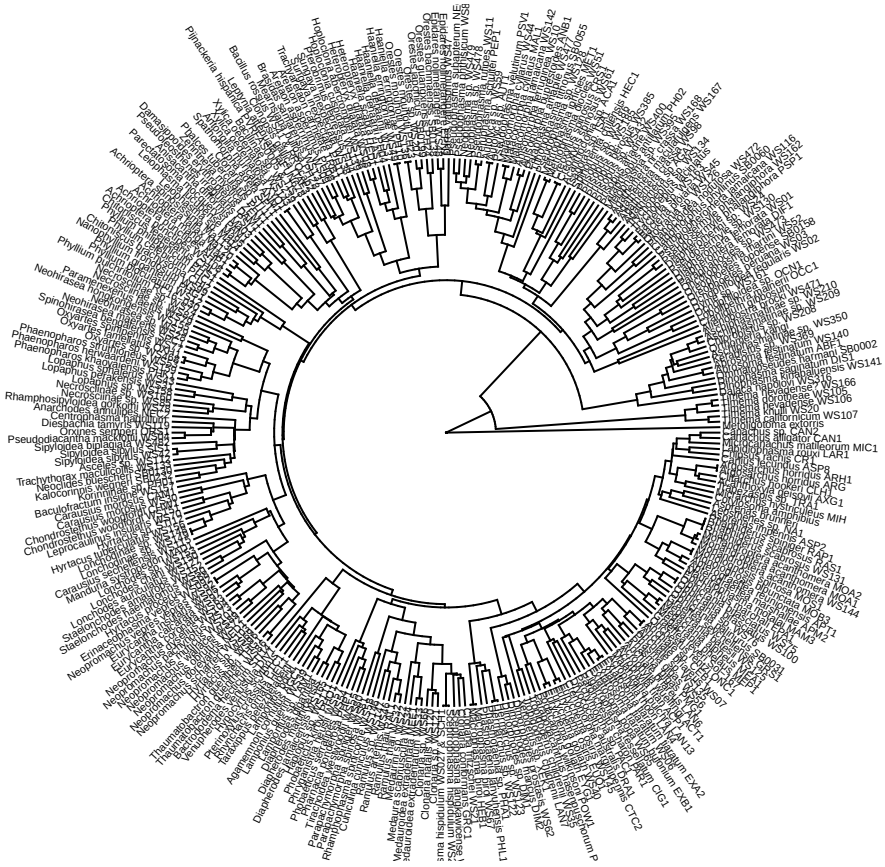
Load necessary packages to run script

```
library(readxl)
library(ape)
library(phytools)
library(plyr)
library(hypervolume)
library(purrr)
library(geiger)
library(dispRity)
library(evobiR)
library(dynRB)
library(ggplot2)
library(cowplot)
library(randomForest)
library(caret)
library(reshape2)
library(dplyr)
library(ggpubr)
library(corrplot)
library(factoextra)

# Display versions of loaded packages
installed.packages()[names(sessionInfo()$otherPkgs), "Version"]
```

```
##   factoextra     corrplot       ggpubr        dplyr     reshape2        caret
##      "1.0.7"       "0.92"      "0.6.0"      "1.1.2"      "1.4.4"     "6.0-94"
##      lattice randomForest      cowplot      ggplot2        dynRB       evobiR
##     "0.21-8"    "4.7-1.1"      "1.1.1"      "3.4.2"       "0.18"        "1.1"
##     dispRity       geiger        purrr  hypervolume         Rcpp         plyr
##      "1.7.0"     "2.0.11"      "1.0.1"      "3.1.1"     "1.0.10"      "1.8.8"
##     phytools         maps          ape       readxl      formatR      tinytex
##      "1.5-1"      "3.4.1"      "5.7-1"      "1.4.2"       "1.14"       "0.49"
##        knitr
##       "1.43"
```

Load phylogenetic tree

```
tree <- read.nexus("Phasmid_convergence_MCCphylogeny_nexus")  #load tree (NEXUS)
tree <- ladderize(tree, right = FALSE)
tree$tip.label <- gsub("'", "", tree$tip.label)  #delete unwanted ' ' ' in tip labels
plotTree(tree, type = "fan", fsize = 0.3, lwd = 1)
```



Load morphological data

```
X <- read_excel("DatasetS1.xlsx", sheet = "pca_coordinates")
X <- subset(X, is.na(X$habitat_use) == F & is.na(X$pca_mix_dim1) ==
    F)
```

Make dataset and phylogeny match

```
X <- as.data.frame(X)
# Attributing rownames to the dataset
rownames(X) <- X$taxon
## Cleaning both the data and the tree
cleaned_data <- clean.data(X, tree)
```

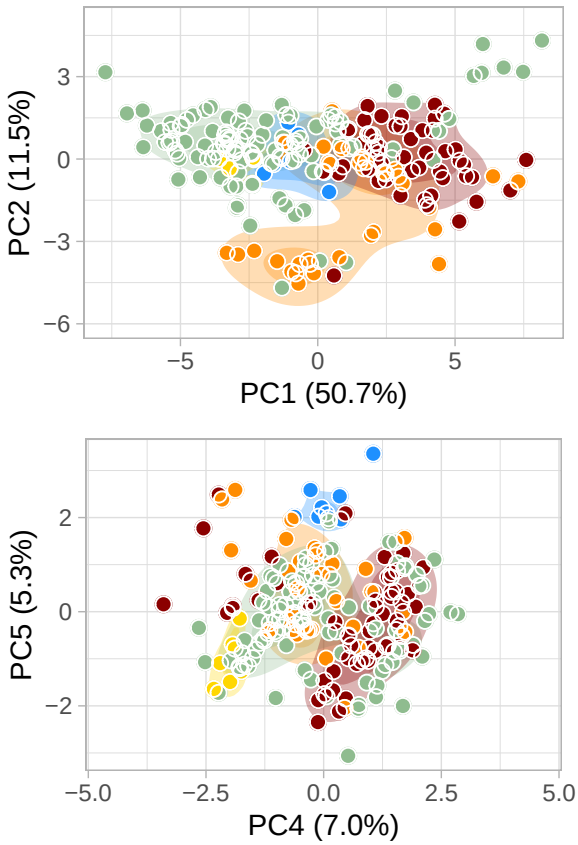
```
## Extracting the cleaned dataset and the cleaned tree
df <- cleaned_data$data
ttree <- cleaned_data$tree
name.check(ttree, df)
```

```
## [1] "OK"
```

```
# reorder data to match the order of tips in tree
X <- ReorderData(ttree, df, taxa.names = "row names")
```

Hypervolumes in morphospace - Habitat

```
# Density
X$habitat2 <- factor(X$habitat_use, levels = c("laying on branches and leaves",
    "hanging from branches and leaves", "laying on leaf litter, logs, bark, trunk",
    "laying on palm leaves", "hanging from grass"))

p1 <- ggplot(data = X, aes(x = pca_mix_dim1, y = pca_mix_dim2,
    fill = habitat2)) + stat_density_2d(contour_var = "ndensity",
    geom = "polygon", breaks = c(1/3, 2/3), alpha = 0.3) + coord_fixed() +
    labs(x = "PC1 (50.7%)", y = "PC2 (11.5%)") + scale_fill_manual(values = c("darkorange",
    "darkseagreen", "darkred", "dodgerblue", "gold")) + scale_colour_manual(values = c("darkorange",
    "darkseagreen", "darkred", "dodgerblue", "gold")) + geom_point(aes(color = habitat2),
    size = 2.5, alpha = 1) + geom_point(colour = "white", shape = 1,
    size = 2.5, alpha = 1) + ylim(-6, 5) + theme_light() + theme(legend.position = "none")


p2 <- ggplot(data = X, aes(x = pca_mix_dim4, y = pca_mix_dim5,
    fill = habitat2)) + stat_density_2d(contour_var = "ndensity",
    geom = "polygon", breaks = c(1/3, 2/3), alpha = 0.3) + coord_fixed() +
    labs(x = "PC4 (7.0%)", y = "PC5 (5.3%)") + scale_fill_manual(values = c("darkorange",
    "darkseagreen", "darkred", "dodgerblue", "gold")) + scale_colour_manual(values = c("darkorange",
    "darkseagreen", "darkred", "dodgerblue", "gold")) + geom_point(aes(color = habitat2),
    size = 2.5, alpha = 1) + geom_point(colour = "white", shape = 1,
    size = 2.5, alpha = 1) + theme_light() + xlim(-4.6, 4.6) +
    theme(legend.position = "none")

plot_grid(p1, p2, ncol = 1)
```



Hypervolumes and overlaps - Habitat

Create appropriate dataset with 7 first dimensions of morphospace

```
Xrb <- matrix(nrow = length(X$habitat2), ncol = 8)
colnames(Xrb) <- c("habitat", "PC1", "PC2", "PC3", "PC4", "PC5",
    "PC6", "PC7")
Xrb <- as.data.frame(Xrb)
Xrb$habitat <- as.character(X$habitat2)
Xrb$PC1 <- as.numeric(X$pca_mix_dim1)
Xrb$PC2 <- as.numeric(X$pca_mix_dim2)
Xrb$PC3 <- as.numeric(X$pca_mix_dim3)
Xrb$PC4 <- as.numeric(X$pca_mix_dim4)
Xrb$PC5 <- as.numeric(X$pca_mix_dim5)
Xrb$PC6 <- as.numeric(X$pca_mix_dim6)
Xrb$PC7 <- as.numeric(X$pca_mix_dim7)
```

Using hypervolume package

```
Xrb_litter = Xrb[Xrb$habitat == "laying on leaf litter, logs, bark, trunk",
    c("PC1", "PC2", "PC3", "PC4", "PC5", "PC6", "PC7")]
```

```
Xrb_hang = Xrb[Xrb$habitat == "hanging from branches and leaves",
    c("PC1", "PC2", "PC3", "PC4", "PC5", "PC6", "PC7")]
Xrb_branch = Xrb[Xrb$habitat == "laying on branches and leaves",
    c("PC1", "PC2", "PC3", "PC4", "PC5", "PC6", "PC7")]
Xrb_grass = Xrb[Xrb$habitat == "hanging from grass", c("PC1",
    "PC2", "PC3", "PC4", "PC5", "PC6", "PC7")]
Xrb_palm = Xrb[Xrb$habitat == "laying on palm leaves", c("PC1",
    "PC2", "PC3", "PC4", "PC5", "PC6", "PC7")]

hv1 = hypervolume_box(Xrb_litter, name = "litter")
```

```
##
## Building tree...
## done.
## Ball query...
##
## done.
## Binding random points... done.
## Beginning volume calculation... done.
```

```
hv2 = hypervolume_box(Xrb_hang, name = "hang")
```

```
##
## Building tree...
## done.
## Ball query...
##
## done.
## Binding random points... done.
## Beginning volume calculation... done.
```

```
hv3 = hypervolume_box(Xrb_branch, name = "branch")
```

```
##
## Building tree...
## done.
## Ball query...
##
## done.
## Binding random points... done.
## Beginning volume calculation... done.
```

```
hv4 = hypervolume_box(Xrb_grass, name = "grass")
```

```
##
## Building tree...
## done.
## Ball query...
##
## done.
## Binding random points... done.
## Beginning volume calculation... done.
```

```
hv5 = hypervolume_box(Xrb_palm, name = "palm")
```

```
##
## Building tree...
## done.
## Ball query...
##
## done.
## Binding random points... done.
## Beginning volume calculation... done.
```

Calculate overlap/distance between pairs of habitats

```
hv <- list(hv1, hv2, hv3, hv4, hv5)
jacc <- matrix(nrow = length(hv), ncol = length(hv))
sorensen <- matrix(nrow = length(hv), ncol = length(hv))
frac_unique_1 <- matrix(nrow = length(hv), ncol = length(hv))
frac_unique_2 <- matrix(nrow = length(hv), ncol = length(hv))
dist_min <- matrix(nrow = length(hv), ncol = length(hv))
dist_centr <- matrix(nrow = length(hv), ncol = length(hv))

for (i in c(1:length(hv))) {
    for (j in c(1:length(hv))) {
        if (j <= i) {
        } else {
            hv_set <- hypervolume_set(hv[[i]], hv[[j]], check.memory = FALSE)
            stats <- hypervolume_overlap_statistics(hv_set)
            centr <- hypervolume_distance(hv[[i]], hv[[j]], type = "centroid")
            min <- hypervolume_distance(hv[[i]], hv[[j]], type = "minimum",
                num.points.max = 500, check.memory = FALSE)

            jacc[i, j] <- stats[1]
            sorensen[i, j] <- stats[2]
            frac_unique_1[i, j] <- stats[3]
            frac_unique_2[i, j] <- stats[4]
            dist_min[i, j] <- min
            dist_centr[i, j] <- centr
        }
    }
}
```

```
## Choosing num.points.max=442336 (use a larger value for more accuracy.)
## Using minimum density of 1.429278
## Retaining 35667 points in hv1 and 150805 points in hv2.
## Beginning ball queries...
##
## Building tree...
## done.
## Ball query...
##
## done.
```

```
##
## Building tree...
## done.
## Ball query...
##
## done.
## Finished ball queries.
## Choosing num.points.max=442336 (use a larger value for more accuracy.)
## Using minimum density of 2.075205
## Retaining 51786 points in hv1 and 193381 points in hv2.
## Beginning ball queries...
##
## Building tree...
## done.
## Ball query...
##
## done.
##
## Building tree...
## done.
## Ball query...
##
## done.
## Finished ball queries.
## Choosing num.points.max=442336 (use a larger value for more accuracy.)
## Using minimum density of 6.992550
## Retaining 174499 points in hv1 and 951 points in hv2.
## Beginning ball queries...
##
## Building tree...
## done.
## Ball query...
##
## done.
##
## Building tree...
## done.
## Ball query...
##
## done.
## Finished ball queries.
## Choosing num.points.max=442336 (use a larger value for more accuracy.)
## Using minimum density of 6.992550
## Retaining 174499 points in hv1 and 6654 points in hv2.
## Beginning ball queries...
##
## Building tree...
## done.
## Ball query...
##
## done.
##
## Building tree...
## done.
```

```
## Ball query...
##
## done.
## Finished ball queries.
## Choosing num.points.max=442336 (use a larger value for more accuracy.)
## Using minimum density of 1.429278
## Retaining 150805 points in hv1 and 133189 points in hv2.
## Beginning ball queries...
##
## Building tree...
## done.
## Ball query...
##
## done.
##
## Building tree...
## done.
## Ball query...
##
## done.
## Finished ball queries.
## Choosing num.points.max=442336 (use a larger value for more accuracy.)
## Using minimum density of 1.429278
## Retaining 150805 points in hv1 and 194 points in hv2.
## Beginning ball queries...
##
## Building tree...
## done.
## Ball query...
##
## done.
##
## Building tree...
## done.
## Ball query...
##
## done.
## Finished ball queries.
## Choosing num.points.max=442336 (use a larger value for more accuracy.)
## Using minimum density of 1.429278
## Retaining 150805 points in hv1 and 1360 points in hv2.
## Beginning ball queries...
##
## Building tree...
## done.
## Ball query...
##
## done.
##
## Building tree...
## done.
## Ball query...
##
## done.
```

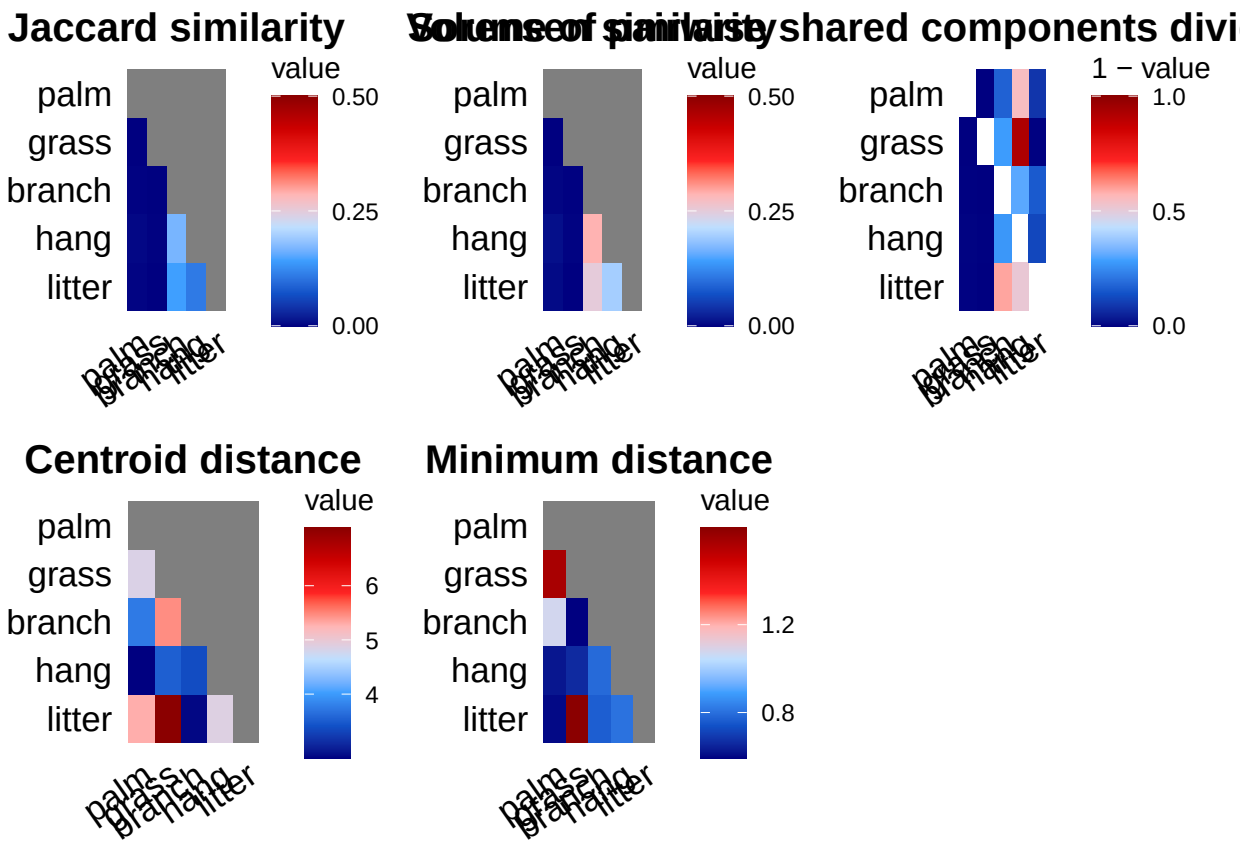
```
## Finished ball queries.
## Choosing num.points.max=442336 (use a larger value for more accuracy.)
## Using minimum density of 2.075205
## Retaining 193381 points in hv1 and 282 points in hv2.
## Beginning ball queries...
##
## Building tree...
## done.
## Ball query...
##
## done.
##
## Building tree...
## done.
## Ball query...
##
## done.
## Finished ball queries.
## Choosing num.points.max=442336 (use a larger value for more accuracy.)
## Using minimum density of 2.075205
## Retaining 193381 points in hv1 and 1974 points in hv2.
## Beginning ball queries...
##
## Building tree...
## done.
## Ball query...
##
## done.
##
## Building tree...
## done.
## Ball query...
##
## done.
## Finished ball queries.
## Choosing num.points.max=442336 (use a larger value for more accuracy.)
## Using minimum density of 257.356596
## Retaining 35015 points in hv1 and 244925 points in hv2.
## Beginning ball queries...
##
## Building tree...
## done.
## Ball query...
##
## done.
##
## Building tree...
## done.
## Ball query...
##
## done.
## Finished ball queries.
```

```
jacc <- t(jacc)
sorensen <- t(sorensen)
frac_unique_1 <- t(frac_unique_1)
frac_unique_2 <- t(frac_unique_2)
dist_centr <- t(dist_centr)
dist_min <- t(dist_min)
```

Plot heatmaps

```
theme_change <- theme(plot.title = element_text(family = "Helvetica",
    face = "bold", size = (15), hjust = 0.5), plot.subtitle = element_text(family = "Helvetica",
    size = (10), hjust = 0.5), plot.background = element_blank(),
    panel.grid.minor = element_blank(), panel.grid.major = element_blank(),
    panel.background = element_blank(), panel.border = element_blank(),
    axis.line = element_blank(), axis.ticks = element_blank(),
    axis.text.x = element_text(colour = "black", size = rel(1.5),
        angle = 35, hjust = 1), axis.text.y = element_text(colour = "black",
        size = rel(1.5)), axis.title.x = element_blank(), axis.title.y = element_blank())
col1 <- colorRampPalette(c("navyblue", "dodgerblue", "white",
    "red", "darkred"))  #define color gradient

matrix <- jacc
row.names(matrix) <- c("litter", "hang", "branch", "grass", "palm")
colnames(matrix) <- c("litter", "hang", "branch", "grass", "palm")

lev <- ordered(c("palm", "grass", "branch", "hang", "litter"))
melt_mat <- melt(matrix)
p1 <- ggplot(melt_mat, aes(x = ordered(Var1, levels = lev), y = Var2,
    fill = value)) + geom_tile() + scale_fill_gradientn(colours = col1(8),
    breaks = c(0, 0.25, 0.5), guide = "colorbar", limits = c(0,
        0.5)) + labs(title = "Jaccard similarity") + theme_change


matrix <- sorensen
row.names(matrix) <- c("litter", "hang", "branch", "grass", "palm")
colnames(matrix) <- c("litter", "hang", "branch", "grass", "palm")
melt_mat <- melt(matrix)
p2 <- ggplot(melt_mat, aes(x = ordered(Var1, levels = lev), y = Var2,
    fill = value)) + geom_tile() + scale_fill_gradientn(colours = col1(8),
    breaks = c(0, 0.25, 0.5), guide = "colorbar", limits = c(0,
        0.5)) + labs(title = "Sorensen similarity") + theme_change


matrix1 <- frac_unique_1
matrix2 <- t(frac_unique_2)
row.names(matrix1) <- c("litter", "hang", "branch", "grass",
    "palm")
colnames(matrix1) <- c("litter", "hang", "branch", "grass", "palm")
row.names(matrix2) <- c("litter", "hang", "branch", "grass",
    "palm")
colnames(matrix2) <- c("litter", "hang", "branch", "grass", "palm")
melt_mat1 <- na.omit(melt(matrix1))
```

```
melt_mat2 <- na.omit(melt(matrix2))
melt_mat <- rbind(melt_mat1, melt_mat2)
p3 <- ggplot(melt_mat, aes(x = ordered(Var1, levels = lev), y = Var2,
    fill = 1 - value)) + geom_tile() + scale_fill_gradientn(colours = col1(8),
    breaks = c(0, 0.5, 1), guide = "colorbar", limits = c(0,
        1)) + labs(title = "Volume of pairwise shared components divided by volume of y") +
    theme_change


matrix <- dist_centr
row.names(matrix) <- c("litter", "hang", "branch", "grass", "palm")
colnames(matrix) <- c("litter", "hang", "branch", "grass", "palm")
melt_mat <- melt(matrix)
p4 <- ggplot(melt_mat, aes(x = ordered(Var1, levels = lev), y = Var2,
    fill = value)) + geom_tile() + scale_fill_gradientn(colours = col1(8),
    breaks = c(4, 5, 6), guide = "colorbar") + labs(title = "Centroid distance") +
    theme_change


matrix <- dist_min
row.names(matrix) <- c("litter", "hang", "branch", "grass", "palm")
colnames(matrix) <- c("litter", "hang", "branch", "grass", "palm")
melt_mat <- melt(matrix)
p5 <- ggplot(melt_mat, aes(x = ordered(Var1, levels = lev), y = Var2,
    fill = value)) + geom_tile() + scale_fill_gradientn(colours = col1(8),
    breaks = c(0.4, 0.8, 1.2), guide = "colorbar") + labs(title = "Minimum distance") +
    theme_change

plot_grid(p1, p2, p3, p4, p5, label = "AUTO", nrow = 2)
```



Unsing dynRB package

Calculate hypervolume size and overlap

```
# Size and pairwise overlap
r <- dynRB_VPa(Xrb)
```

```
## [1] 1
## [1] 2
## [1] 3
## [1] 4
## [1] 5
## [1] 6
## [1] 7
## [1] 8
## [1] 9
## [1] 10
## [1] 11
## [1] 12
## [1] 13
## [1] 14
## [1] 15
## [1] 16
```

```
## [1] 17
## [1] 18
## [1] 19
## [1] 20
## [1] 21
## [1] 22
## [1] 23
## [1] 24
## [1] 25
##                                         V1
## 1          hanging from branches and leaves
## 2                        hanging from grass
## 3             laying on branches and leaves
## 4  laying on leaf litter, logs, bark, trunk
## 5                      laying on palm leaves
## 6          hanging from branches and leaves
## 7                        hanging from grass
## 8             laying on branches and leaves
## 9  laying on leaf litter, logs, bark, trunk
## 10                     laying on palm leaves
## 11         hanging from branches and leaves
## 12                       hanging from grass
## 13            laying on branches and leaves
## 14 laying on leaf litter, logs, bark, trunk
## 15                     laying on palm leaves
## 16         hanging from branches and leaves
## 17                       hanging from grass
## 18            laying on branches and leaves
## 19 laying on leaf litter, logs, bark, trunk
## 20                     laying on palm leaves
## 21         hanging from branches and leaves
## 22                       hanging from grass
## 23            laying on branches and leaves
## 24 laying on leaf litter, logs, bark, trunk
## 25                     laying on palm leaves
##                                         V2    port_prod  vol_V1_prod
## 1          hanging from branches and leaves 1.000000e+00 8.026471e-02
## 2          hanging from branches and leaves 2.440322e-05 6.373489e-06
## 3          hanging from branches and leaves 9.552701e-02 2.708696e-02
## 4          hanging from branches and leaves 3.985398e-02 9.275388e-03
## 5          hanging from branches and leaves 0.000000e+00 6.429999e-05
## 6                        hanging from grass 3.411457e-01 8.026471e-02
## 7                        hanging from grass 1.000000e+00 6.373489e-06
## 8                        hanging from grass 5.028213e-02 2.708696e-02
## 9                        hanging from grass 0.000000e+00 9.275388e-03
## 10                       hanging from grass 0.000000e+00 6.429999e-05
## 11            laying on branches and leaves 2.377482e-01 8.026471e-02
## 12            laying on branches and leaves 8.395322e-06 6.373489e-06
## 13            laying on branches and leaves 1.000000e+00 2.708696e-02
## 14            laying on branches and leaves 8.144047e-02 9.275388e-03
## 15            laying on branches and leaves 2.329100e-04 6.429999e-05
## 16 laying on leaf litter, logs, bark, trunk 3.149566e-01 8.026471e-02
## 17 laying on leaf litter, logs, bark, trunk 0.000000e+00 6.373489e-06
## 18 laying on leaf litter, logs, bark, trunk 2.559732e-01 2.708696e-02
```

```
## 19 laying on leaf litter, logs, bark, trunk 1.000000e+00 9.275388e-03
## 20 laying on leaf litter, logs, bark, trunk 2.242259e-05 6.429999e-05
## 21                     laying on palm leaves 0.000000e+00 8.026471e-02
## 22                     laying on palm leaves 0.000000e+00 6.373489e-06
## 23                     laying on palm leaves 1.256811e-01 2.708696e-02
## 24                     laying on palm leaves 6.106268e-03 9.275388e-03
## 25                     laying on palm leaves 1.000000e+00 6.429999e-05
##     vol_V2_prod
## 1  8.026471e-02
## 2  8.026471e-02
## 3  8.026471e-02
## 4  8.026471e-02
## 5  8.026471e-02
## 6  6.373489e-06
## 7  6.373489e-06
## 8  6.373489e-06
## 9  6.373489e-06
## 10 6.373489e-06
## 11 2.708696e-02
## 12 2.708696e-02
## 13 2.708696e-02
## 14 2.708696e-02
## 15 2.708696e-02
## 16 9.275388e-03
## 17 9.275388e-03
## 18 9.275388e-03
## 19 9.275388e-03
## 20 9.275388e-03
## 21 6.429999e-05
## 22 6.429999e-05
## 23 6.429999e-05
## 24 6.429999e-05
## 25 6.429999e-05
```

```
r$result
```

```
##                                       V1
## 1          hanging from branches and leaves
## 2                        hanging from grass
## 3             laying on branches and leaves
## 4  laying on leaf litter, logs, bark, trunk
## 5                      laying on palm leaves
## 6          hanging from branches and leaves
## 7                        hanging from grass
## 8             laying on branches and leaves
## 9  laying on leaf litter, logs, bark, trunk
## 10                     laying on palm leaves
## 11         hanging from branches and leaves
## 12                       hanging from grass
## 13            laying on branches and leaves
## 14 laying on leaf litter, logs, bark, trunk
## 15                     laying on palm leaves
## 16         hanging from branches and leaves
## 17                       hanging from grass
```

```
## 18            laying on branches and leaves
## 19 laying on leaf litter, logs, bark, trunk
## 20                     laying on palm leaves
## 21         hanging from branches and leaves
## 22                        hanging from grass
## 23            laying on branches and leaves
## 24 laying on leaf litter, logs, bark, trunk
## 25                     laying on palm leaves
##                                         V2    port_prod port_mean port_gmean
## 1          hanging from branches and leaves 1.000000e+00 1.0000000 1.00000000
## 2          hanging from branches and leaves 2.440322e-05 0.2785816 0.13636491
## 3          hanging from branches and leaves 9.552701e-02 0.7055622 0.68074627
## 4          hanging from branches and leaves 3.985398e-02 0.6805866 0.56350439
## 5          hanging from branches and leaves 0.000000e+00 0.3491063 0.00000000
## 6                         hanging from grass 3.411457e-01 0.8905466 0.52079172
## 7                         hanging from grass 1.000000e+00 1.0000000 1.00000000
## 8                         hanging from grass 5.028213e-02 0.6071049 0.38025652
## 9                         hanging from grass 0.000000e+00 0.7916137 0.00000000
## 10                        hanging from grass 0.000000e+00 0.4176534 0.00000000
## 11            laying on branches and leaves 2.377482e-01 0.7929074 0.76188259
## 12            laying on branches and leaves 8.395322e-06 0.2022186 0.11357210
## 13            laying on branches and leaves 1.000000e+00 1.0000000 1.00000000
## 14            laying on branches and leaves 8.144047e-02 0.6704278 0.66073281
## 15            laying on branches and leaves 2.329100e-04 0.3734930 0.18744212
## 16 laying on leaf litter, logs, bark, trunk 3.149566e-01 0.8730048 0.75080560
## 17 laying on leaf litter, logs, bark, trunk 0.000000e+00 0.3390452 0.00000000
## 18 laying on leaf litter, logs, bark, trunk 2.559732e-01 0.7884876 0.78182337
## 19 laying on leaf litter, logs, bark, trunk 1.000000e+00 1.0000000 1.00000000
## 20 laying on leaf litter, logs, bark, trunk 2.242259e-05 0.3216908 0.07940308
## 21                     laying on palm leaves 0.000000e+00 0.8509387 0.00000000
## 22                     laying on palm leaves 0.000000e+00 0.3071580 0.00000000
## 23                     laying on palm leaves 1.256811e-01 0.8178359 0.44802457
## 24                     laying on palm leaves 6.106268e-03 0.5905056 0.17040009
## 25                     laying on palm leaves 1.000000e+00 1.0000000 1.00000000
##     vol_V1_prod vol_V1_mean vol_V1_gmean  vol_V2_prod vol_V2_mean vol_V2_gmean
## 1  8.026471e-02   0.9664312    0.9626571 8.026471e-02   0.9664312    0.9626571
## 2  6.373489e-06   0.4744041    0.4397935 8.026471e-02   0.9664312    0.9626571
## 3  2.708696e-02   0.9111737    0.9103507 8.026471e-02   0.9664312    0.9626571
## 4  9.275388e-03   0.8471250    0.8335036 8.026471e-02   0.9664312    0.9626571
## 5  6.429999e-05   0.5704378    0.5544605 8.026471e-02   0.9664312    0.9626571
## 6  8.026471e-02   0.9664312    0.9626571 6.373489e-06   0.4744041    0.4397935
## 7  6.373489e-06   0.4744041    0.4397935 6.373489e-06   0.4744041    0.4397935
## 8  2.708696e-02   0.9111737    0.9103507 6.373489e-06   0.4744041    0.4397935
## 9  9.275388e-03   0.8471250    0.8335036 6.373489e-06   0.4744041    0.4397935
## 10 6.429999e-05   0.5704378    0.5544605 6.373489e-06   0.4744041    0.4397935
## 11 8.026471e-02   0.9664312    0.9626571 2.708696e-02   0.9111737    0.9103507
## 12 6.373489e-06   0.4744041    0.4397935 2.708696e-02   0.9111737    0.9103507
## 13 2.708696e-02   0.9111737    0.9103507 2.708696e-02   0.9111737    0.9103507
## 14 9.275388e-03   0.8471250    0.8335036 2.708696e-02   0.9111737    0.9103507
## 15 6.429999e-05   0.5704378    0.5544605 2.708696e-02   0.9111737    0.9103507
## 16 8.026471e-02   0.9664312    0.9626571 9.275388e-03   0.8471250    0.8335036
## 17 6.373489e-06   0.4744041    0.4397935 9.275388e-03   0.8471250    0.8335036
## 18 2.708696e-02   0.9111737    0.9103507 9.275388e-03   0.8471250    0.8335036
## 19 9.275388e-03   0.8471250    0.8335036 9.275388e-03   0.8471250    0.8335036
```

```
## 20 6.429999e-05   0.5704378    0.5544605 9.275388e-03   0.8471250    0.8335036
## 21 8.026471e-02   0.9664312    0.9626571 6.429999e-05   0.5704378    0.5544605
## 22 6.373489e-06   0.4744041    0.4397935 6.429999e-05   0.5704378    0.5544605
## 23 2.708696e-02   0.9111737    0.9103507 6.429999e-05   0.5704378    0.5544605
## 24 9.275388e-03   0.8471250    0.8335036 6.429999e-05   0.5704378    0.5544605
## 25 6.429999e-05   0.5704378    0.5544605 6.429999e-05   0.5704378    0.5544605
```

```
# Quantification of overlaps per dimension
r1 <- dynRB_Pn(Xrb)
```

```
## [1] 1
## [1] 2
## [1] 3
## [1] 4
## [1] 5
## [1] 6
## [1] 7
## [1] 8
## [1] 9
## [1] 10
## [1] 11
## [1] 12
## [1] 13
## [1] 14
## [1] 15
## [1] 16
## [1] 17
## [1] 18
## [1] 19
## [1] 20
## [1] 21
## [1] 22
## [1] 23
## [1] 24
## [1] 25
##                                         V1
## 1          hanging from branches and leaves
## 2                          hanging from grass
## 3             laying on branches and leaves
## 4  laying on leaf litter, logs, bark, trunk
## 5                       laying on palm leaves
## 6          hanging from branches and leaves
## 7                          hanging from grass
## 8             laying on branches and leaves
## 9  laying on leaf litter, logs, bark, trunk
## 10                      laying on palm leaves
## 11         hanging from branches and leaves
## 12                         hanging from grass
## 13            laying on branches and leaves
## 14 laying on leaf litter, logs, bark, trunk
## 15                      laying on palm leaves
## 16         hanging from branches and leaves
## 17                         hanging from grass
## 18            laying on branches and leaves
```

```
## 19 laying on leaf litter, logs, bark, trunk
## 20                     laying on palm leaves
## 21         hanging from branches and leaves
## 22                         hanging from grass
## 23            laying on branches and leaves
## 24 laying on leaf litter, logs, bark, trunk
## 25                     laying on palm leaves
##                                         V2         PC1        PC2        PC3
## 1          hanging from branches and leaves 1.000000000 1.00000000 1.00000000
## 2          hanging from branches and leaves 0.210093186 0.15419043 0.06797012
## 3          hanging from branches and leaves 0.245567579 0.18422464 0.83133033
## 4          hanging from branches and leaves 0.090450812 0.47179467 0.13086272
## 5          hanging from branches and leaves 0.230951054 0.26416445 0.36483523
## 6                          hanging from grass 0.754957567 0.49773293 0.29872106
## 7                          hanging from grass 1.000000000 1.00000000 1.00000000
## 8                          hanging from grass 0.022221437 0.36840968 0.54328816
## 9                          hanging from grass 0.000000000 0.96703375 0.82078817
## 10                         hanging from grass 0.033996642 0.67273909 0.07913739
## 11            laying on branches and leaves 0.336640512 0.16731929 0.56598094
## 12            laying on branches and leaves 0.006520454 0.08255016 0.11941625
## 13            laying on branches and leaves 1.000000000 1.00000000 1.00000000
## 14            laying on branches and leaves 0.218087538 0.19757597 0.27186404
## 15            laying on branches and leaves 0.201298722 0.12316184 0.36586459
## 16 laying on leaf litter, logs, bark, trunk 0.183762469 0.50901019 0.20111997
## 17 laying on leaf litter, logs, bark, trunk 0.000000000 0.27460778 0.28621764
## 18 laying on leaf litter, logs, bark, trunk 0.303436493 0.32532605 0.45220830
## 19 laying on leaf litter, logs, bark, trunk 1.000000000 1.00000000 1.00000000
## 20 laying on leaf litter, logs, bark, trunk 0.003746752 0.44542313 0.09191161
## 21                     laying on palm leaves 0.605950491 0.47956676 0.59938087
## 22                     laying on palm leaves 0.026421728 0.36539124 0.03243976
## 23                     laying on palm leaves 0.416935434 0.34024043 0.84317380
## 24                     laying on palm leaves 0.007461446 0.87495960 0.12397693
## 25                     laying on palm leaves 1.000000000 1.00000000 1.00000000
##            PC4         PC5        PC6        PC7
## 1  1.000000000 1.000000000 1.00000000 1.00000000
## 2  0.007245944 0.147382935 0.11493125 0.47281327
## 3  0.538143134 0.531894990 0.71956128 0.26642829
## 4  0.481805738 0.888464818 0.74639091 0.57809040
## 5  0.202545765 0.000000000 0.57861936 0.08817817
## 6  0.060941341 0.339478548 0.30148918 0.93812826
## 7  1.000000000 1.000000000 1.00000000 1.00000000
## 8  0.055257466 0.093784584 0.17467979 0.17518207
## 9  0.129375534 0.385738150 0.23646719 0.75493422
## 10 0.000000000 0.000000000 0.14318899 0.11801872
## 11 0.856507649 0.482495802 0.77047317 0.26797356
## 12 0.008246031 0.036707930 0.08404161 0.12277058
## 13 1.000000000 1.000000000 1.00000000 1.00000000
## 14 0.427191240 0.573826192 0.76873067 0.20261539
## 15 0.229707180 0.012052704 0.74612937 0.02214705
## 16 0.555625433 0.770764887 0.89744298 0.93180583
## 17 0.016146077 0.151655583 0.11882992 0.59934011
## 18 0.326731016 0.575980672 0.86729906 0.25902412
## 19 1.000000000 1.000000000 1.00000000 1.00000000
## 20 0.149927635 0.003067077 0.70551432 0.06270849
```

```
## 21 0.865627804 0.000000000 0.68811003 0.19163046
## 22 0.000000000 0.000000000 0.08289027 0.19765878
## 23 0.601310676 0.036089895 0.81467072 0.06650936
## 24 0.523962305 0.010433731 0.69380825 0.10825052
## 25 1.000000000 1.000000000 1.00000000 1.00000000
```

```
r1$result
```

```
##                                         V1
## 1          hanging from branches and leaves
## 2                        hanging from grass
## 3             laying on branches and leaves
## 4  laying on leaf litter, logs, bark, trunk
## 5                      laying on palm leaves
## 6          hanging from branches and leaves
## 7                        hanging from grass
## 8             laying on branches and leaves
## 9  laying on leaf litter, logs, bark, trunk
## 10                     laying on palm leaves
## 11         hanging from branches and leaves
## 12                       hanging from grass
## 13            laying on branches and leaves
## 14 laying on leaf litter, logs, bark, trunk
## 15                     laying on palm leaves
## 16         hanging from branches and leaves
## 17                       hanging from grass
## 18            laying on branches and leaves
## 19 laying on leaf litter, logs, bark, trunk
## 20                     laying on palm leaves
## 21         hanging from branches and leaves
## 22                       hanging from grass
## 23            laying on branches and leaves
## 24 laying on leaf litter, logs, bark, trunk
## 25                     laying on palm leaves
##                                         V2         PC1         PC2         PC3
## 1          hanging from branches and leaves 1.000000000 1.00000000 1.00000000
## 2          hanging from branches and leaves 0.210093186 0.15419043 0.06797012
## 3          hanging from branches and leaves 0.245567579 0.18422464 0.83133033
## 4          hanging from branches and leaves 0.090450812 0.47179467 0.13086272
## 5          hanging from branches and leaves 0.230951054 0.26416445 0.36483523
## 6                        hanging from grass 0.754957567 0.49773293 0.29872106
## 7                        hanging from grass 1.000000000 1.00000000 1.00000000
## 8                        hanging from grass 0.022221437 0.36840968 0.54328816
## 9                        hanging from grass 0.000000000 0.96703375 0.82078817
## 10                       hanging from grass 0.033996642 0.67273909 0.07913739
## 11            laying on branches and leaves 0.336640512 0.16731929 0.56598094
## 12            laying on branches and leaves 0.006520454 0.08255016 0.11941625
## 13            laying on branches and leaves 1.000000000 1.00000000 1.00000000
## 14            laying on branches and leaves 0.218087538 0.19757597 0.27186404
## 15            laying on branches and leaves 0.201298722 0.12316184 0.36586459
## 16 laying on leaf litter, logs, bark, trunk 0.183762469 0.50901019 0.20111997
## 17 laying on leaf litter, logs, bark, trunk 0.000000000 0.27460778 0.28621764
## 18 laying on leaf litter, logs, bark, trunk 0.303436493 0.32532605 0.45220830
## 19 laying on leaf litter, logs, bark, trunk 1.000000000 1.00000000 1.00000000
```

```
## 20 laying on leaf litter, logs, bark, trunk 0.003746752 0.44542313 0.09191161
## 21                    laying on palm leaves 0.605950491 0.47956676 0.59938087
## 22                    laying on palm leaves 0.026421728 0.36539124 0.03243976
## 23                    laying on palm leaves 0.416935434 0.34024043 0.84317380
## 24                    laying on palm leaves 0.007461446 0.87495960 0.12397693
## 25                    laying on palm leaves 1.000000000 1.00000000 1.00000000
##            PC4         PC5        PC6        PC7
## 1  1.000000000 1.000000000 1.00000000 1.00000000
## 2  0.007245944 0.147382935 0.11493125 0.47281327
## 3  0.538143134 0.531894990 0.71956128 0.26642829
## 4  0.481805738 0.888464818 0.74639091 0.57809040
## 5  0.202545765 0.000000000 0.57861936 0.08817817
## 6  0.060941341 0.339478548 0.30148918 0.93812826
## 7  1.000000000 1.000000000 1.00000000 1.00000000
## 8  0.055257466 0.093784584 0.17467979 0.17518207
## 9  0.129375534 0.385738150 0.23646719 0.75493422
## 10 0.000000000 0.000000000 0.14318899 0.11801872
## 11 0.856507649 0.482495802 0.77047317 0.26797356
## 12 0.008246031 0.036707930 0.08404161 0.12277058
## 13 1.000000000 1.000000000 1.00000000 1.00000000
## 14 0.427191240 0.573826192 0.76873067 0.20261539
## 15 0.229707180 0.012052704 0.74612937 0.02214705
## 16 0.555625433 0.770764887 0.89744298 0.93180583
## 17 0.016146077 0.151655583 0.11882992 0.59934011
## 18 0.326731016 0.575980672 0.86729906 0.25902412
## 19 1.000000000 1.000000000 1.00000000 1.00000000
## 20 0.149927635 0.003067077 0.70551432 0.06270849
## 21 0.865627804 0.000000000 0.68811003 0.19163046
## 22 0.000000000 0.000000000 0.08289027 0.19765878
## 23 0.601310676 0.036089895 0.81467072 0.06650936
## 24 0.523962305 0.010433731 0.69380825 0.10825052
## 25 1.000000000 1.000000000 1.00000000 1.00000000
```

```
# Quantification of sizes per dimension
r2 <- dynRB_Vn(Xrb)
```

```
## [1] 1
## [1] 2
## [1] 3
## [1] 4
## [1] 5
##                                         V1       PC1       PC2       PC3
## 1         hanging from branches and leaves 0.5426586 0.3553761 0.3919268
## 2                        hanging from grass 0.1527619 0.1012398 0.1061405
## 3            laying on branches and leaves 0.4630451 0.7970514 0.5705280
## 4 laying on leaf litter, logs, bark, trunk 0.3249917 0.3540151 0.3055534
## 5                     laying on palm leaves 0.1761936 0.1666608 0.2198220
##          PC4       PC5       PC6       PC7
## 1 0.60290402 0.4079075 0.4665972 0.3995189
## 2 0.07439702 0.2128673 0.1579574 0.2024307
## 3 0.38070971 0.5448182 0.4385814 0.3718108
## 4 0.54008980 0.5011369 0.3935210 0.2508620
## 5 0.14165851 0.1392975 0.4032588 0.1448645
```

```
r2$result
```

```
##                                         V1       PC1       PC2       PC3
## 1         hanging from branches and leaves 0.5426586 0.3553761 0.3919268
## 2                        hanging from grass 0.1527619 0.1012398 0.1061405
## 3           laying on branches and leaves 0.4630451 0.7970514 0.5705280
## 4 laying on leaf litter, logs, bark, trunk 0.3249917 0.3540151 0.3055534
## 5                     laying on palm leaves 0.1761936 0.1666608 0.2198220
##          PC4       PC5       PC6       PC7
## 1 0.60290402 0.4079075 0.4665972 0.3995189
## 2 0.07439702 0.2128673 0.1579574 0.2024307
## 3 0.38070971 0.5448182 0.4385814 0.3718108
## 4 0.54008980 0.5011369 0.3935210 0.2508620
## 5 0.14165851 0.1392975 0.4032588 0.1448645
```

Plot heatmaps

```
# Functions to define color gradients
signif.floor <- function(x, n) {
    pow <- floor(log10(abs(x))) + 1 - n
    y <- floor(x/10^pow) * 10^pow
    # handle the x = 0 case
    y[x == 0] <- 0
    y
}
signif.ceiling <- function(x, n) {
    pow <- floor(log10(abs(x))) + 1 - n
    y <- ceiling(x/10^pow) * 10^pow
    # handle the x = 0 case
    y[x == 0] <- 0
    y
}

# Plot
theme_change <- theme(plot.title = element_text(family = "Helvetica",
    face = "bold", size = (15), hjust = 0.5), plot.subtitle = element_text(family = "Helvetica",
    size = (10), hjust = 0.5), plot.background = element_blank(),
    panel.grid.minor = element_blank(), panel.grid.major = element_blank(),
    panel.background = element_blank(), panel.border = element_blank(),
    axis.line = element_blank(), axis.ticks = element_blank(),
    axis.text.x = element_text(colour = "black", size = rel(1.5),
        angle = 35, hjust = 1), axis.text.y = element_text(colour = "black",
        size = rel(1.5)), axis.title.x = element_blank(), axis.title.y = element_blank())
result <- r$result
```

Overall overlap (product)

```
Overlap <- as.numeric(ifelse(result$V1 == result$V2, "NA", result$port_prod))
Result2 <- cbind(result, Overlap)
```

```
breaks <- seq(min(Result2$Overlap, na.rm = T), max(Result2$Overlap,
    na.rm = T), by = 0.1)
col1 <- colorRampPalette(c("navyblue", "dodgerblue", "white",
    "red", "darkred"))  #define color gradient

Result2$V1 <- gsub("hanging from branches and leaves", "hang",
    Result2$V1)
Result2$V1 <- gsub("hanging from grass", "grass", Result2$V1)
Result2$V1 <- gsub("laying on branches and leaves", "branch",
    Result2$V1)
Result2$V1 <- gsub("laying on leaf litter, logs, bark, trunk",
    "litter", Result2$V1)
Result2$V1 <- gsub("laying on palm leaves", "palm", Result2$V1)
Result2$V2 <- gsub("hanging from branches and leaves", "hang",
    Result2$V2)
Result2$V2 <- gsub("hanging from grass", "grass", Result2$V2)
Result2$V2 <- gsub("laying on branches and leaves", "branch",
    Result2$V2)
Result2$V2 <- gsub("laying on leaf litter, logs, bark, trunk",
    "litter", Result2$V2)
Result2$V2 <- gsub("laying on palm leaves", "palm", Result2$V2)

lev <- ordered(c("palm", "grass", "branch", "hang", "litter"))
lev2 <- ordered(c("litter", "hang", "branch", "grass", "palm"))

p6 <- ggplot(Result2, aes(x = ordered(V1, levels = lev), y = ordered(V2,
    levels = lev2))) + geom_tile(data = subset(Result2, !is.na(Overlap)),
    aes(fill = Overlap), color = "black") + geom_tile(data = subset(Result2,
    is.na(Overlap)), fill = "lightgrey", color = "black") + scale_fill_gradientn(colours = col1(8),
    breaks = round(breaks, 1), guide = "colorbar", limits = c(signif.floor(min(breaks),
        1), signif.ceiling(max(breaks), 1))) + labs(title = "Overall overlap",
    subtitle = "Aggregation = product") + theme_change
```

Overall overlap (arithmetic mean)

```
Overlap <- as.numeric(ifelse(result$V1 == result$V2, "NA", result$port_mean))
Result2 <- cbind(result, Overlap)
breaks <- seq(min(Result2$Overlap, na.rm = T) - 0.05, max(Result2$Overlap +
    0.05, na.rm = T), by = 0.05)
col1 <- colorRampPalette(c("navyblue", "dodgerblue", "white",
    "red", "darkred"))  #define color gradient
Result2$V1 <- gsub("hanging from branches and leaves", "hang",
    Result2$V1)
Result2$V1 <- gsub("hanging from grass", "grass", Result2$V1)
Result2$V1 <- gsub("laying on branches and leaves", "branch",
    Result2$V1)
Result2$V1 <- gsub("laying on leaf litter, logs, bark, trunk",
    "litter", Result2$V1)
Result2$V1 <- gsub("laying on palm leaves", "palm", Result2$V1)
Result2$V2 <- gsub("hanging from branches and leaves", "hang",
    Result2$V2)
```

```
Result2$V2 <- gsub("hanging from grass", "grass", Result2$V2)
Result2$V2 <- gsub("laying on branches and leaves", "branch",
    Result2$V2)
Result2$V2 <- gsub("laying on leaf litter, logs, bark, trunk",
    "litter", Result2$V2)
Result2$V2 <- gsub("laying on palm leaves", "palm", Result2$V2)
lev <- ordered(c("palm", "grass", "branch", "hang", "litter"))
lev2 <- ordered(c("litter", "hang", "branch", "grass", "palm"))

p11 <- ggplot(Result2, aes(x = ordered(V1, levels = lev), y = ordered(V2,
    levels = lev2))) + geom_tile(data = subset(Result2, !is.na(Overlap)),
    aes(fill = Overlap), color = "black") + geom_tile(data = subset(Result2,
    is.na(Overlap)), fill = "lightgrey", color = "black") + scale_fill_gradientn(colours = col1(8),
    breaks = round(breaks, 2), guide = "colorbar", limits = c(signif.floor(min(breaks),
        2), signif.ceiling(max(breaks), 2))) + labs(title = "Overall overlap",
    subtitle = "Aggregation = mean") + theme_change
```

Overall overlap (geometric mean)

```
Overlap <- as.numeric(ifelse(result$V1 == result$V2, "NA", result$port_gmean))
Result2 <- cbind(result, Overlap)
breaks <- seq(min(Result2$Overlap, na.rm = T) - 0.05, max(Result2$Overlap +
    0.05, na.rm = T), by = 0.05)
col1 <- colorRampPalette(c("navyblue", "dodgerblue", "white",
    "red", "darkred"))  #define color gradient
Result2$V1 <- gsub("hanging from branches and leaves", "hang",
    Result2$V1)
Result2$V1 <- gsub("hanging from grass", "grass", Result2$V1)
Result2$V1 <- gsub("laying on branches and leaves", "branch",
    Result2$V1)
Result2$V1 <- gsub("laying on leaf litter, logs, bark, trunk",
    "litter", Result2$V1)
Result2$V1 <- gsub("laying on palm leaves", "palm", Result2$V1)
Result2$V2 <- gsub("hanging from branches and leaves", "hang",
    Result2$V2)
Result2$V2 <- gsub("hanging from grass", "grass", Result2$V2)
Result2$V2 <- gsub("laying on branches and leaves", "branch",
    Result2$V2)
Result2$V2 <- gsub("laying on leaf litter, logs, bark, trunk",
    "litter", Result2$V2)
Result2$V2 <- gsub("laying on palm leaves", "palm", Result2$V2)
lev <- ordered(c("palm", "grass", "branch", "hang", "litter"))
lev2 <- ordered(c("litter", "hang", "branch", "grass", "palm"))

p12 <- ggplot(Result2, aes(x = ordered(V1, levels = lev), y = ordered(V2,
    levels = lev2))) + geom_tile(data = subset(Result2, !is.na(Overlap)),
    aes(fill = Overlap), color = "black") + geom_tile(data = subset(Result2,
    is.na(Overlap)), fill = "lightgrey", color = "black") + scale_fill_gradientn(colours = col1(8),
    breaks = round(breaks, 2), guide = "colorbar", limits = c(signif.floor(min(breaks),
        2), signif.ceiling(max(breaks), 2))) + labs(title = "Overall overlap",
    subtitle = "Aggregation = geometric mean") + theme_change
```

Overlap per dimension

```
result <- r1$result
Overlap <- as.numeric(ifelse(result$V1 == result$V2, "NA", result$PC1))
Result2 <- cbind(result, Overlap)
breaks <- seq(min(Result2$Overlap, na.rm = T) - 0.05, max(Result2$Overlap,
    na.rm = T) + 0.1, by = 0.1)
col1 <- colorRampPalette(c("navyblue", "dodgerblue", "white",
    "red", "darkred"))  #define color gradient
Result2$V1 <- gsub("hanging from branches and leaves", "hang",
    Result2$V1)
Result2$V1 <- gsub("hanging from grass", "grass", Result2$V1)
Result2$V1 <- gsub("laying on branches and leaves", "branch",
    Result2$V1)
Result2$V1 <- gsub("laying on leaf litter, logs, bark, trunk",
    "litter", Result2$V1)
Result2$V1 <- gsub("laying on palm leaves", "palm", Result2$V1)
Result2$V2 <- gsub("hanging from branches and leaves", "hang",
    Result2$V2)
Result2$V2 <- gsub("hanging from grass", "grass", Result2$V2)
Result2$V2 <- gsub("laying on branches and leaves", "branch",
    Result2$V2)
Result2$V2 <- gsub("laying on leaf litter, logs, bark, trunk",
    "litter", Result2$V2)
Result2$V2 <- gsub("laying on palm leaves", "palm", Result2$V2)
lev <- ordered(c("palm", "grass", "branch", "hang", "litter"))
lev2 <- ordered(c("litter", "hang", "branch", "grass", "palm"))
p13 <- ggplot(Result2, aes(x = ordered(V1, levels = lev), y = ordered(V2,
    levels = lev2))) + geom_tile(data = subset(Result2, !is.na(Overlap)),
    aes(fill = Overlap), color = "black") + geom_tile(data = subset(Result2,
    is.na(Overlap)), fill = "lightgrey", color = "black") + scale_fill_gradientn(colours = col1(8),
    breaks = round(breaks, 2), guide = "colorbar", limits = c(signif.floor(min(breaks),
        2), signif.ceiling(max(breaks), 2))) + labs(title = "Overlap PC1",
    subtitle = "Relative body width") + theme_change
```

PC1 (Relative body width)

```
Overlap <- as.numeric(ifelse(result$V1 == result$V2, "NA", result$PC2))
Result2 <- cbind(result, Overlap)
breaks <- seq(min(Result2$Overlap, na.rm = T) - 0.05, max(Result2$Overlap,
    na.rm = T) + 0.1, by = 0.1)
col1 <- colorRampPalette(c("navyblue", "dodgerblue", "white",
    "red", "darkred"))  #define color gradient
Result2$V1 <- gsub("hanging from branches and leaves", "hang",
    Result2$V1)
Result2$V1 <- gsub("hanging from grass", "grass", Result2$V1)
Result2$V1 <- gsub("laying on branches and leaves", "branch",
    Result2$V1)
Result2$V1 <- gsub("laying on leaf litter, logs, bark, trunk",
```

```
    "litter", Result2$V1)
Result2$V1 <- gsub("laying on palm leaves", "palm", Result2$V1)
Result2$V2 <- gsub("hanging from branches and leaves", "hang",
    Result2$V2)
Result2$V2 <- gsub("hanging from grass", "grass", Result2$V2)
Result2$V2 <- gsub("laying on branches and leaves", "branch",
    Result2$V2)
Result2$V2 <- gsub("laying on leaf litter, logs, bark, trunk",
    "litter", Result2$V2)
Result2$V2 <- gsub("laying on palm leaves", "palm", Result2$V2)
lev <- ordered(c("palm", "grass", "branch", "hang", "litter"))
lev2 <- ordered(c("litter", "hang", "branch", "grass", "palm"))
p14 <- ggplot(Result2, aes(x = ordered(V1, levels = lev), y = ordered(V2,
    levels = lev2))) + geom_tile(data = subset(Result2, !is.na(Overlap)),
    aes(fill = Overlap), color = "black") + geom_tile(data = subset(Result2,
    is.na(Overlap)), fill = "lightgrey", color = "black") + scale_fill_gradientn(colours = col1(8),
    breaks = round(breaks, 2), guide = "colorbar", limits = c(signif.floor(min(breaks),
        2), signif.ceiling(max(breaks), 2))) + labs(title = "Overlap PC2",
    subtitle = "Relative wing size") + theme_change
```

PC2 (Relative wing size)

```
Overlap <- as.numeric(ifelse(result$V1 == result$V2, "NA", result$PC3))
Result2 <- cbind(result, Overlap)
breaks <- seq(min(Result2$Overlap, na.rm = T) - 0.05, max(Result2$Overlap,
    na.rm = T) + 0.1, by = 0.1)
col1 <- colorRampPalette(c("navyblue", "dodgerblue", "white",
    "red", "darkred"))  #define color gradient
Result2$V1 <- gsub("hanging from branches and leaves", "hang",
    Result2$V1)
Result2$V1 <- gsub("hanging from grass", "grass", Result2$V1)
Result2$V1 <- gsub("laying on branches and leaves", "branch",
    Result2$V1)
Result2$V1 <- gsub("laying on leaf litter, logs, bark, trunk",
    "litter", Result2$V1)
Result2$V1 <- gsub("laying on palm leaves", "palm", Result2$V1)
Result2$V2 <- gsub("hanging from branches and leaves", "hang",
    Result2$V2)
Result2$V2 <- gsub("hanging from grass", "grass", Result2$V2)
Result2$V2 <- gsub("laying on branches and leaves", "branch",
    Result2$V2)
Result2$V2 <- gsub("laying on leaf litter, logs, bark, trunk",
    "litter", Result2$V2)
Result2$V2 <- gsub("laying on palm leaves", "palm", Result2$V2)
lev <- ordered(c("palm", "grass", "branch", "hang", "litter"))
lev2 <- ordered(c("litter", "hang", "branch", "grass", "palm"))
p15 <- ggplot(Result2, aes(x = ordered(V1, levels = lev), y = ordered(V2,
    levels = lev2))) + geom_tile(data = subset(Result2, !is.na(Overlap)),
    aes(fill = Overlap), color = "black") + geom_tile(data = subset(Result2,
    is.na(Overlap)), fill = "lightgrey", color = "black") + scale_fill_gradientn(colours = col1(8),
```

```
    breaks = round(breaks, 2), guide = "colorbar", limits = c(signif.floor(min(breaks),
        2), signif.ceiling(max(breaks), 2))) + labs(title = "Overlap PC3",
    subtitle = "Relative body height") + theme_change
```

PC3 (Relative body height)

```
Overlap <- as.numeric(ifelse(result$V1 == result$V2, "NA", result$PC4))
Result2 <- cbind(result, Overlap)
breaks <- seq(min(Result2$Overlap, na.rm = T) - 0.05, max(Result2$Overlap,
    na.rm = T) + 0.1, by = 0.1)
col1 <- colorRampPalette(c("navyblue", "dodgerblue", "white",
    "red", "darkred"))  #define color gradient
Result2$V1 <- gsub("hanging from branches and leaves", "hang",
    Result2$V1)
Result2$V1 <- gsub("hanging from grass", "grass", Result2$V1)
Result2$V1 <- gsub("laying on branches and leaves", "branch",
    Result2$V1)
Result2$V1 <- gsub("laying on leaf litter, logs, bark, trunk",
    "litter", Result2$V1)
Result2$V1 <- gsub("laying on palm leaves", "palm", Result2$V1)
Result2$V2 <- gsub("hanging from branches and leaves", "hang",
    Result2$V2)
Result2$V2 <- gsub("hanging from grass", "grass", Result2$V2)
Result2$V2 <- gsub("laying on branches and leaves", "branch",
    Result2$V2)
Result2$V2 <- gsub("laying on leaf litter, logs, bark, trunk",
    "litter", Result2$V2)
Result2$V2 <- gsub("laying on palm leaves", "palm", Result2$V2)
lev <- ordered(c("palm", "grass", "branch", "hang", "litter"))
lev2 <- ordered(c("litter", "hang", "branch", "grass", "palm"))
p16 <- ggplot(Result2, aes(x = ordered(V1, levels = lev), y = ordered(V2,
    levels = lev2))) + geom_tile(data = subset(Result2, !is.na(Overlap)),
    aes(fill = Overlap), color = "black") + geom_tile(data = subset(Result2,
    is.na(Overlap)), fill = "lightgrey", color = "black") + scale_fill_gradientn(colours = col1(8),
    breaks = round(breaks, 2), guide = "colorbar", limits = c(signif.floor(min(breaks),
        2), signif.ceiling(max(breaks), 2))) + labs(title = "Overlap PC4",
    subtitle = "Spininess") + theme_change
```

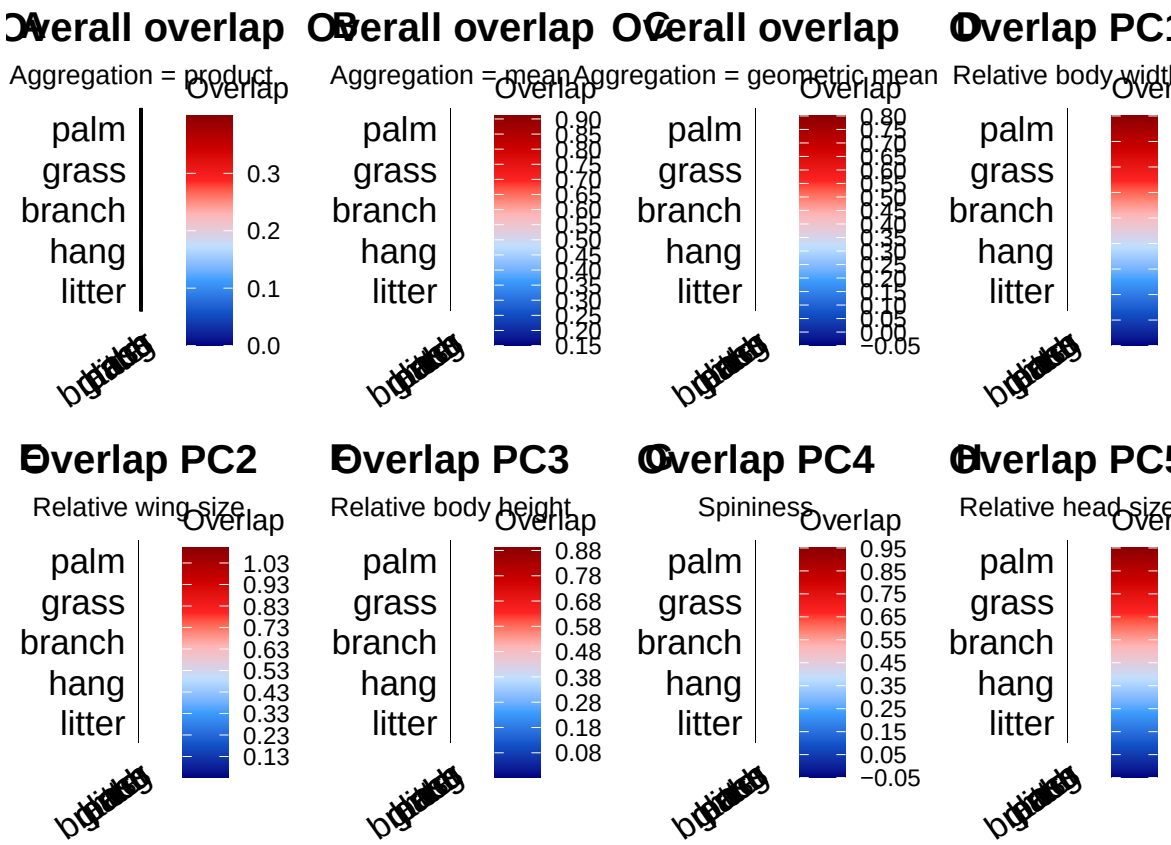
PC4 (Spininess)

```
Overlap <- as.numeric(ifelse(result$V1 == result$V2, "NA", result$PC5))
Result2 <- cbind(result, Overlap)
breaks <- seq(min(Result2$Overlap, na.rm = T) - 0.05, max(Result2$Overlap,
    na.rm = T) + 0.1, by = 0.1)
col1 <- colorRampPalette(c("navyblue", "dodgerblue", "white",
    "red", "darkred"))  #define color gradient
Result2$V1 <- gsub("hanging from branches and leaves", "hang",
```

```
    Result2$V1)
Result2$V1 <- gsub("hanging from grass", "grass", Result2$V1)
Result2$V1 <- gsub("laying on branches and leaves", "branch",
    Result2$V1)
Result2$V1 <- gsub("laying on leaf litter, logs, bark, trunk",
    "litter", Result2$V1)
Result2$V1 <- gsub("laying on palm leaves", "palm", Result2$V1)
Result2$V2 <- gsub("hanging from branches and leaves", "hang",
    Result2$V2)
Result2$V2 <- gsub("hanging from grass", "grass", Result2$V2)
Result2$V2 <- gsub("laying on branches and leaves", "branch",
    Result2$V2)
Result2$V2 <- gsub("laying on leaf litter, logs, bark, trunk",
    "litter", Result2$V2)
Result2$V2 <- gsub("laying on palm leaves", "palm", Result2$V2)
lev <- ordered(c("palm", "grass", "branch", "hang", "litter"))
lev2 <- ordered(c("litter", "hang", "branch", "grass", "palm"))
p17 <- ggplot(Result2, aes(x = ordered(V1, levels = lev), y = ordered(V2,
    levels = lev2))) + geom_tile(data = subset(Result2, !is.na(Overlap)),
    aes(fill = Overlap), color = "black") + geom_tile(data = subset(Result2,
    is.na(Overlap)), fill = "lightgrey", color = "black") + scale_fill_gradientn(colours = col1(8),
    breaks = round(breaks, 2), guide = "colorbar", limits = c(signif.floor(min(breaks),
        2), signif.ceiling(max(breaks), 2))) + labs(title = "Overlap PC5",
    subtitle = "Relative head size") + theme_change
```

PC5 (Relative head size)

```
plot_grid(p6, p11, p12, p13, p14, p15, p16, p17, nrow = 2, labels = "AUTO")
```



Plot all dimensions

Hypervolume size - Habitat

```
result <- r2$result
hs <- subset(result, result$V1 == "hanging from branches and leaves")
ht <- subset(result, result$V1 == "hanging from grass")
ll <- subset(result, result$V1 == "laying on leaf litter, logs, bark, trunk")
lp <- subset(result, result$V1 == "laying on palm leaves")
lb <- subset(result, result$V1 == "laying on branches and leaves")


hs <- as.data.frame(t(hs[, -1]))
hs$habitat <- "hanging from branches and leaves"
hs$PC <- row.names(hs)
colnames(hs) <- c("range", "habitat", "PC")

ht <- as.data.frame(t(ht[, -1]))
ht$habitat <- "hanging from grass"
ht$PC <- row.names(ht)
colnames(ht) <- c("range", "habitat", "PC")

ll <- as.data.frame(t(ll[, -1]))
ll$habitat <- "laying on leaf litter, logs, bark, trunk"
ll$PC <- row.names(ll)
```

```
colnames(ll) <- c("range", "habitat", "PC")

lp <- as.data.frame(t(lp[, -1]))
lp$habitat <- "laying on palm leaves"
lp$PC <- row.names(lp)
colnames(lp) <- c("range", "habitat", "PC")

lb <- as.data.frame(t(lb[, -1]))
lb$habitat <- "laying on branches and leaves"
lb$PC <- row.names(lb)
colnames(lb) <- c("range", "habitat", "PC")

hab <- rbind(hs, ht, ll, lp, lb)


hab$PC <- factor(hab$PC, levels = c("PC1", "PC2", "PC3", "PC4",
    "PC5", "PC6", "PC7"))
p <- ggplot(hab, aes(x = PC, y = range)) + geom_bar(aes(fill = habitat),
    stat = "identity", position = position_dodge(0.6), width = 0.5) +
    scale_fill_manual(values = c("darkseagreen", "gold", "darkorange",
        "darkred", "dodgerblue")) + ylab("Occupied range") +
    xlab("") + #guides(fill=F)+ xlab("") + #guides(fill=F)+
theme_classic()
```

Relative hypervolume size on each PC axis

Full hypervolume size

```
result <- r$result
vol <- as.data.frame(matrix(nrow = 5, ncol = 2))
colnames(vol) <- c("volume", "habitat")
vol$habitat <- c("hanging from branches and leaves", "hanging from grass",
    "laying on branches and leaves", "laying on leaf litter, logs, bark, trunk",
    "laying on palm leaves")
# product
vol[, 1] <- c(result[1:5, 6])
p1 <- ggplot(vol, aes(x = habitat, y = volume)) + geom_bar(aes(fill = habitat),
    stat = "identity", width = 0.8) + scale_fill_manual(values = c("darkseagreen",
    "gold", "darkorange", "darkred", "dodgerblue")) + ylab("Full niche hypervolume") +
    # xlab('')+
coord_cartesian(ylim = c(-1e-04, 0.1)) + labs(title = "Product") +
    scale_x_discrete(labels = NULL, breaks = NULL) + guides(fill = F) +
    theme_classic()
```

Product

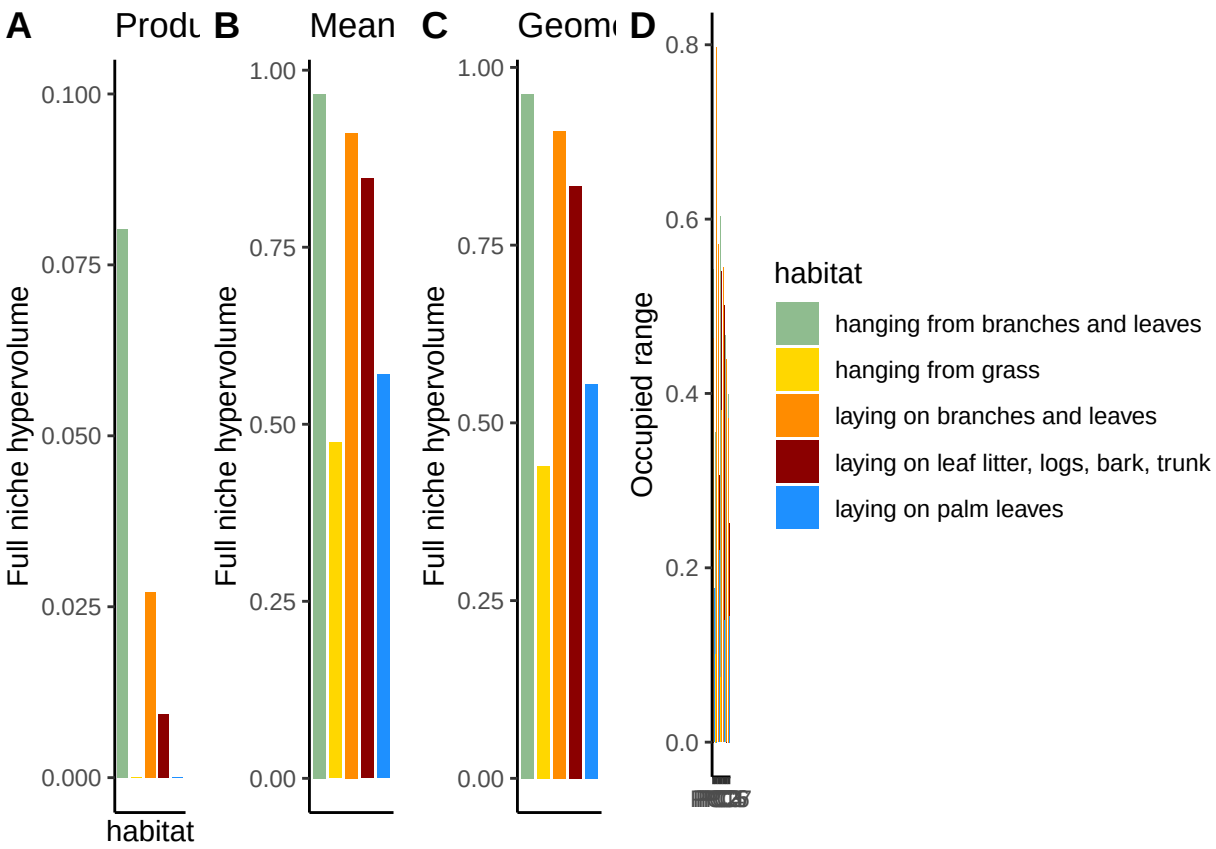
```
vol[, 1] <- c(result[1:5, 7])
p2 <- ggplot(vol, aes(x = habitat, y = volume)) + geom_bar(aes(fill = habitat),
    stat = "identity", width = 0.8) + scale_fill_manual(values = c("darkseagreen",
    "gold", "darkorange", "darkred", "dodgerblue")) + ylab("Full niche hypervolume") +
    ylab("Full niche hypervolume") + xlab("") + labs(title = "Mean") +
    scale_x_discrete(labels = NULL, breaks = NULL) + guides(fill = F) +
    theme_classic()
```

Arithmetic mean

```
vol[, 1] <- c(result[1:5, 8])
p3 <- ggplot(vol, aes(x = habitat, y = volume)) + geom_bar(aes(fill = habitat),
    stat = "identity", width = 0.8) + scale_fill_manual(values = c("darkseagreen",
    "gold", "darkorange", "darkred", "dodgerblue")) + ylab("Full niche hypervolume") +
    ylab("Full niche hypervolume") + xlab("") + labs(title = "Geometric mean") +
    scale_x_discrete(labels = NULL, breaks = NULL) + guides(fill = F) +
    theme_classic()
```

Geometric mean

```
plot_grid(p1, p2, p3, p, nrow = 1, rel_widths = (c(1, 1, 1, 3)),
    labels = "AUTO")
```



Plots

Hypervolume size - Clade

Using the DynRB package

```
Xrc <- matrix(nrow = length(X$clade), ncol = 8)
colnames(Xrc) <- c("clade", "PC1", "PC2", "PC3", "PC4", "PC5",
    "PC6", "PC7")
Xrc <- as.data.frame(Xrc)
Xrc$clade <- as.character(X$clade)
Xrc$PC1 <- as.numeric(X$pca_mix_dim1)
Xrc$PC2 <- as.numeric(X$pca_mix_dim2)
Xrc$PC3 <- as.numeric(X$pca_mix_dim3)
Xrc$PC4 <- as.numeric(X$pca_mix_dim4)
Xrc$PC5 <- as.numeric(X$pca_mix_dim5)
Xrc$PC6 <- as.numeric(X$pca_mix_dim6)
Xrc$PC7 <- as.numeric(X$pca_mix_dim7)

# Size and pairwise overlap
rc <- dynRB_VPa(Xrc)
```

```
## [1] 1
## [1] 2
## [1] 3
```

```
## [1] 4
## [1] 5
## [1] 6
## [1] 7
## [1] 8
## [1] 9
## [1] 10
## [1] 11
## [1] 12
## [1] 13
## [1] 14
## [1] 15
## [1] 16
## [1] 17
## [1] 18
## [1] 19
## [1] 20
## [1] 21
## [1] 22
## [1] 23
## [1] 24
## [1] 25
## [1] 26
## [1] 27
## [1] 28
## [1] 29
## [1] 30
## [1] 31
## [1] 32
## [1] 33
## [1] 34
## [1] 35
## [1] 36
## [1] 37
## [1] 38
## [1] 39
## [1] 40
## [1] 41
## [1] 42
## [1] 43
## [1] 44
## [1] 45
## [1] 46
## [1] 47
## [1] 48
## [1] 49
## [1] 50
## [1] 51
## [1] 52
## [1] 53
## [1] 54
## [1] 55
## [1] 56
## [1] 57
```

```
## [1] 58
## [1] 59
## [1] 60
## [1] 61
## [1] 62
## [1] 63
## [1] 64
## [1] 65
## [1] 66
## [1] 67
## [1] 68
## [1] 69
## [1] 70
## [1] 71
## [1] 72
## [1] 73
## [1] 74
## [1] 75
## [1] 76
## [1] 77
## [1] 78
## [1] 79
## [1] 80
## [1] 81
## [1] 82
## [1] 83
## [1] 84
## [1] 85
## [1] 86
## [1] 87
## [1] 88
## [1] 89
## [1] 90
## [1] 91
## [1] 92
## [1] 93
## [1] 94
## [1] 95
## [1] 96
## [1] 97
## [1] 98
## [1] 99
## [1] 100
## [1] 101
## [1] 102
## [1] 103
## [1] 104
## [1] 105
## [1] 106
## [1] 107
## [1] 108
## [1] 109
## [1] 110
## [1] 111
```

```
## [1] 112
## [1] 113
## [1] 114
## [1] 115
## [1] 116
## [1] 117
## [1] 118
## [1] 119
## [1] 120
## [1] 121
## [1] 122
## [1] 123
## [1] 124
## [1] 125
## [1] 126
## [1] 127
## [1] 128
## [1] 129
## [1] 130
## [1] 131
## [1] 132
## [1] 133
## [1] 134
## [1] 135
## [1] 136
## [1] 137
## [1] 138
## [1] 139
## [1] 140
## [1] 141
## [1] 142
## [1] 143
## [1] 144
## [1] 145
## [1] 146
## [1] 147
## [1] 148
## [1] 149
## [1] 150
## [1] 151
## [1] 152
## [1] 153
## [1] 154
## [1] 155
## [1] 156
## [1] 157
## [1] 158
## [1] 159
## [1] 160
## [1] 161
## [1] 162
## [1] 163
## [1] 164
## [1] 165
```

```
## [1] 166
## [1] 167
## [1] 168
## [1] 169
## [1] 170
## [1] 171
## [1] 172
## [1] 173
## [1] 174
## [1] 175
## [1] 176
## [1] 177
## [1] 178
## [1] 179
## [1] 180
## [1] 181
## [1] 182
## [1] 183
## [1] 184
## [1] 185
## [1] 186
## [1] 187
## [1] 188
## [1] 189
## [1] 190
## [1] 191
## [1] 192
## [1] 193
## [1] 194
## [1] 195
## [1] 196
## [1] 197
## [1] 198
## [1] 199
## [1] 200
## [1] 201
## [1] 202
## [1] 203
## [1] 204
## [1] 205
## [1] 206
## [1] 207
## [1] 208
## [1] 209
## [1] 210
## [1] 211
## [1] 212
## [1] 213
## [1] 214
## [1] 215
## [1] 216
## [1] 217
## [1] 218
## [1] 219
```

```
## [1] 220
## [1] 221
## [1] 222
## [1] 223
## [1] 224
## [1] 225
## [1] 226
## [1] 227
## [1] 228
## [1] 229
## [1] 230
## [1] 231
## [1] 232
## [1] 233
## [1] 234
## [1] 235
## [1] 236
## [1] 237
## [1] 238
## [1] 239
## [1] 240
## [1] 241
## [1] 242
## [1] 243
## [1] 244
## [1] 245
## [1] 246
## [1] 247
## [1] 248
## [1] 249
## [1] 250
## [1] 251
## [1] 252
## [1] 253
## [1] 254
## [1] 255
## [1] 256
##                            V1                          V2    port_prod
## 1       African/Malagasy clade     African/Malagasy clade 1.000000e+00
## 2                 Agathemeridae     African/Malagasy clade 0.000000e+00
## 3              Aschiphasmatinae     African/Malagasy clade 3.275021e-04
## 4   Clitumninae/Pachymorphinae     African/Malagasy clade 9.763066e-03
## 5               Diapheromerinae     African/Malagasy clade 5.359756e-02
## 6                European clade     African/Malagasy clade 0.000000e+00
## 7              Heteropteryginae     African/Malagasy clade 1.407811e-03
## 8                 Lanceocercata     African/Malagasy clade 2.382017e-01
## 9                   Lonchodinae     African/Malagasy clade 9.646317e-02
## 10                Necrosciinae     African/Malagasy clade 1.714932e-01
## 11   Palophinae/Cladomorphinae     African/Malagasy clade 1.622733e-02
## 12                  Pharnaciini     African/Malagasy clade 2.117387e-05
## 13                   Phylliinae     African/Malagasy clade 0.000000e+00
## 14            Pseudophasmatinae     African/Malagasy clade 5.408692e-03
## 15              Stephanacridini     African/Malagasy clade 9.882564e-08
## 16                  Timematinae     African/Malagasy clade 0.000000e+00
```

```
## 17      African/Malagasy clade              Agathemeridae 0.000000e+00
## 18                Agathemeridae              Agathemeridae 1.000000e+00
## 19             Aschiphasmatinae              Agathemeridae 0.000000e+00
## 20  Clitumninae/Pachymorphinae              Agathemeridae 0.000000e+00
## 21              Diapheromerinae              Agathemeridae 0.000000e+00
## 22               European clade              Agathemeridae 0.000000e+00
## 23            Heteropteryginae              Agathemeridae 0.000000e+00
## 24               Lanceocercata              Agathemeridae 0.000000e+00
## 25                 Lonchodinae              Agathemeridae 0.000000e+00
## 26                Necrosciinae              Agathemeridae 0.000000e+00
## 27   Palophinae/Cladomorphinae              Agathemeridae 0.000000e+00
## 28                 Pharnaciini              Agathemeridae 0.000000e+00
## 29                  Phylliinae              Agathemeridae 0.000000e+00
## 30           Pseudophasmatinae              Agathemeridae 0.000000e+00
## 31             Stephanacridini              Agathemeridae 0.000000e+00
## 32                 Timematinae              Agathemeridae 0.000000e+00
## 33      African/Malagasy clade           Aschiphasmatinae 2.056023e-02
## 34                Agathemeridae           Aschiphasmatinae 0.000000e+00
## 35             Aschiphasmatinae           Aschiphasmatinae 1.000000e+00
## 36  Clitumninae/Pachymorphinae           Aschiphasmatinae 0.000000e+00
## 37              Diapheromerinae           Aschiphasmatinae 7.943962e-03
## 38               European clade           Aschiphasmatinae 0.000000e+00
## 39            Heteropteryginae           Aschiphasmatinae 7.914129e-03
## 40               Lanceocercata           Aschiphasmatinae 2.672427e-01
## 41                 Lonchodinae           Aschiphasmatinae 5.320893e-03
## 42                Necrosciinae           Aschiphasmatinae 5.734753e-02
## 43   Palophinae/Cladomorphinae           Aschiphasmatinae 1.176894e-03
## 44                 Pharnaciini           Aschiphasmatinae 0.000000e+00
## 45                  Phylliinae           Aschiphasmatinae 0.000000e+00
## 46           Pseudophasmatinae           Aschiphasmatinae 1.520808e-01
## 47             Stephanacridini           Aschiphasmatinae 0.000000e+00
## 48                 Timematinae           Aschiphasmatinae 0.000000e+00
## 49      African/Malagasy clade Clitumninae/Pachymorphinae 4.412046e-01
## 50                Agathemeridae Clitumninae/Pachymorphinae 0.000000e+00
## 51             Aschiphasmatinae Clitumninae/Pachymorphinae 0.000000e+00
## 52  Clitumninae/Pachymorphinae Clitumninae/Pachymorphinae 1.000000e+00
## 53              Diapheromerinae Clitumninae/Pachymorphinae 3.765548e-01
## 54               European clade Clitumninae/Pachymorphinae 2.483243e-05
## 55            Heteropteryginae Clitumninae/Pachymorphinae 0.000000e+00
## 56               Lanceocercata Clitumninae/Pachymorphinae 3.184679e-01
## 57                 Lonchodinae Clitumninae/Pachymorphinae 6.143690e-01
## 58                Necrosciinae Clitumninae/Pachymorphinae 2.081693e-01
## 59   Palophinae/Cladomorphinae Clitumninae/Pachymorphinae 1.837032e-02
## 60                 Pharnaciini Clitumninae/Pachymorphinae 3.702183e-05
## 61                  Phylliinae Clitumninae/Pachymorphinae 0.000000e+00
## 62           Pseudophasmatinae Clitumninae/Pachymorphinae 0.000000e+00
## 63             Stephanacridini Clitumninae/Pachymorphinae 0.000000e+00
## 64                 Timematinae Clitumninae/Pachymorphinae 0.000000e+00
## 65      African/Malagasy clade              Diapheromerinae 2.417317e-01
## 66                Agathemeridae              Diapheromerinae 0.000000e+00
## 67             Aschiphasmatinae              Diapheromerinae 2.754138e-04
## 68  Clitumninae/Pachymorphinae              Diapheromerinae 4.029842e-02
## 69              Diapheromerinae              Diapheromerinae 1.000000e+00
## 70               European clade              Diapheromerinae 1.586802e-05
```

```
## 71            Heteropteryginae          Diapheromerinae 2.830717e-03
## 72               Lanceocercata          Diapheromerinae 4.064139e-01
## 73                 Lonchodinae          Diapheromerinae 1.361778e-01
## 74                Necrosciinae          Diapheromerinae 1.531475e-01
## 75   Palophinae/Cladomorphinae          Diapheromerinae 3.099556e-02
## 76                 Pharnaciini          Diapheromerinae 0.000000e+00
## 77                  Phylliinae          Diapheromerinae 0.000000e+00
## 78           Pseudophasmatinae          Diapheromerinae 1.642537e-02
## 79             Stephanacridini          Diapheromerinae 2.676573e-07
## 80                 Timematinae          Diapheromerinae 0.000000e+00
## 81      African/Malagasy clade           European clade 0.000000e+00
## 82                Agathemeridae           European clade 0.000000e+00
## 83             Aschiphasmatinae           European clade 0.000000e+00
## 84  Clitumninae/Pachymorphinae           European clade 7.994354e-03
## 85              Diapheromerinae           European clade 7.078366e-02
## 86               European clade           European clade 1.000000e+00
## 87             Heteropteryginae           European clade 0.000000e+00
## 88                Lanceocercata           European clade 0.000000e+00
## 89                  Lonchodinae           European clade 0.000000e+00
## 90                 Necrosciinae           European clade 0.000000e+00
## 91   Palophinae/Cladomorphinae           European clade 0.000000e+00
## 92                 Pharnaciini           European clade 0.000000e+00
## 93                  Phylliinae           European clade 0.000000e+00
## 94           Pseudophasmatinae           European clade 0.000000e+00
## 95             Stephanacridini           European clade 0.000000e+00
## 96                 Timematinae           European clade 0.000000e+00
## 97      African/Malagasy clade         Heteropteryginae 3.033358e-02
## 98                Agathemeridae         Heteropteryginae 0.000000e+00
## 99             Aschiphasmatinae         Heteropteryginae 1.603868e-03
## 100 Clitumninae/Pachymorphinae         Heteropteryginae 0.000000e+00
## 101             Diapheromerinae         Heteropteryginae 1.478070e-02
## 102              European clade         Heteropteryginae 0.000000e+00
## 103            Heteropteryginae         Heteropteryginae 1.000000e+00
## 104               Lanceocercata         Heteropteryginae 4.422066e-01
## 105                 Lonchodinae         Heteropteryginae 1.238987e-01
## 106                Necrosciinae         Heteropteryginae 4.397350e-02
## 107  Palophinae/Cladomorphinae         Heteropteryginae 4.555807e-02
## 108                Pharnaciini         Heteropteryginae 0.000000e+00
## 109                 Phylliinae         Heteropteryginae 0.000000e+00
## 110          Pseudophasmatinae         Heteropteryginae 1.541589e-02
## 111            Stephanacridini         Heteropteryginae 0.000000e+00
## 112                Timematinae         Heteropteryginae 0.000000e+00
## 113     African/Malagasy clade            Lanceocercata 4.966182e-02
## 114               Agathemeridae            Lanceocercata 0.000000e+00
## 115            Aschiphasmatinae            Lanceocercata 9.062417e-04
## 116 Clitumninae/Pachymorphinae            Lanceocercata 1.598793e-03
## 117             Diapheromerinae            Lanceocercata 2.034120e-02
## 118              European clade            Lanceocercata 0.000000e+00
## 119            Heteropteryginae            Lanceocercata 5.179991e-03
## 120               Lanceocercata            Lanceocercata 1.000000e+00
## 121                 Lonchodinae            Lanceocercata 2.146974e-02
## 122                Necrosciinae            Lanceocercata 1.001263e-01
## 123  Palophinae/Cladomorphinae            Lanceocercata 1.335272e-02
## 124                Pharnaciini            Lanceocercata 2.139655e-06
```

```
## 125                 Phylliinae             Lanceocercata 0.000000e+00
## 126          Pseudophasmatinae             Lanceocercata 2.560251e-02
## 127            Stephanacridini             Lanceocercata 7.896274e-09
## 128                Timematinae             Lanceocercata 0.000000e+00
## 129     African/Malagasy clade               Lonchodinae 4.241710e-01
## 130               Agathemeridae               Lonchodinae 0.000000e+00
## 131           Aschiphasmatinae               Lonchodinae 2.947715e-04
## 132 Clitumninae/Pachymorphinae               Lonchodinae 6.774484e-02
## 133            Diapheromerinae               Lonchodinae 1.459946e-01
## 134              European clade               Lonchodinae 0.000000e+00
## 135           Heteropteryginae               Lonchodinae 3.223264e-02
## 136              Lanceocercata               Lonchodinae 4.421265e-01
## 137                Lonchodinae               Lonchodinae 1.000000e+00
## 138                Necrosciinae               Lonchodinae 1.917005e-01
## 139  Palophinae/Cladomorphinae               Lonchodinae 6.468927e-02
## 140                 Pharnaciini               Lonchodinae 9.699221e-06
## 141                 Phylliinae               Lonchodinae 0.000000e+00
## 142          Pseudophasmatinae               Lonchodinae 0.000000e+00
## 143            Stephanacridini               Lonchodinae 0.000000e+00
## 144                Timematinae               Lonchodinae 0.000000e+00
## 145     African/Malagasy clade              Necrosciinae 2.151400e-01
## 146               Agathemeridae              Necrosciinae 0.000000e+00
## 147           Aschiphasmatinae              Necrosciinae 1.319990e-03
## 148 Clitumninae/Pachymorphinae              Necrosciinae 8.310035e-03
## 149            Diapheromerinae              Necrosciinae 6.335222e-02
## 150              European clade              Necrosciinae 0.000000e+00
## 151           Heteropteryginae              Necrosciinae 5.241305e-03
## 152              Lanceocercata              Necrosciinae 6.719758e-01
## 153                Lonchodinae              Necrosciinae 6.712249e-02
## 154                Necrosciinae              Necrosciinae 1.000000e+00
## 155  Palophinae/Cladomorphinae              Necrosciinae 2.926076e-02
## 156                 Pharnaciini              Necrosciinae 3.304761e-06
## 157                 Phylliinae              Necrosciinae 0.000000e+00
## 158          Pseudophasmatinae              Necrosciinae 1.018411e-01
## 159            Stephanacridini              Necrosciinae 0.000000e+00
## 160                Timematinae              Necrosciinae 0.000000e+00
## 161     African/Malagasy clade Palophinae/Cladomorphinae 2.537918e-01
## 162               Agathemeridae Palophinae/Cladomorphinae 0.000000e+00
## 163           Aschiphasmatinae Palophinae/Cladomorphinae 1.836290e-04
## 164 Clitumninae/Pachymorphinae Palophinae/Cladomorphinae 5.747381e-03
## 165            Diapheromerinae Palophinae/Cladomorphinae 1.178798e-01
## 166              European clade Palophinae/Cladomorphinae 0.000000e+00
## 167           Heteropteryginae Palophinae/Cladomorphinae 3.560793e-02
## 168              Lanceocercata Palophinae/Cladomorphinae 8.255467e-01
## 169                Lonchodinae Palophinae/Cladomorphinae 2.064705e-01
## 170                Necrosciinae Palophinae/Cladomorphinae 2.443124e-01
## 171  Palophinae/Cladomorphinae Palophinae/Cladomorphinae 1.000000e+00
## 172                 Pharnaciini Palophinae/Cladomorphinae 0.000000e+00
## 173                 Phylliinae Palophinae/Cladomorphinae 0.000000e+00
## 174          Pseudophasmatinae Palophinae/Cladomorphinae 1.749771e-02
## 175            Stephanacridini Palophinae/Cladomorphinae 5.311823e-08
## 176                Timematinae Palophinae/Cladomorphinae 0.000000e+00
## 177     African/Malagasy clade               Pharnaciini 3.691901e-01
## 178               Agathemeridae               Pharnaciini 0.000000e+00
```

```
## 179           Aschiphasmatinae              Pharnaciini 0.000000e+00
## 180 Clitumninae/Pachymorphinae              Pharnaciini 1.634723e-02
## 181            Diapheromerinae              Pharnaciini 0.000000e+00
## 182             European clade              Pharnaciini 0.000000e+00
## 183          Heteropteryginae              Pharnaciini 0.000000e+00
## 184             Lanceocercata              Pharnaciini 1.695196e-01
## 185               Lonchodinae              Pharnaciini 3.869827e-02
## 186              Necrosciinae              Pharnaciini 3.150878e-02
## 187  Palophinae/Cladomorphinae              Pharnaciini 0.000000e+00
## 188               Pharnaciini              Pharnaciini 1.000000e+00
## 189                Phylliinae              Pharnaciini 0.000000e+00
## 190         Pseudophasmatinae              Pharnaciini 0.000000e+00
## 191           Stephanacridini              Pharnaciini 0.000000e+00
## 192               Timematinae              Pharnaciini 0.000000e+00
## 193    African/Malagasy clade                Phylliinae 0.000000e+00
## 194             Agathemeridae                Phylliinae 0.000000e+00
## 195           Aschiphasmatinae                Phylliinae 0.000000e+00
## 196 Clitumninae/Pachymorphinae                Phylliinae 0.000000e+00
## 197            Diapheromerinae                Phylliinae 0.000000e+00
## 198             European clade                Phylliinae 0.000000e+00
## 199          Heteropteryginae                Phylliinae 0.000000e+00
## 200             Lanceocercata                Phylliinae 0.000000e+00
## 201               Lonchodinae                Phylliinae 0.000000e+00
## 202              Necrosciinae                Phylliinae 0.000000e+00
## 203  Palophinae/Cladomorphinae                Phylliinae 0.000000e+00
## 204               Pharnaciini                Phylliinae 0.000000e+00
## 205                Phylliinae                Phylliinae 1.000000e+00
## 206         Pseudophasmatinae                Phylliinae 0.000000e+00
## 207           Stephanacridini                Phylliinae 0.000000e+00
## 208               Timematinae                Phylliinae 0.000000e+00
## 209    African/Malagasy clade         Pseudophasmatinae 2.004219e-02
## 210             Agathemeridae         Pseudophasmatinae 0.000000e+00
## 211           Aschiphasmatinae         Pseudophasmatinae 6.938575e-03
## 212 Clitumninae/Pachymorphinae         Pseudophasmatinae 0.000000e+00
## 213            Diapheromerinae         Pseudophasmatinae 1.528486e-02
## 214             European clade         Pseudophasmatinae 0.000000e+00
## 215          Heteropteryginae         Pseudophasmatinae 3.183924e-03
## 216             Lanceocercata         Pseudophasmatinae 3.404328e-01
## 217               Lonchodinae         Pseudophasmatinae 0.000000e+00
## 218              Necrosciinae         Pseudophasmatinae 1.842550e-01
## 219  Palophinae/Cladomorphinae         Pseudophasmatinae 4.601739e-03
## 220               Pharnaciini         Pseudophasmatinae 0.000000e+00
## 221                Phylliinae         Pseudophasmatinae 0.000000e+00
## 222         Pseudophasmatinae         Pseudophasmatinae 1.000000e+00
## 223           Stephanacridini         Pseudophasmatinae 0.000000e+00
## 224               Timematinae         Pseudophasmatinae 0.000000e+00
## 225    African/Malagasy clade           Stephanacridini 3.811380e-01
## 226             Agathemeridae           Stephanacridini 0.000000e+00
## 227           Aschiphasmatinae           Stephanacridini 0.000000e+00
## 228 Clitumninae/Pachymorphinae           Stephanacridini 0.000000e+00
## 229            Diapheromerinae           Stephanacridini 2.217445e-01
## 230             European clade           Stephanacridini 0.000000e+00
## 231          Heteropteryginae           Stephanacridini 0.000000e+00
## 232             Lanceocercata           Stephanacridini 2.505661e-01
```

```
## 233                Lonchodinae           Stephanacridini 0.000000e+00
## 234               Necrosciinae           Stephanacridini 0.000000e+00
## 235  Palophinae/Cladomorphinae           Stephanacridini 1.971288e-02
## 236                Pharnaciini           Stephanacridini 0.000000e+00
## 237                 Phylliinae           Stephanacridini 0.000000e+00
## 238          Pseudophasmatinae           Stephanacridini 0.000000e+00
## 239            Stephanacridini           Stephanacridini 1.000000e+00
## 240                Timematinae           Stephanacridini 0.000000e+00
## 241     African/Malagasy clade               Timematinae 0.000000e+00
## 242              Agathemeridae               Timematinae 0.000000e+00
## 243           Aschiphasmatinae               Timematinae 0.000000e+00
## 244 Clitumninae/Pachymorphinae               Timematinae 0.000000e+00
## 245            Diapheromerinae               Timematinae 0.000000e+00
## 246             European clade               Timematinae 0.000000e+00
## 247           Heteropteryginae               Timematinae 0.000000e+00
## 248              Lanceocercata               Timematinae 0.000000e+00
## 249                Lonchodinae               Timematinae 0.000000e+00
## 250               Necrosciinae               Timematinae 0.000000e+00
## 251  Palophinae/Cladomorphinae               Timematinae 0.000000e+00
## 252                Pharnaciini               Timematinae 0.000000e+00
## 253                 Phylliinae               Timematinae 0.000000e+00
## 254          Pseudophasmatinae               Timematinae 0.000000e+00
## 255            Stephanacridini               Timematinae 0.000000e+00
## 256                Timematinae               Timematinae 1.000000e+00
##      vol_V1_prod  vol_V2_prod
## 1   8.953343e-03 8.953343e-03
## 2   4.963308e-08 8.953343e-03
## 3   1.227698e-04 8.953343e-03
## 4   1.850251e-04 8.953343e-03
## 5   2.005731e-03 8.953343e-03
## 6   7.722328e-07 8.953343e-03
## 7   4.382212e-04 8.953343e-03
## 8   4.127894e-02 8.953343e-03
## 9   1.688916e-03 8.953343e-03
## 10  4.767779e-03 8.953343e-03
## 11  5.551642e-04 8.953343e-03
## 12  8.530158e-07 8.953343e-03
## 13  3.673400e-05 8.953343e-03
## 14  2.642797e-03 8.953343e-03
## 15  2.572885e-09 8.953343e-03
## 16  2.861688e-09 8.953343e-03
## 17  8.953343e-03 4.963308e-08
## 18  4.963308e-08 4.963308e-08
## 19  1.227698e-04 4.963308e-08
## 20  1.850251e-04 4.963308e-08
## 21  2.005731e-03 4.963308e-08
## 22  7.722328e-07 4.963308e-08
## 23  4.382212e-04 4.963308e-08
## 24  4.127894e-02 4.963308e-08
## 25  1.688916e-03 4.963308e-08
## 26  4.767779e-03 4.963308e-08
## 27  5.551642e-04 4.963308e-08
## 28  8.530158e-07 4.963308e-08
## 29  3.673400e-05 4.963308e-08
```

```
## 30  2.642797e-03 4.963308e-08
## 31  2.572885e-09 4.963308e-08
## 32  2.861688e-09 4.963308e-08
## 33  8.953343e-03 1.227698e-04
## 34  4.963308e-08 1.227698e-04
## 35  1.227698e-04 1.227698e-04
## 36  1.850251e-04 1.227698e-04
## 37  2.005731e-03 1.227698e-04
## 38  7.722328e-07 1.227698e-04
## 39  4.382212e-04 1.227698e-04
## 40  4.127894e-02 1.227698e-04
## 41  1.688916e-03 1.227698e-04
## 42  4.767779e-03 1.227698e-04
## 43  5.551642e-04 1.227698e-04
## 44  8.530158e-07 1.227698e-04
## 45  3.673400e-05 1.227698e-04
## 46  2.642797e-03 1.227698e-04
## 47  2.572885e-09 1.227698e-04
## 48  2.861688e-09 1.227698e-04
## 49  8.953343e-03 1.850251e-04
## 50  4.963308e-08 1.850251e-04
## 51  1.227698e-04 1.850251e-04
## 52  1.850251e-04 1.850251e-04
## 53  2.005731e-03 1.850251e-04
## 54  7.722328e-07 1.850251e-04
## 55  4.382212e-04 1.850251e-04
## 56  4.127894e-02 1.850251e-04
## 57  1.688916e-03 1.850251e-04
## 58  4.767779e-03 1.850251e-04
## 59  5.551642e-04 1.850251e-04
## 60  8.530158e-07 1.850251e-04
## 61  3.673400e-05 1.850251e-04
## 62  2.642797e-03 1.850251e-04
## 63  2.572885e-09 1.850251e-04
## 64  2.861688e-09 1.850251e-04
## 65  8.953343e-03 2.005731e-03
## 66  4.963308e-08 2.005731e-03
## 67  1.227698e-04 2.005731e-03
## 68  1.850251e-04 2.005731e-03
## 69  2.005731e-03 2.005731e-03
## 70  7.722328e-07 2.005731e-03
## 71  4.382212e-04 2.005731e-03
## 72  4.127894e-02 2.005731e-03
## 73  1.688916e-03 2.005731e-03
## 74  4.767779e-03 2.005731e-03
## 75  5.551642e-04 2.005731e-03
## 76  8.530158e-07 2.005731e-03
## 77  3.673400e-05 2.005731e-03
## 78  2.642797e-03 2.005731e-03
## 79  2.572885e-09 2.005731e-03
## 80  2.861688e-09 2.005731e-03
## 81  8.953343e-03 7.722328e-07
## 82  4.963308e-08 7.722328e-07
## 83  1.227698e-04 7.722328e-07
```

```
## 84  1.850251e-04 7.722328e-07
## 85  2.005731e-03 7.722328e-07
## 86  7.722328e-07 7.722328e-07
## 87  4.382212e-04 7.722328e-07
## 88  4.127894e-02 7.722328e-07
## 89  1.688916e-03 7.722328e-07
## 90  4.767779e-03 7.722328e-07
## 91  5.551642e-04 7.722328e-07
## 92  8.530158e-07 7.722328e-07
## 93  3.673400e-05 7.722328e-07
## 94  2.642797e-03 7.722328e-07
## 95  2.572885e-09 7.722328e-07
## 96  2.861688e-09 7.722328e-07
## 97  8.953343e-03 4.382212e-04
## 98  4.963308e-08 4.382212e-04
## 99  1.227698e-04 4.382212e-04
## 100 1.850251e-04 4.382212e-04
## 101 2.005731e-03 4.382212e-04
## 102 7.722328e-07 4.382212e-04
## 103 4.382212e-04 4.382212e-04
## 104 4.127894e-02 4.382212e-04
## 105 1.688916e-03 4.382212e-04
## 106 4.767779e-03 4.382212e-04
## 107 5.551642e-04 4.382212e-04
## 108 8.530158e-07 4.382212e-04
## 109 3.673400e-05 4.382212e-04
## 110 2.642797e-03 4.382212e-04
## 111 2.572885e-09 4.382212e-04
## 112 2.861688e-09 4.382212e-04
## 113 8.953343e-03 4.127894e-02
## 114 4.963308e-08 4.127894e-02
## 115 1.227698e-04 4.127894e-02
## 116 1.850251e-04 4.127894e-02
## 117 2.005731e-03 4.127894e-02
## 118 7.722328e-07 4.127894e-02
## 119 4.382212e-04 4.127894e-02
## 120 4.127894e-02 4.127894e-02
## 121 1.688916e-03 4.127894e-02
## 122 4.767779e-03 4.127894e-02
## 123 5.551642e-04 4.127894e-02
## 124 8.530158e-07 4.127894e-02
## 125 3.673400e-05 4.127894e-02
## 126 2.642797e-03 4.127894e-02
## 127 2.572885e-09 4.127894e-02
## 128 2.861688e-09 4.127894e-02
## 129 8.953343e-03 1.688916e-03
## 130 4.963308e-08 1.688916e-03
## 131 1.227698e-04 1.688916e-03
## 132 1.850251e-04 1.688916e-03
## 133 2.005731e-03 1.688916e-03
## 134 7.722328e-07 1.688916e-03
## 135 4.382212e-04 1.688916e-03
## 136 4.127894e-02 1.688916e-03
## 137 1.688916e-03 1.688916e-03
```

```
## 138 4.767779e-03 1.688916e-03
## 139 5.551642e-04 1.688916e-03
## 140 8.530158e-07 1.688916e-03
## 141 3.673400e-05 1.688916e-03
## 142 2.642797e-03 1.688916e-03
## 143 2.572885e-09 1.688916e-03
## 144 2.861688e-09 1.688916e-03
## 145 8.953343e-03 4.767779e-03
## 146 4.963308e-08 4.767779e-03
## 147 1.227698e-04 4.767779e-03
## 148 1.850251e-04 4.767779e-03
## 149 2.005731e-03 4.767779e-03
## 150 7.722328e-07 4.767779e-03
## 151 4.382212e-04 4.767779e-03
## 152 4.127894e-02 4.767779e-03
## 153 1.688916e-03 4.767779e-03
## 154 4.767779e-03 4.767779e-03
## 155 5.551642e-04 4.767779e-03
## 156 8.530158e-07 4.767779e-03
## 157 3.673400e-05 4.767779e-03
## 158 2.642797e-03 4.767779e-03
## 159 2.572885e-09 4.767779e-03
## 160 2.861688e-09 4.767779e-03
## 161 8.953343e-03 5.551642e-04
## 162 4.963308e-08 5.551642e-04
## 163 1.227698e-04 5.551642e-04
## 164 1.850251e-04 5.551642e-04
## 165 2.005731e-03 5.551642e-04
## 166 7.722328e-07 5.551642e-04
## 167 4.382212e-04 5.551642e-04
## 168 4.127894e-02 5.551642e-04
## 169 1.688916e-03 5.551642e-04
## 170 4.767779e-03 5.551642e-04
## 171 5.551642e-04 5.551642e-04
## 172 8.530158e-07 5.551642e-04
## 173 3.673400e-05 5.551642e-04
## 174 2.642797e-03 5.551642e-04
## 175 2.572885e-09 5.551642e-04
## 176 2.861688e-09 5.551642e-04
## 177 8.953343e-03 8.530158e-07
## 178 4.963308e-08 8.530158e-07
## 179 1.227698e-04 8.530158e-07
## 180 1.850251e-04 8.530158e-07
## 181 2.005731e-03 8.530158e-07
## 182 7.722328e-07 8.530158e-07
## 183 4.382212e-04 8.530158e-07
## 184 4.127894e-02 8.530158e-07
## 185 1.688916e-03 8.530158e-07
## 186 4.767779e-03 8.530158e-07
## 187 5.551642e-04 8.530158e-07
## 188 8.530158e-07 8.530158e-07
## 189 3.673400e-05 8.530158e-07
## 190 2.642797e-03 8.530158e-07
## 191 2.572885e-09 8.530158e-07
```

```
## 192 2.861688e-09 8.530158e-07
## 193 8.953343e-03 3.673400e-05
## 194 4.963308e-08 3.673400e-05
## 195 1.227698e-04 3.673400e-05
## 196 1.850251e-04 3.673400e-05
## 197 2.005731e-03 3.673400e-05
## 198 7.722328e-07 3.673400e-05
## 199 4.382212e-04 3.673400e-05
## 200 4.127894e-02 3.673400e-05
## 201 1.688916e-03 3.673400e-05
## 202 4.767779e-03 3.673400e-05
## 203 5.551642e-04 3.673400e-05
## 204 8.530158e-07 3.673400e-05
## 205 3.673400e-05 3.673400e-05
## 206 2.642797e-03 3.673400e-05
## 207 2.572885e-09 3.673400e-05
## 208 2.861688e-09 3.673400e-05
## 209 8.953343e-03 2.642797e-03
## 210 4.963308e-08 2.642797e-03
## 211 1.227698e-04 2.642797e-03
## 212 1.850251e-04 2.642797e-03
## 213 2.005731e-03 2.642797e-03
## 214 7.722328e-07 2.642797e-03
## 215 4.382212e-04 2.642797e-03
## 216 4.127894e-02 2.642797e-03
## 217 1.688916e-03 2.642797e-03
## 218 4.767779e-03 2.642797e-03
## 219 5.551642e-04 2.642797e-03
## 220 8.530158e-07 2.642797e-03
## 221 3.673400e-05 2.642797e-03
## 222 2.642797e-03 2.642797e-03
## 223 2.572885e-09 2.642797e-03
## 224 2.861688e-09 2.642797e-03
## 225 8.953343e-03 2.572885e-09
## 226 4.963308e-08 2.572885e-09
## 227 1.227698e-04 2.572885e-09
## 228 1.850251e-04 2.572885e-09
## 229 2.005731e-03 2.572885e-09
## 230 7.722328e-07 2.572885e-09
## 231 4.382212e-04 2.572885e-09
## 232 4.127894e-02 2.572885e-09
## 233 1.688916e-03 2.572885e-09
## 234 4.767779e-03 2.572885e-09
## 235 5.551642e-04 2.572885e-09
## 236 8.530158e-07 2.572885e-09
## 237 3.673400e-05 2.572885e-09
## 238 2.642797e-03 2.572885e-09
## 239 2.572885e-09 2.572885e-09
## 240 2.861688e-09 2.572885e-09
## 241 8.953343e-03 2.861688e-09
## 242 4.963308e-08 2.861688e-09
## 243 1.227698e-04 2.861688e-09
## 244 1.850251e-04 2.861688e-09
## 245 2.005731e-03 2.861688e-09
```

```
## 246 7.722328e-07 2.861688e-09
## 247 4.382212e-04 2.861688e-09
## 248 4.127894e-02 2.861688e-09
## 249 1.688916e-03 2.861688e-09
## 250 4.767779e-03 2.861688e-09
## 251 5.551642e-04 2.861688e-09
## 252 8.530158e-07 2.861688e-09
## 253 3.673400e-05 2.861688e-09
## 254 2.642797e-03 2.861688e-09
## 255 2.572885e-09 2.861688e-09
## 256 2.861688e-09 2.861688e-09
```

```
rc$result
```

```
##                            V1                          V2    port_prod
## 1       African/Malagasy clade     African/Malagasy clade 1.000000e+00
## 2                Agathemeridae     African/Malagasy clade 0.000000e+00
## 3            Aschiphasmatinae     African/Malagasy clade 3.275021e-04
## 4   Clitumninae/Pachymorphinae     African/Malagasy clade 9.763066e-03
## 5             Diapheromerinae     African/Malagasy clade 5.359756e-02
## 6              European clade     African/Malagasy clade 0.000000e+00
## 7            Heteropteryginae     African/Malagasy clade 1.407811e-03
## 8               Lanceocercata     African/Malagasy clade 2.382017e-01
## 9                 Lonchodinae     African/Malagasy clade 9.646317e-02
## 10               Necrosciinae     African/Malagasy clade 1.714932e-01
## 11   Palophinae/Cladomorphinae     African/Malagasy clade 1.622733e-02
## 12                Pharnaciini     African/Malagasy clade 2.117387e-05
## 13                 Phylliinae     African/Malagasy clade 0.000000e+00
## 14          Pseudophasmatinae     African/Malagasy clade 5.408692e-03
## 15            Stephanacridini     African/Malagasy clade 9.882564e-08
## 16                Timematinae     African/Malagasy clade 0.000000e+00
## 17      African/Malagasy clade              Agathemeridae 0.000000e+00
## 18               Agathemeridae              Agathemeridae 1.000000e+00
## 19           Aschiphasmatinae              Agathemeridae 0.000000e+00
## 20  Clitumninae/Pachymorphinae              Agathemeridae 0.000000e+00
## 21            Diapheromerinae              Agathemeridae 0.000000e+00
## 22             European clade              Agathemeridae 0.000000e+00
## 23           Heteropteryginae              Agathemeridae 0.000000e+00
## 24              Lanceocercata              Agathemeridae 0.000000e+00
## 25                Lonchodinae              Agathemeridae 0.000000e+00
## 26               Necrosciinae              Agathemeridae 0.000000e+00
## 27   Palophinae/Cladomorphinae              Agathemeridae 0.000000e+00
## 28                Pharnaciini              Agathemeridae 0.000000e+00
## 29                 Phylliinae              Agathemeridae 0.000000e+00
## 30          Pseudophasmatinae              Agathemeridae 0.000000e+00
## 31            Stephanacridini              Agathemeridae 0.000000e+00
## 32                Timematinae              Agathemeridae 0.000000e+00
## 33      African/Malagasy clade          Aschiphasmatinae 2.056023e-02
## 34               Agathemeridae          Aschiphasmatinae 0.000000e+00
## 35           Aschiphasmatinae          Aschiphasmatinae 1.000000e+00
## 36  Clitumninae/Pachymorphinae          Aschiphasmatinae 0.000000e+00
## 37            Diapheromerinae          Aschiphasmatinae 7.943962e-03
## 38             European clade          Aschiphasmatinae 0.000000e+00
## 39           Heteropteryginae          Aschiphasmatinae 7.914129e-03
```

```
## 40               Lanceocercata           Aschiphasmatinae 2.672427e-01
## 41                 Lonchodinae           Aschiphasmatinae 5.320893e-03
## 42                Necrosciinae           Aschiphasmatinae 5.734753e-02
## 43  Palophinae/Cladomorphinae           Aschiphasmatinae 1.176894e-03
## 44                 Pharnaciini           Aschiphasmatinae 0.000000e+00
## 45                  Phylliinae           Aschiphasmatinae 0.000000e+00
## 46          Pseudophasmatinae           Aschiphasmatinae 1.520808e-01
## 47            Stephanacridini           Aschiphasmatinae 0.000000e+00
## 48                Timematinae           Aschiphasmatinae 0.000000e+00
## 49     African/Malagasy clade Clitumninae/Pachymorphinae 4.412046e-01
## 50              Agathemeridae Clitumninae/Pachymorphinae 0.000000e+00
## 51           Aschiphasmatinae Clitumninae/Pachymorphinae 0.000000e+00
## 52 Clitumninae/Pachymorphinae Clitumninae/Pachymorphinae 1.000000e+00
## 53            Diapheromerinae Clitumninae/Pachymorphinae 3.765548e-01
## 54             European clade Clitumninae/Pachymorphinae 2.483243e-05
## 55          Heteropteryginae Clitumninae/Pachymorphinae 0.000000e+00
## 56             Lanceocercata Clitumninae/Pachymorphinae 3.184679e-01
## 57               Lonchodinae Clitumninae/Pachymorphinae 6.143690e-01
## 58              Necrosciinae Clitumninae/Pachymorphinae 2.081693e-01
## 59  Palophinae/Cladomorphinae Clitumninae/Pachymorphinae 1.837032e-02
## 60               Pharnaciini Clitumninae/Pachymorphinae 3.702183e-05
## 61                Phylliinae Clitumninae/Pachymorphinae 0.000000e+00
## 62          Pseudophasmatinae Clitumninae/Pachymorphinae 0.000000e+00
## 63            Stephanacridini Clitumninae/Pachymorphinae 0.000000e+00
## 64                Timematinae Clitumninae/Pachymorphinae 0.000000e+00
## 65     African/Malagasy clade           Diapheromerinae 2.417317e-01
## 66              Agathemeridae           Diapheromerinae 0.000000e+00
## 67           Aschiphasmatinae           Diapheromerinae 2.754138e-04
## 68 Clitumninae/Pachymorphinae           Diapheromerinae 4.029842e-02
## 69            Diapheromerinae           Diapheromerinae 1.000000e+00
## 70             European clade           Diapheromerinae 1.586802e-05
## 71          Heteropteryginae           Diapheromerinae 2.830717e-03
## 72             Lanceocercata           Diapheromerinae 4.064139e-01
## 73               Lonchodinae           Diapheromerinae 1.361778e-01
## 74              Necrosciinae           Diapheromerinae 1.531475e-01
## 75  Palophinae/Cladomorphinae           Diapheromerinae 3.099556e-02
## 76               Pharnaciini           Diapheromerinae 0.000000e+00
## 77                Phylliinae           Diapheromerinae 0.000000e+00
## 78          Pseudophasmatinae           Diapheromerinae 1.642537e-02
## 79            Stephanacridini           Diapheromerinae 2.676573e-07
## 80                Timematinae           Diapheromerinae 0.000000e+00
## 81     African/Malagasy clade            European clade 0.000000e+00
## 82              Agathemeridae            European clade 0.000000e+00
## 83           Aschiphasmatinae            European clade 0.000000e+00
## 84 Clitumninae/Pachymorphinae            European clade 7.994354e-03
## 85            Diapheromerinae            European clade 7.078366e-02
## 86             European clade            European clade 1.000000e+00
## 87          Heteropteryginae            European clade 0.000000e+00
## 88             Lanceocercata            European clade 0.000000e+00
## 89               Lonchodinae            European clade 0.000000e+00
## 90              Necrosciinae            European clade 0.000000e+00
## 91  Palophinae/Cladomorphinae            European clade 0.000000e+00
## 92               Pharnaciini            European clade 0.000000e+00
## 93                Phylliinae            European clade 0.000000e+00
```

```
## 94           Pseudophasmatinae            European clade 0.000000e+00
## 95             Stephanacridini            European clade 0.000000e+00
## 96                 Timematinae            European clade 0.000000e+00
## 97      African/Malagasy clade          Heteropteryginae 3.033358e-02
## 98                Agathemeridae          Heteropteryginae 0.000000e+00
## 99             Aschiphasmatinae          Heteropteryginae 1.603868e-03
## 100 Clitumninae/Pachymorphinae          Heteropteryginae 0.000000e+00
## 101            Diapheromerinae          Heteropteryginae 1.478070e-02
## 102             European clade          Heteropteryginae 0.000000e+00
## 103           Heteropteryginae          Heteropteryginae 1.000000e+00
## 104              Lanceocercata          Heteropteryginae 4.422066e-01
## 105                Lonchodinae          Heteropteryginae 1.238987e-01
## 106               Necrosciinae          Heteropteryginae 4.397350e-02
## 107  Palophinae/Cladomorphinae          Heteropteryginae 4.555807e-02
## 108                Pharnaciini          Heteropteryginae 0.000000e+00
## 109                 Phylliinae          Heteropteryginae 0.000000e+00
## 110          Pseudophasmatinae          Heteropteryginae 1.541589e-02
## 111            Stephanacridini          Heteropteryginae 0.000000e+00
## 112                Timematinae          Heteropteryginae 0.000000e+00
## 113     African/Malagasy clade             Lanceocercata 4.966182e-02
## 114               Agathemeridae             Lanceocercata 0.000000e+00
## 115            Aschiphasmatinae             Lanceocercata 9.062417e-04
## 116 Clitumninae/Pachymorphinae             Lanceocercata 1.598793e-03
## 117            Diapheromerinae             Lanceocercata 2.034120e-02
## 118             European clade             Lanceocercata 0.000000e+00
## 119           Heteropteryginae             Lanceocercata 5.179991e-03
## 120              Lanceocercata             Lanceocercata 1.000000e+00
## 121                Lonchodinae             Lanceocercata 2.146974e-02
## 122               Necrosciinae             Lanceocercata 1.001263e-01
## 123  Palophinae/Cladomorphinae             Lanceocercata 1.335272e-02
## 124                Pharnaciini             Lanceocercata 2.139655e-06
## 125                 Phylliinae             Lanceocercata 0.000000e+00
## 126          Pseudophasmatinae             Lanceocercata 2.560251e-02
## 127            Stephanacridini             Lanceocercata 7.896274e-09
## 128                Timematinae             Lanceocercata 0.000000e+00
## 129     African/Malagasy clade               Lonchodinae 4.241710e-01
## 130               Agathemeridae               Lonchodinae 0.000000e+00
## 131            Aschiphasmatinae               Lonchodinae 2.947715e-04
## 132 Clitumninae/Pachymorphinae               Lonchodinae 6.774484e-02
## 133            Diapheromerinae               Lonchodinae 1.459946e-01
## 134             European clade               Lonchodinae 0.000000e+00
## 135           Heteropteryginae               Lonchodinae 3.223264e-02
## 136              Lanceocercata               Lonchodinae 4.421265e-01
## 137                Lonchodinae               Lonchodinae 1.000000e+00
## 138               Necrosciinae               Lonchodinae 1.917005e-01
## 139  Palophinae/Cladomorphinae               Lonchodinae 6.468927e-02
## 140                Pharnaciini               Lonchodinae 9.699221e-06
## 141                 Phylliinae               Lonchodinae 0.000000e+00
## 142          Pseudophasmatinae               Lonchodinae 0.000000e+00
## 143            Stephanacridini               Lonchodinae 0.000000e+00
## 144                Timematinae               Lonchodinae 0.000000e+00
## 145     African/Malagasy clade              Necrosciinae 2.151400e-01
## 146               Agathemeridae              Necrosciinae 0.000000e+00
## 147            Aschiphasmatinae              Necrosciinae 1.319990e-03
```

```
## 148 Clitumninae/Pachymorphinae              Necrosciinae 8.310035e-03
## 149            Diapheromerinae              Necrosciinae 6.335222e-02
## 150             European clade              Necrosciinae 0.000000e+00
## 151          Heteropteryginae              Necrosciinae 5.241305e-03
## 152             Lanceocercata              Necrosciinae 6.719758e-01
## 153               Lonchodinae              Necrosciinae 6.712249e-02
## 154              Necrosciinae              Necrosciinae 1.000000e+00
## 155  Palophinae/Cladomorphinae              Necrosciinae 2.926076e-02
## 156               Pharnaciini              Necrosciinae 3.304761e-06
## 157                Phylliinae              Necrosciinae 0.000000e+00
## 158         Pseudophasmatinae              Necrosciinae 1.018411e-01
## 159           Stephanacridini              Necrosciinae 0.000000e+00
## 160               Timematinae              Necrosciinae 0.000000e+00
## 161    African/Malagasy clade Palophinae/Cladomorphinae 2.537918e-01
## 162             Agathemeridae Palophinae/Cladomorphinae 0.000000e+00
## 163          Aschiphasmatinae Palophinae/Cladomorphinae 1.836290e-04
## 164 Clitumninae/Pachymorphinae Palophinae/Cladomorphinae 5.747381e-03
## 165            Diapheromerinae Palophinae/Cladomorphinae 1.178798e-01
## 166             European clade Palophinae/Cladomorphinae 0.000000e+00
## 167          Heteropteryginae Palophinae/Cladomorphinae 3.560793e-02
## 168             Lanceocercata Palophinae/Cladomorphinae 8.255467e-01
## 169               Lonchodinae Palophinae/Cladomorphinae 2.064705e-01
## 170              Necrosciinae Palophinae/Cladomorphinae 2.443124e-01
## 171  Palophinae/Cladomorphinae Palophinae/Cladomorphinae 1.000000e+00
## 172               Pharnaciini Palophinae/Cladomorphinae 0.000000e+00
## 173                Phylliinae Palophinae/Cladomorphinae 0.000000e+00
## 174         Pseudophasmatinae Palophinae/Cladomorphinae 1.749771e-02
## 175           Stephanacridini Palophinae/Cladomorphinae 5.311823e-08
## 176               Timematinae Palophinae/Cladomorphinae 0.000000e+00
## 177    African/Malagasy clade               Pharnaciini 3.691901e-01
## 178             Agathemeridae               Pharnaciini 0.000000e+00
## 179          Aschiphasmatinae               Pharnaciini 0.000000e+00
## 180 Clitumninae/Pachymorphinae               Pharnaciini 1.634723e-02
## 181            Diapheromerinae               Pharnaciini 0.000000e+00
## 182             European clade               Pharnaciini 0.000000e+00
## 183          Heteropteryginae               Pharnaciini 0.000000e+00
## 184             Lanceocercata               Pharnaciini 1.695196e-01
## 185               Lonchodinae               Pharnaciini 3.869827e-02
## 186              Necrosciinae               Pharnaciini 3.150878e-02
## 187  Palophinae/Cladomorphinae               Pharnaciini 0.000000e+00
## 188               Pharnaciini               Pharnaciini 1.000000e+00
## 189                Phylliinae               Pharnaciini 0.000000e+00
## 190         Pseudophasmatinae               Pharnaciini 0.000000e+00
## 191           Stephanacridini               Pharnaciini 0.000000e+00
## 192               Timematinae               Pharnaciini 0.000000e+00
## 193    African/Malagasy clade                Phylliinae 0.000000e+00
## 194             Agathemeridae                Phylliinae 0.000000e+00
## 195          Aschiphasmatinae                Phylliinae 0.000000e+00
## 196 Clitumninae/Pachymorphinae                Phylliinae 0.000000e+00
## 197            Diapheromerinae                Phylliinae 0.000000e+00
## 198             European clade                Phylliinae 0.000000e+00
## 199          Heteropteryginae                Phylliinae 0.000000e+00
## 200             Lanceocercata                Phylliinae 0.000000e+00
## 201               Lonchodinae                Phylliinae 0.000000e+00
```

```
## 202               Necrosciinae               Phylliinae 0.000000e+00
## 203  Palophinae/Cladomorphinae               Phylliinae 0.000000e+00
## 204                Pharnaciini               Phylliinae 0.000000e+00
## 205                 Phylliinae               Phylliinae 1.000000e+00
## 206          Pseudophasmatinae               Phylliinae 0.000000e+00
## 207            Stephanacridini               Phylliinae 0.000000e+00
## 208                Timematinae               Phylliinae 0.000000e+00
## 209     African/Malagasy clade          Pseudophasmatinae 2.004219e-02
## 210              Agathemeridae          Pseudophasmatinae 0.000000e+00
## 211           Aschiphasmatinae          Pseudophasmatinae 6.938575e-03
## 212 Clitumninae/Pachymorphinae          Pseudophasmatinae 0.000000e+00
## 213            Diapheromerinae          Pseudophasmatinae 1.528486e-02
## 214             European clade          Pseudophasmatinae 0.000000e+00
## 215           Heteropteryginae          Pseudophasmatinae 3.183924e-03
## 216              Lanceocercata          Pseudophasmatinae 3.404328e-01
## 217                Lonchodinae          Pseudophasmatinae 0.000000e+00
## 218               Necrosciinae          Pseudophasmatinae 1.842550e-01
## 219  Palophinae/Cladomorphinae          Pseudophasmatinae 4.601739e-03
## 220                Pharnaciini          Pseudophasmatinae 0.000000e+00
## 221                 Phylliinae          Pseudophasmatinae 0.000000e+00
## 222          Pseudophasmatinae          Pseudophasmatinae 1.000000e+00
## 223            Stephanacridini          Pseudophasmatinae 0.000000e+00
## 224                Timematinae          Pseudophasmatinae 0.000000e+00
## 225     African/Malagasy clade            Stephanacridini 3.811380e-01
## 226              Agathemeridae            Stephanacridini 0.000000e+00
## 227           Aschiphasmatinae            Stephanacridini 0.000000e+00
## 228 Clitumninae/Pachymorphinae            Stephanacridini 0.000000e+00
## 229            Diapheromerinae            Stephanacridini 2.217445e-01
## 230             European clade            Stephanacridini 0.000000e+00
## 231           Heteropteryginae            Stephanacridini 0.000000e+00
## 232              Lanceocercata            Stephanacridini 2.505661e-01
## 233                Lonchodinae            Stephanacridini 0.000000e+00
## 234               Necrosciinae            Stephanacridini 0.000000e+00
## 235  Palophinae/Cladomorphinae            Stephanacridini 1.971288e-02
## 236                Pharnaciini            Stephanacridini 0.000000e+00
## 237                 Phylliinae            Stephanacridini 0.000000e+00
## 238          Pseudophasmatinae            Stephanacridini 0.000000e+00
## 239            Stephanacridini            Stephanacridini 1.000000e+00
## 240                Timematinae            Stephanacridini 0.000000e+00
## 241     African/Malagasy clade                Timematinae 0.000000e+00
## 242              Agathemeridae                Timematinae 0.000000e+00
## 243           Aschiphasmatinae                Timematinae 0.000000e+00
## 244 Clitumninae/Pachymorphinae                Timematinae 0.000000e+00
## 245            Diapheromerinae                Timematinae 0.000000e+00
## 246             European clade                Timematinae 0.000000e+00
## 247           Heteropteryginae                Timematinae 0.000000e+00
## 248              Lanceocercata                Timematinae 0.000000e+00
## 249                Lonchodinae                Timematinae 0.000000e+00
## 250               Necrosciinae                Timematinae 0.000000e+00
## 251  Palophinae/Cladomorphinae                Timematinae 0.000000e+00
## 252                Pharnaciini                Timematinae 0.000000e+00
## 253                 Phylliinae                Timematinae 0.000000e+00
## 254          Pseudophasmatinae                Timematinae 0.000000e+00
## 255            Stephanacridini                Timematinae 0.000000e+00
```

```
## 256                Timematinae                Timematinae 1.000000e+00
##      port_mean port_gmean  vol_V1_prod vol_V1_mean vol_V1_gmean  vol_V2_prod
## 1   1.00000000 1.00000000 8.953343e-03   0.8719701    0.8489090 8.953343e-03
## 2   0.09565504 0.00000000 4.963308e-08   0.2997245    0.2647680 8.953343e-03
## 3   0.35826539 0.29373149 1.227698e-04   0.6074820    0.5936156 8.953343e-03
## 4   0.51522336 0.50529197 1.850251e-04   0.6339217    0.6076417 8.953343e-03
## 5   0.65173472 0.63371262 2.005731e-03   0.7496253    0.7451235 8.953343e-03
## 6   0.19619718 0.00000000 7.722328e-07   0.4082043    0.3566448 8.953343e-03
## 7   0.52079523 0.28140411 4.382212e-04   0.6769434    0.6571513 8.953343e-03
## 8   0.81067593 0.80604853 4.127894e-02   0.9290058    0.9252524 8.953343e-03
## 9   0.71797742 0.71219998 1.688916e-03   0.7756071    0.7427276 8.953343e-03
## 10  0.76316052 0.76584858 4.767779e-03   0.8081557    0.8007580 8.953343e-03
## 11  0.59318272 0.42573781 5.551642e-04   0.6796223    0.6760241 8.953343e-03
## 12  0.24275438 0.15976768 8.530158e-07   0.4297822    0.3608378 8.953343e-03
## 13  0.18061747 0.00000000 3.673400e-05   0.5327732    0.5279986 8.953343e-03
## 14  0.57368225 0.41393725 2.642797e-03   0.7775782    0.7686443 8.953343e-03
## 15  0.14893707 0.07383753 2.572885e-09   0.2891650    0.1879559 8.953343e-03
## 16  0.04217356 0.00000000 2.861688e-09   0.2030123    0.1903365 8.953343e-03
## 17  0.42399979 0.00000000 8.953343e-03   0.8719701    0.8489090 4.963308e-08
## 18  1.00000000 1.00000000 4.963308e-08   0.2997245    0.2647680 4.963308e-08
## 19  0.78302864 0.00000000 1.227698e-04   0.6074820    0.5936156 4.963308e-08
## 20  0.42312095 0.00000000 1.850251e-04   0.6339217    0.6076417 4.963308e-08
## 21  0.27793721 0.00000000 2.005731e-03   0.7496253    0.7451235 4.963308e-08
## 22  0.13231575 0.00000000 7.722328e-07   0.4082043    0.3566448 4.963308e-08
## 23  0.34425538 0.00000000 4.382212e-04   0.6769434    0.6571513 4.963308e-08
## 24  0.64330618 0.00000000 4.127894e-02   0.9290058    0.9252524 4.963308e-08
## 25  0.38503379 0.00000000 1.688916e-03   0.7756071    0.7427276 4.963308e-08
## 26  0.57353826 0.00000000 4.767779e-03   0.8081557    0.8007580 4.963308e-08
## 27  0.28344468 0.00000000 5.551642e-04   0.6796223    0.6760241 4.963308e-08
## 28  0.26983037 0.00000000 8.530158e-07   0.4297822    0.3608378 4.963308e-08
## 29  0.44372166 0.00000000 3.673400e-05   0.5327732    0.5279986 4.963308e-08
## 30  0.60839403 0.00000000 2.642797e-03   0.7775782    0.7686443 4.963308e-08
## 31  0.34470745 0.00000000 2.572885e-09   0.2891650    0.1879559 4.963308e-08
## 32  0.25516235 0.00000000 2.861688e-09   0.2030123    0.1903365 4.963308e-08
## 33  0.61457914 0.51790487 8.953343e-03   0.8719701    0.8489090 1.227698e-04
## 34  0.28448978 0.00000000 4.963308e-08   0.2997245    0.2647680 1.227698e-04
## 35  1.00000000 1.00000000 1.227698e-04   0.6074820    0.5936156 1.227698e-04
## 36  0.53490405 0.00000000 1.850251e-04   0.6339217    0.6076417 1.227698e-04
## 37  0.53547345 0.25987854 2.005731e-03   0.7496253    0.7451235 1.227698e-04
## 38  0.18869901 0.00000000 7.722328e-07   0.4082043    0.3566448 1.227698e-04
## 39  0.54524989 0.37180675 4.382212e-04   0.6769434    0.6571513 1.227698e-04
## 40  0.79499891 0.72820519 4.127894e-02   0.9290058    0.9252524 1.227698e-04
## 41  0.56988908 0.31858374 1.688916e-03   0.7756071    0.7427276 1.227698e-04
## 42  0.71987038 0.51415133 4.767779e-03   0.8081557    0.8007580 1.227698e-04
## 43  0.35697675 0.25558347 5.551642e-04   0.6796223    0.6760241 1.227698e-04
## 44  0.20904125 0.00000000 8.530158e-07   0.4297822    0.3608378 1.227698e-04
## 45  0.34654904 0.00000000 3.673400e-05   0.5327732    0.5279986 1.227698e-04
## 46  0.79365000 0.70726576 2.642797e-03   0.7775782    0.7686443 1.227698e-04
## 47  0.17081942 0.00000000 2.572885e-09   0.2891650    0.1879559 1.227698e-04
## 48  0.16458961 0.00000000 2.861688e-09   0.2030123    0.1903365 1.227698e-04
## 49  0.86452879 0.84546589 8.953343e-03   0.8719701    0.8489090 1.850251e-04
## 50  0.14730561 0.00000000 4.963308e-08   0.2997245    0.2647680 1.850251e-04
## 51  0.51920183 0.00000000 1.227698e-04   0.6074820    0.5936156 1.850251e-04
## 52  1.00000000 1.00000000 1.850251e-04   0.6339217    0.6076417 1.850251e-04
```

```
## 53  0.83173780 0.84152538 2.005731e-03   0.7496253    0.7451235 1.850251e-04
## 54  0.31174604 0.12664835 7.722328e-07   0.4082043    0.3566448 1.850251e-04
## 55  0.66789358 0.00000000 4.382212e-04   0.6769434    0.6571513 1.850251e-04
## 56  0.82117178 0.79779736 4.127894e-02   0.9290058    0.9252524 1.850251e-04
## 57  0.93230950 0.92801576 1.688916e-03   0.7756071    0.7427276 1.850251e-04
## 58  0.80496576 0.78156374 4.767779e-03   0.8081557    0.8007580 1.850251e-04
## 59  0.60015923 0.36301853 5.551642e-04   0.6796223    0.6760241 1.850251e-04
## 60  0.33459139 0.14942114 8.530158e-07   0.4297822    0.3608378 1.850251e-04
## 61  0.36526830 0.00000000 3.673400e-05   0.5327732    0.5279986 1.850251e-04
## 62  0.73846672 0.00000000 2.642797e-03   0.7775782    0.7686443 1.850251e-04
## 63  0.16606841 0.00000000 2.572885e-09   0.2891650    0.1879559 1.850251e-04
## 64  0.10101288 0.00000000 2.861688e-09   0.2030123    0.1903365 1.850251e-04
## 65  0.80574493 0.78672774 8.953343e-03   0.8719701    0.8489090 2.005731e-03
## 66  0.07241822 0.00000000 4.963308e-08   0.2997245    0.2647680 2.005731e-03
## 67  0.38647235 0.16416728 1.227698e-04   0.6074820    0.5936156 2.005731e-03
## 68  0.64356672 0.62675104 1.850251e-04   0.6339217    0.6076417 2.005731e-03
## 69  1.00000000 1.00000000 2.005731e-03   0.7496253    0.7451235 2.005731e-03
## 70  0.33087842 0.10794184 7.722328e-07   0.4082043    0.3566448 2.005731e-03
## 71  0.60376020 0.18343600 4.382212e-04   0.6769434    0.6571513 2.005731e-03
## 72  0.87818287 0.85852629 4.127894e-02   0.9290058    0.9252524 2.005731e-03
## 73  0.77673786 0.74298898 1.688916e-03   0.7756071    0.7427276 2.005731e-03
## 74  0.76535217 0.75820181 4.767779e-03   0.8081557    0.8007580 2.005731e-03
## 75  0.64951188 0.49216837 5.551642e-04   0.6796223    0.6760241 2.005731e-03
## 76  0.31702570 0.00000000 8.530158e-07   0.4297822    0.3608378 2.005731e-03
## 77  0.27722012 0.00000000 3.673400e-05   0.5327732    0.5279986 2.005731e-03
## 78  0.66514112 0.50319810 2.642797e-03   0.7775782    0.7686443 2.005731e-03
## 79  0.18573180 0.07943700 2.572885e-09   0.2891650    0.1879559 2.005731e-03
## 80  0.04297645 0.00000000 2.861688e-09   0.2030123    0.1903365 2.005731e-03
## 81  0.64533422 0.00000000 8.953343e-03   0.8719701    0.8489090 7.722328e-07
## 82  0.08497548 0.00000000 4.963308e-08   0.2997245    0.2647680 7.722328e-07
## 83  0.36515546 0.00000000 1.227698e-04   0.6074820    0.5936156 7.722328e-07
## 84  0.59768771 0.28552542 1.850251e-04   0.6339217    0.6076417 7.722328e-07
## 85  0.78883298 0.35240351 2.005731e-03   0.7496253    0.7451235 7.722328e-07
## 86  1.00000000 1.00000000 7.722328e-07   0.4082043    0.3566448 7.722328e-07
## 87  0.76497352 0.00000000 4.382212e-04   0.6769434    0.6571513 7.722328e-07
## 88  0.88919034 0.00000000 4.127894e-02   0.9290058    0.9252524 7.722328e-07
## 89  0.68770644 0.00000000 1.688916e-03   0.7756071    0.7427276 7.722328e-07
## 90  0.66178012 0.00000000 4.767779e-03   0.8081557    0.8007580 7.722328e-07
## 91  0.79954453 0.00000000 5.551642e-04   0.6796223    0.6760241 7.722328e-07
## 92  0.22012136 0.00000000 8.530158e-07   0.4297822    0.3608378 7.722328e-07
## 93  0.43010285 0.00000000 3.673400e-05   0.5327732    0.5279986 7.722328e-07
## 94  0.55566232 0.00000000 2.642797e-03   0.7775782    0.7686443 7.722328e-07
## 95  0.19142019 0.00000000 2.572885e-09   0.2891650    0.1879559 7.722328e-07
## 96  0.28419246 0.00000000 2.861688e-09   0.2030123    0.1903365 7.722328e-07
## 97  0.74035865 0.43468585 8.953343e-03   0.8719701    0.8489090 4.382212e-04
## 98  0.09565192 0.00000000 4.963308e-08   0.2997245    0.2647680 4.382212e-04
## 99  0.45321521 0.30725445 1.227698e-04   0.6074820    0.5936156 4.382212e-04
## 100 0.57340016 0.00000000 1.850251e-04   0.6339217    0.6076417 4.382212e-04
## 101 0.70439480 0.23148670 2.005731e-03   0.7496253    0.7451235 4.382212e-04
## 102 0.37022465 0.00000000 7.722328e-07   0.4082043    0.3566448 4.382212e-04
## 103 1.00000000 1.00000000 4.382212e-04   0.6769434    0.6571513 4.382212e-04
## 104 0.89050540 0.78563198 4.127894e-02   0.9290058    0.9252524 4.382212e-04
## 105 0.74460498 0.62598685 1.688916e-03   0.7756071    0.7427276 4.382212e-04
## 106 0.75326830 0.40963520 4.767779e-03   0.8081557    0.8007580 4.382212e-04
```

```
## 107 0.71836109 0.47172529 5.551642e-04   0.6796223    0.6760241 4.382212e-04
## 108 0.21205214 0.00000000 8.530158e-07   0.4297822    0.3608378 4.382212e-04
## 109 0.28073423 0.00000000 3.673400e-05   0.5327732    0.5279986 4.382212e-04
## 110 0.56381171 0.49039377 2.642797e-03   0.7775782    0.7686443 4.382212e-04
## 111 0.14678988 0.00000000 2.572885e-09   0.2891650    0.1879559 4.382212e-04
## 112 0.10021431 0.00000000 2.861688e-09   0.2030123    0.1903365 4.382212e-04
## 113 0.68749707 0.64313083 8.953343e-03   0.8719701    0.8489090 4.127894e-02
## 114 0.10684879 0.00000000 4.963308e-08   0.2997245    0.2647680 4.127894e-02
## 115 0.37724081 0.32751765 1.227698e-04   0.6074820    0.5936156 4.127894e-02
## 116 0.40372926 0.37978880 1.850251e-04   0.6339217    0.6076417 4.127894e-02
## 117 0.57190394 0.55274661 2.005731e-03   0.7496253    0.7451235 4.127894e-02
## 118 0.22522506 0.00000000 7.722328e-07   0.4082043    0.3566448 4.127894e-02
## 119 0.49362989 0.41678233 4.382212e-04   0.6769434    0.6571513 4.127894e-02
## 120 1.00000000 1.00000000 4.127894e-02   0.9290058    0.9252524 4.127894e-02
## 121 0.60525812 0.57240512 1.688916e-03   0.7756071    0.7427276 4.127894e-02
## 122 0.73823901 0.71485396 4.767779e-03   0.8081557    0.8007580 4.127894e-02
## 123 0.54468534 0.53399278 5.551642e-04   0.6796223    0.6760241 4.127894e-02
## 124 0.20215501 0.12562655 8.530158e-07   0.4297822    0.3608378 4.127894e-02
## 125 0.15533517 0.00000000 3.673400e-05   0.5327732    0.5279986 4.127894e-02
## 126 0.61546961 0.58243394 2.642797e-03   0.7775782    0.7686443 4.127894e-02
## 127 0.15239463 0.02571976 2.572885e-09   0.2891650    0.1879559 4.127894e-02
## 128 0.05861035 0.00000000 2.861688e-09   0.2030123    0.1903365 4.127894e-02
## 129 0.85911311 0.86488468 8.953343e-03   0.8719701    0.8489090 1.688916e-03
## 130 0.10014971 0.00000000 4.963308e-08   0.2997245    0.2647680 1.688916e-03
## 131 0.40181388 0.21513715 1.227698e-04   0.6074820    0.5936156 1.688916e-03
## 132 0.67437227 0.67723506 1.850251e-04   0.6339217    0.6076417 1.688916e-03
## 133 0.73637816 0.72896413 2.005731e-03   0.7496253    0.7451235 1.688916e-03
## 134 0.26888913 0.00000000 7.722328e-07   0.4082043    0.3566448 1.688916e-03
## 135 0.63374100 0.51323035 4.382212e-04   0.6769434    0.6571513 1.688916e-03
## 136 0.86727195 0.87100818 4.127894e-02   0.9290058    0.9252524 1.688916e-03
## 137 1.00000000 1.00000000 1.688916e-03   0.7756071    0.7427276 1.688916e-03
## 138 0.77906065 0.77945959 4.767779e-03   0.8081557    0.8007580 1.688916e-03
## 139 0.64724897 0.66713032 5.551642e-04   0.6796223    0.6760241 1.688916e-03
## 140 0.25529330 0.12975580 8.530158e-07   0.4297822    0.3608378 1.688916e-03
## 141 0.24567222 0.00000000 3.673400e-05   0.5327732    0.5279986 1.688916e-03
## 142 0.65574934 0.00000000 2.642797e-03   0.7775782    0.7686443 1.688916e-03
## 143 0.13259606 0.00000000 2.572885e-09   0.2891650    0.1879559 1.688916e-03
## 144 0.05933493 0.00000000 2.861688e-09   0.2030123    0.1903365 1.688916e-03
## 145 0.81401467 0.78931414 8.953343e-03   0.8719701    0.8489090 4.767779e-03
## 146 0.13509521 0.00000000 4.963308e-08   0.2997245    0.2647680 4.767779e-03
## 147 0.43006913 0.30421051 1.227698e-04   0.6074820    0.5936156 4.767779e-03
## 148 0.52128884 0.48671141 1.850251e-04   0.6339217    0.6076417 4.767779e-03
## 149 0.64294468 0.63534350 2.005731e-03   0.7496253    0.7451235 4.767779e-03
## 150 0.21923334 0.00000000 7.722328e-07   0.4082043    0.3566448 4.767779e-03
## 151 0.53057183 0.29777400 4.382212e-04   0.6769434    0.6571513 4.767779e-03
## 152 0.92449207 0.92543341 4.127894e-02   0.9290058    0.9252524 4.767779e-03
## 153 0.70295721 0.66473267 1.688916e-03   0.7756071    0.7427276 4.767779e-03
## 154 1.00000000 1.00000000 4.767779e-03   0.8081557    0.8007580 4.767779e-03
## 155 0.59042519 0.57890695 5.551642e-04   0.6796223    0.6760241 4.767779e-03
## 156 0.22013247 0.12590122 8.530158e-07   0.4297822    0.3608378 4.767779e-03
## 157 0.18717082 0.00000000 3.673400e-05   0.5327732    0.5279986 4.767779e-03
## 158 0.72206146 0.71300354 2.642797e-03   0.7775782    0.7686443 4.767779e-03
## 159 0.16999767 0.00000000 2.572885e-09   0.2891650    0.1879559 4.767779e-03
## 160 0.07497167 0.00000000 2.861688e-09   0.2030123    0.1903365 4.767779e-03
```

```
## 161 0.85659175 0.62666256 8.953343e-03   0.8719701    0.8489090 5.551642e-04
## 162 0.08311792 0.00000000 4.963308e-08   0.2997245    0.2647680 5.551642e-04
## 163 0.29269237 0.20049948 1.227698e-04   0.6074820    0.5936156 5.551642e-04
## 164 0.52368121 0.30747012 1.850251e-04   0.6339217    0.6076417 5.551642e-04
## 165 0.76253546 0.58077919 2.005731e-03   0.7496253    0.7451235 5.551642e-04
## 166 0.39224894 0.00000000 7.722328e-07   0.4082043    0.3566448 5.551642e-04
## 167 0.70600443 0.45289733 4.382212e-04   0.6769434    0.6571513 5.551642e-04
## 168 0.96736915 0.96539672 4.127894e-02   0.9290058    0.9252524 5.551642e-04
## 169 0.77984111 0.79396577 1.688916e-03   0.7756071    0.7427276 5.551642e-04
## 170 0.82805209 0.80502215 4.767779e-03   0.8081557    0.8007580 5.551642e-04
## 171 1.00000000 1.00000000 5.551642e-04   0.6796223    0.6760241 5.551642e-04
## 172 0.25109417 0.00000000 8.530158e-07   0.4297822    0.3608378 5.551642e-04
## 173 0.23928399 0.00000000 3.673400e-05   0.5327732    0.5279986 5.551642e-04
## 174 0.62283249 0.42590247 2.642797e-03   0.7775782    0.7686443 5.551642e-04
## 175 0.16674623 0.04398215 2.572885e-09   0.2891650    0.1879559 5.551642e-04
## 176 0.10282328 0.00000000 2.861688e-09   0.2030123    0.1903365 5.551642e-04
## 177 0.79645883 0.63368905 8.953343e-03   0.8719701    0.8489090 8.530158e-07
## 178 0.20328804 0.00000000 4.963308e-08   0.2997245    0.2647680 8.530158e-07
## 179 0.40247741 0.00000000 1.227698e-04   0.6074820    0.5936156 8.530158e-07
## 180 0.59614565 0.34785016 1.850251e-04   0.6339217    0.6076417 8.530158e-07
## 181 0.70146885 0.00000000 2.005731e-03   0.7496253    0.7451235 8.530158e-07
## 182 0.19495195 0.00000000 7.722328e-07   0.4082043    0.3566448 8.530158e-07
## 183 0.45108355 0.00000000 4.382212e-04   0.6769434    0.6571513 8.530158e-07
## 184 0.76277510 0.60355829 4.127894e-02   0.9290058    0.9252524 8.530158e-07
## 185 0.66434159 0.41156452 1.688916e-03   0.7756071    0.7427276 8.530158e-07
## 186 0.64522171 0.45228801 4.767779e-03   0.8081557    0.8007580 8.530158e-07
## 187 0.50593241 0.00000000 5.551642e-04   0.6796223    0.6760241 8.530158e-07
## 188 1.00000000 1.00000000 8.530158e-07   0.4297822    0.3608378 8.530158e-07
## 189 0.27164700 0.00000000 3.673400e-05   0.5327732    0.5279986 8.530158e-07
## 190 0.50835738 0.00000000 2.642797e-03   0.7775782    0.7686443 8.530158e-07
## 191 0.19754170 0.00000000 2.572885e-09   0.2891650    0.1879559 8.530158e-07
## 192 0.04832299 0.00000000 2.861688e-09   0.2030123    0.1903365 8.530158e-07
## 193 0.38120117 0.00000000 8.953343e-03   0.8719701    0.8489090 3.673400e-05
## 194 0.18699386 0.00000000 4.963308e-08   0.2997245    0.2647680 3.673400e-05
## 195 0.42607617 0.00000000 1.227698e-04   0.6074820    0.5936156 3.673400e-05
## 196 0.48915997 0.00000000 1.850251e-04   0.6339217    0.6076417 3.673400e-05
## 197 0.46722243 0.00000000 2.005731e-03   0.7496253    0.7451235 3.673400e-05
## 198 0.31711227 0.00000000 7.722328e-07   0.4082043    0.3566448 3.673400e-05
## 199 0.40154052 0.00000000 4.382212e-04   0.6769434    0.6571513 3.673400e-05
## 200 0.40987606 0.00000000 4.127894e-02   0.9290058    0.9252524 3.673400e-05
## 201 0.43434253 0.00000000 1.688916e-03   0.7756071    0.7427276 3.673400e-05
## 202 0.38559674 0.00000000 4.767779e-03   0.8081557    0.8007580 3.673400e-05
## 203 0.34840358 0.00000000 5.551642e-04   0.6796223    0.6760241 3.673400e-05
## 204 0.19253977 0.00000000 8.530158e-07   0.4297822    0.3608378 3.673400e-05
## 205 1.00000000 1.00000000 3.673400e-05   0.5327732    0.5279986 3.673400e-05
## 206 0.44270192 0.00000000 2.642797e-03   0.7775782    0.7686443 3.673400e-05
## 207 0.03314362 0.00000000 2.572885e-09   0.2891650    0.1879559 3.673400e-05
## 208 0.18315471 0.00000000 2.861688e-09   0.2030123    0.1903365 3.673400e-05
## 209 0.64990886 0.47896411 8.953343e-03   0.8719701    0.8489090 2.642797e-03
## 210 0.15574178 0.00000000 4.963308e-08   0.2997245    0.2647680 2.642797e-03
## 211 0.53271241 0.45685615 1.227698e-04   0.6074820    0.5936156 2.642797e-03
## 212 0.54446119 0.00000000 1.850251e-04   0.6339217    0.6076417 2.642797e-03
## 213 0.60830138 0.46911436 2.005731e-03   0.7496253    0.7451235 2.642797e-03
## 214 0.20469019 0.00000000 7.722328e-07   0.4082043    0.3566448 2.642797e-03
```

```
## 215 0.45173272 0.37530333 4.382212e-04   0.6769434    0.6571513 2.642797e-03
## 216 0.82691150 0.82345156 4.127894e-02   0.9290058    0.9252524 2.642797e-03
## 217 0.63945650 0.00000000 1.688916e-03   0.7756071    0.7427276 2.642797e-03
## 218 0.78050033 0.77457291 4.767779e-03   0.8081557    0.8007580 2.642797e-03
## 219 0.48807226 0.34486986 5.551642e-04   0.6796223    0.6760241 2.642797e-03
## 220 0.18172291 0.00000000 8.530158e-07   0.4297822    0.3608378 2.642797e-03
## 221 0.24481701 0.00000000 3.673400e-05   0.5327732    0.5279986 2.642797e-03
## 222 1.00000000 1.00000000 2.642797e-03   0.7775782    0.7686443 2.642797e-03
## 223 0.14673465 0.00000000 2.572885e-09   0.2891650    0.1879559 2.642797e-03
## 224 0.09846820 0.00000000 2.861688e-09   0.2030123    0.1903365 2.642797e-03
## 225 0.74140541 0.64652175 8.953343e-03   0.8719701    0.8489090 2.572885e-09
## 226 0.45294328 0.00000000 4.963308e-08   0.2997245    0.2647680 2.572885e-09
## 227 0.46030577 0.00000000 1.227698e-04   0.6074820    0.5936156 2.572885e-09
## 228 0.55585014 0.00000000 1.850251e-04   0.6339217    0.6076417 2.572885e-09
## 229 0.72025291 0.56524277 2.005731e-03   0.7496253    0.7451235 2.572885e-09
## 230 0.30308938 0.00000000 7.722328e-07   0.4082043    0.3566448 2.572885e-09
## 231 0.52987910 0.00000000 4.382212e-04   0.6769434    0.6571513 2.572885e-09
## 232 0.97108214 0.30093175 4.127894e-02   0.9290058    0.9252524 2.572885e-09
## 233 0.59810016 0.00000000 1.688916e-03   0.7756071    0.7427276 2.572885e-09
## 234 0.74839329 0.00000000 4.767779e-03   0.8081557    0.8007580 2.572885e-09
## 235 0.60633058 0.27150565 5.551642e-04   0.6796223    0.6760241 2.572885e-09
## 236 0.31791306 0.00000000 8.530158e-07   0.4297822    0.3608378 2.572885e-09
## 237 0.09498876 0.00000000 3.673400e-05   0.5327732    0.5279986 2.572885e-09
## 238 0.62762097 0.00000000 2.642797e-03   0.7775782    0.7686443 2.572885e-09
## 239 1.00000000 1.00000000 2.572885e-09   0.2891650    0.1879559 2.572885e-09
## 240 0.02816310 0.00000000 2.861688e-09   0.2030123    0.1903365 2.572885e-09
## 241 0.32017518 0.00000000 8.953343e-03   0.8719701    0.8489090 2.861688e-09
## 242 0.33398733 0.00000000 4.963308e-08   0.2997245    0.2647680 2.861688e-09
## 243 0.71708422 0.00000000 1.227698e-04   0.6074820    0.5936156 2.861688e-09
## 244 0.42304777 0.00000000 1.850251e-04   0.6339217    0.6076417 2.861688e-09
## 245 0.28569573 0.00000000 2.005731e-03   0.7496253    0.7451235 2.861688e-09
## 246 0.58685911 0.00000000 7.722328e-07   0.4082043    0.3566448 2.861688e-09
## 247 0.49562410 0.00000000 4.382212e-04   0.6769434    0.6571513 2.861688e-09
## 248 0.54405949 0.00000000 4.127894e-02   0.9290058    0.9252524 2.861688e-09
## 249 0.34198320 0.00000000 1.688916e-03   0.7756071    0.7427276 2.861688e-09
## 250 0.55176550 0.00000000 4.767779e-03   0.8081557    0.8007580 2.861688e-09
## 251 0.51578326 0.00000000 5.551642e-04   0.6796223    0.6760241 2.861688e-09
## 252 0.11608263 0.00000000 8.530158e-07   0.4297822    0.3608378 2.861688e-09
## 253 0.62626694 0.00000000 3.673400e-05   0.5327732    0.5279986 2.861688e-09
## 254 0.60436649 0.00000000 2.642797e-03   0.7775782    0.7686443 2.861688e-09
## 255 0.02883505 0.00000000 2.572885e-09   0.2891650    0.1879559 2.861688e-09
## 256 1.00000000 1.00000000 2.861688e-09   0.2030123    0.1903365 2.861688e-09
##     vol_V2_mean vol_V2_gmean
## 1     0.8719701    0.8489090
## 2     0.8719701    0.8489090
## 3     0.8719701    0.8489090
## 4     0.8719701    0.8489090
## 5     0.8719701    0.8489090
## 6     0.8719701    0.8489090
## 7     0.8719701    0.8489090
## 8     0.8719701    0.8489090
## 9     0.8719701    0.8489090
## 10    0.8719701    0.8489090
## 11    0.8719701    0.8489090
```

```
## 12    0.8719701    0.8489090
## 13    0.8719701    0.8489090
## 14    0.8719701    0.8489090
## 15    0.8719701    0.8489090
## 16    0.8719701    0.8489090
## 17    0.2997245    0.2647680
## 18    0.2997245    0.2647680
## 19    0.2997245    0.2647680
## 20    0.2997245    0.2647680
## 21    0.2997245    0.2647680
## 22    0.2997245    0.2647680
## 23    0.2997245    0.2647680
## 24    0.2997245    0.2647680
## 25    0.2997245    0.2647680
## 26    0.2997245    0.2647680
## 27    0.2997245    0.2647680
## 28    0.2997245    0.2647680
## 29    0.2997245    0.2647680
## 30    0.2997245    0.2647680
## 31    0.2997245    0.2647680
## 32    0.2997245    0.2647680
## 33    0.6074820    0.5936156
## 34    0.6074820    0.5936156
## 35    0.6074820    0.5936156
## 36    0.6074820    0.5936156
## 37    0.6074820    0.5936156
## 38    0.6074820    0.5936156
## 39    0.6074820    0.5936156
## 40    0.6074820    0.5936156
## 41    0.6074820    0.5936156
## 42    0.6074820    0.5936156
## 43    0.6074820    0.5936156
## 44    0.6074820    0.5936156
## 45    0.6074820    0.5936156
## 46    0.6074820    0.5936156
## 47    0.6074820    0.5936156
## 48    0.6074820    0.5936156
## 49    0.6339217    0.6076417
## 50    0.6339217    0.6076417
## 51    0.6339217    0.6076417
## 52    0.6339217    0.6076417
## 53    0.6339217    0.6076417
## 54    0.6339217    0.6076417
## 55    0.6339217    0.6076417
## 56    0.6339217    0.6076417
## 57    0.6339217    0.6076417
## 58    0.6339217    0.6076417
## 59    0.6339217    0.6076417
## 60    0.6339217    0.6076417
## 61    0.6339217    0.6076417
## 62    0.6339217    0.6076417
## 63    0.6339217    0.6076417
## 64    0.6339217    0.6076417
## 65    0.7496253    0.7451235
```

```
## 66    0.7496253    0.7451235
## 67    0.7496253    0.7451235
## 68    0.7496253    0.7451235
## 69    0.7496253    0.7451235
## 70    0.7496253    0.7451235
## 71    0.7496253    0.7451235
## 72    0.7496253    0.7451235
## 73    0.7496253    0.7451235
## 74    0.7496253    0.7451235
## 75    0.7496253    0.7451235
## 76    0.7496253    0.7451235
## 77    0.7496253    0.7451235
## 78    0.7496253    0.7451235
## 79    0.7496253    0.7451235
## 80    0.7496253    0.7451235
## 81    0.4082043    0.3566448
## 82    0.4082043    0.3566448
## 83    0.4082043    0.3566448
## 84    0.4082043    0.3566448
## 85    0.4082043    0.3566448
## 86    0.4082043    0.3566448
## 87    0.4082043    0.3566448
## 88    0.4082043    0.3566448
## 89    0.4082043    0.3566448
## 90    0.4082043    0.3566448
## 91    0.4082043    0.3566448
## 92    0.4082043    0.3566448
## 93    0.4082043    0.3566448
## 94    0.4082043    0.3566448
## 95    0.4082043    0.3566448
## 96    0.4082043    0.3566448
## 97    0.6769434    0.6571513
## 98    0.6769434    0.6571513
## 99    0.6769434    0.6571513
## 100   0.6769434    0.6571513
## 101   0.6769434    0.6571513
## 102   0.6769434    0.6571513
## 103   0.6769434    0.6571513
## 104   0.6769434    0.6571513
## 105   0.6769434    0.6571513
## 106   0.6769434    0.6571513
## 107   0.6769434    0.6571513
## 108   0.6769434    0.6571513
## 109   0.6769434    0.6571513
## 110   0.6769434    0.6571513
## 111   0.6769434    0.6571513
## 112   0.6769434    0.6571513
## 113   0.9290058    0.9252524
## 114   0.9290058    0.9252524
## 115   0.9290058    0.9252524
## 116   0.9290058    0.9252524
## 117   0.9290058    0.9252524
## 118   0.9290058    0.9252524
## 119   0.9290058    0.9252524
```

```
## 120   0.9290058    0.9252524
## 121   0.9290058    0.9252524
## 122   0.9290058    0.9252524
## 123   0.9290058    0.9252524
## 124   0.9290058    0.9252524
## 125   0.9290058    0.9252524
## 126   0.9290058    0.9252524
## 127   0.9290058    0.9252524
## 128   0.9290058    0.9252524
## 129   0.7756071    0.7427276
## 130   0.7756071    0.7427276
## 131   0.7756071    0.7427276
## 132   0.7756071    0.7427276
## 133   0.7756071    0.7427276
## 134   0.7756071    0.7427276
## 135   0.7756071    0.7427276
## 136   0.7756071    0.7427276
## 137   0.7756071    0.7427276
## 138   0.7756071    0.7427276
## 139   0.7756071    0.7427276
## 140   0.7756071    0.7427276
## 141   0.7756071    0.7427276
## 142   0.7756071    0.7427276
## 143   0.7756071    0.7427276
## 144   0.7756071    0.7427276
## 145   0.8081557    0.8007580
## 146   0.8081557    0.8007580
## 147   0.8081557    0.8007580
## 148   0.8081557    0.8007580
## 149   0.8081557    0.8007580
## 150   0.8081557    0.8007580
## 151   0.8081557    0.8007580
## 152   0.8081557    0.8007580
## 153   0.8081557    0.8007580
## 154   0.8081557    0.8007580
## 155   0.8081557    0.8007580
## 156   0.8081557    0.8007580
## 157   0.8081557    0.8007580
## 158   0.8081557    0.8007580
## 159   0.8081557    0.8007580
## 160   0.8081557    0.8007580
## 161   0.6796223    0.6760241
## 162   0.6796223    0.6760241
## 163   0.6796223    0.6760241
## 164   0.6796223    0.6760241
## 165   0.6796223    0.6760241
## 166   0.6796223    0.6760241
## 167   0.6796223    0.6760241
## 168   0.6796223    0.6760241
## 169   0.6796223    0.6760241
## 170   0.6796223    0.6760241
## 171   0.6796223    0.6760241
## 172   0.6796223    0.6760241
## 173   0.6796223    0.6760241
```

```
## 174   0.6796223    0.6760241
## 175   0.6796223    0.6760241
## 176   0.6796223    0.6760241
## 177   0.4297822    0.3608378
## 178   0.4297822    0.3608378
## 179   0.4297822    0.3608378
## 180   0.4297822    0.3608378
## 181   0.4297822    0.3608378
## 182   0.4297822    0.3608378
## 183   0.4297822    0.3608378
## 184   0.4297822    0.3608378
## 185   0.4297822    0.3608378
## 186   0.4297822    0.3608378
## 187   0.4297822    0.3608378
## 188   0.4297822    0.3608378
## 189   0.4297822    0.3608378
## 190   0.4297822    0.3608378
## 191   0.4297822    0.3608378
## 192   0.4297822    0.3608378
## 193   0.5327732    0.5279986
## 194   0.5327732    0.5279986
## 195   0.5327732    0.5279986
## 196   0.5327732    0.5279986
## 197   0.5327732    0.5279986
## 198   0.5327732    0.5279986
## 199   0.5327732    0.5279986
## 200   0.5327732    0.5279986
## 201   0.5327732    0.5279986
## 202   0.5327732    0.5279986
## 203   0.5327732    0.5279986
## 204   0.5327732    0.5279986
## 205   0.5327732    0.5279986
## 206   0.5327732    0.5279986
## 207   0.5327732    0.5279986
## 208   0.5327732    0.5279986
## 209   0.7775782    0.7686443
## 210   0.7775782    0.7686443
## 211   0.7775782    0.7686443
## 212   0.7775782    0.7686443
## 213   0.7775782    0.7686443
## 214   0.7775782    0.7686443
## 215   0.7775782    0.7686443
## 216   0.7775782    0.7686443
## 217   0.7775782    0.7686443
## 218   0.7775782    0.7686443
## 219   0.7775782    0.7686443
## 220   0.7775782    0.7686443
## 221   0.7775782    0.7686443
## 222   0.7775782    0.7686443
## 223   0.7775782    0.7686443
## 224   0.7775782    0.7686443
## 225   0.2891650    0.1879559
## 226   0.2891650    0.1879559
## 227   0.2891650    0.1879559
```

```
## 228   0.2891650    0.1879559
## 229   0.2891650    0.1879559
## 230   0.2891650    0.1879559
## 231   0.2891650    0.1879559
## 232   0.2891650    0.1879559
## 233   0.2891650    0.1879559
## 234   0.2891650    0.1879559
## 235   0.2891650    0.1879559
## 236   0.2891650    0.1879559
## 237   0.2891650    0.1879559
## 238   0.2891650    0.1879559
## 239   0.2891650    0.1879559
## 240   0.2891650    0.1879559
## 241   0.2030123    0.1903365
## 242   0.2030123    0.1903365
## 243   0.2030123    0.1903365
## 244   0.2030123    0.1903365
## 245   0.2030123    0.1903365
## 246   0.2030123    0.1903365
## 247   0.2030123    0.1903365
## 248   0.2030123    0.1903365
## 249   0.2030123    0.1903365
## 250   0.2030123    0.1903365
## 251   0.2030123    0.1903365
## 252   0.2030123    0.1903365
## 253   0.2030123    0.1903365
## 254   0.2030123    0.1903365
## 255   0.2030123    0.1903365
## 256   0.2030123    0.1903365
```

```
result <- rc$result
vol <- as.data.frame(matrix(nrow = 16, ncol = 2))
colnames(vol) <- c("volume", "clade")
vol$clade <- sort(unique(Xrc$clade))
# product
vol[, 1] <- c(result[1:16, 6])
p1 <- ggplot(vol, aes(x = clade, y = volume)) + geom_bar(aes(fill = clade),
    stat = "identity", width = 0.8) + coord_flip() + scale_fill_manual(values = c("yellow",
    "gray", "aquamarine", "lightgreen", "cyan4", "wheat1", "tomato4",
    "tan1", "red", "violet", "steelblue1", "maroon", "forestgreen",
    "darkblue", "slateblue4", "darkred")) + ylab("Full niche hypervolume") +
    xlab("Genetic clade") + coord_flip() + labs(title = "Product") +
    guides(fill = F) + theme_classic()
```

Product

```
vol[, 1] <- c(result[1:16, 7])
p2 <- ggplot(vol, aes(x = clade, y = volume)) + geom_bar(aes(fill = clade),
```

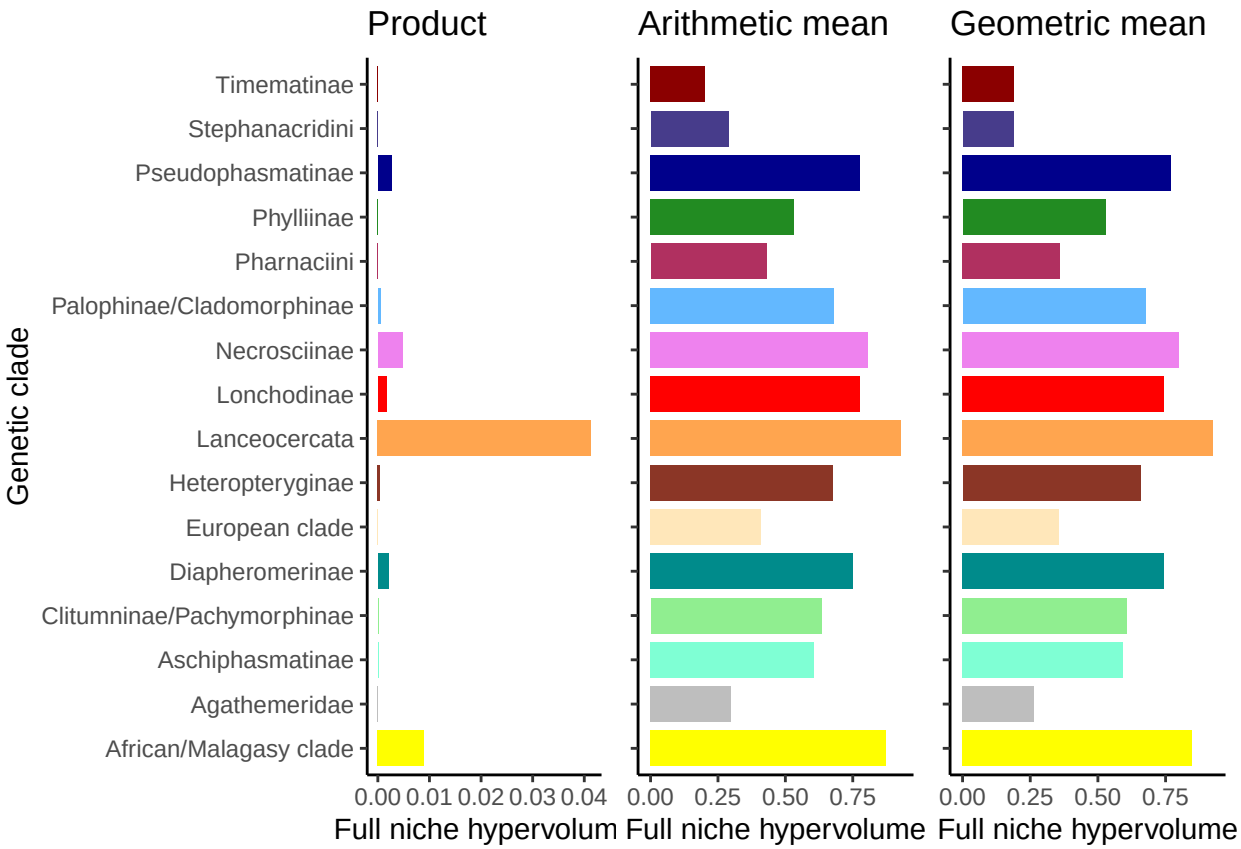
```
    stat = "identity", width = 0.8) + coord_flip() + scale_fill_manual(values = c("yellow",
    "gray", "aquamarine", "lightgreen", "cyan4", "wheat1", "tomato4",
    "tan1", "red", "violet", "steelblue1", "maroon", "forestgreen",
    "darkblue", "slateblue4", "darkred")) + ylab("Full niche hypervolume") +
    coord_flip() + labs(title = "Arithmetic mean") + guides(fill = F) +
    theme_classic() + theme(axis.text.y = element_blank(), axis.title.y = element_blank())
```

Arithmetic mean

```
vol[, 1] <- c(result[1:16, 8])
p3 <- ggplot(vol, aes(x = clade, y = volume)) + geom_bar(aes(fill = clade),
    stat = "identity", width = 0.8) + coord_flip() + scale_fill_manual(values = c("yellow",
    "gray", "aquamarine", "lightgreen", "cyan4", "wheat1", "tomato4",
    "tan1", "red", "violet", "steelblue1", "maroon", "forestgreen",
    "darkblue", "slateblue4", "darkred")) + ylab("Full niche hypervolume") +
    coord_flip() + labs(title = "Geometric mean") + guides(fill = F) +
    theme_classic() + theme(axis.text.y = element_blank(), axis.title.y = element_blank())
```

Geometric mean

```
plot_grid(p1, p2, p3, nrow = 1, rel_widths = (c(2, 1, 1)))
```



Plots

Hypervolume size - Different PCAs

Create datasets

```
# PCAmix - Size corrected
Xrb <- matrix(nrow = length(X$habitat2), ncol = 8)
colnames(Xrb) <- c("habitat", "PC1", "PC2", "PC3", "PC4", "PC5",
    "PC6", "PC7")
Xrb <- as.data.frame(Xrb)
Xrb$habitat <- as.character(X$habitat2)
Xrb$PC1 <- as.numeric(X$pca_mix_dim1)
Xrb$PC2 <- as.numeric(X$pca_mix_dim2)
Xrb$PC3 <- as.numeric(X$pca_mix_dim3)
Xrb$PC4 <- as.numeric(X$pca_mix_dim4)
Xrb$PC5 <- as.numeric(X$pca_mix_dim5)
Xrb$PC6 <- as.numeric(X$pca_mix_dim6)
Xrb$PC7 <- as.numeric(X$pca_mix_dim7)

# Phylogenetic PCA - Size corrected
Xrb2 <- matrix(nrow = length(X$habitat2), ncol = 9)
colnames(Xrb2) <- c("habitat", "PC1", "PC2", "PC3", "PC4", "PC5",
    "PC6", "PC7", "PC8")
Xrb2 <- as.data.frame(Xrb2)
Xrb2$habitat <- as.character(X$habitat2)
```

```
Xrb2$PC1 <- as.numeric(X$pPCA_sizecorr_dim1)
Xrb2$PC2 <- as.numeric(X$pPCA_sizecorr_dim2)
Xrb2$PC3 <- as.numeric(X$pPCA_sizecorr_dim3)
Xrb2$PC4 <- as.numeric(X$pPCA_sizecorr_dim4)
Xrb2$PC5 <- as.numeric(X$pPCA_sizecorr_dim5)
Xrb2$PC6 <- as.numeric(X$pPCA_sizecorr_dim6)
Xrb2$PC7 <- as.numeric(X$pPCA_sizecorr_dim7)
Xrb2$PC8 <- as.numeric(X$pPCA_sizecorr_dim8)

# Phylogenetic PCA - No size correction
Xrb3 <- matrix(nrow = length(X$habitat2), ncol = 7)
colnames(Xrb3) <- c("habitat", "PC1", "PC2", "PC3", "PC4", "PC5",
    "PC6")
Xrb3 <- as.data.frame(Xrb3)
Xrb3$habitat <- as.character(X$habitat2)
Xrb3$PC1 <- as.numeric(X$pPCA_nocorr_dim1)
Xrb3$PC2 <- as.numeric(X$pPCA_nocorr_dim2)
Xrb3$PC3 <- as.numeric(X$pPCA_nocorr_dim3)
Xrb3$PC4 <- as.numeric(X$pPCA_nocorr_dim4)
Xrb3$PC5 <- as.numeric(X$pPCA_nocorr_dim5)
Xrb3$PC6 <- as.numeric(X$pPCA_nocorr_dim6)
```

Using DynRB package

```
rc <- dynRB_VPa(Xrb)
```

```
## [1] 1
## [1] 2
## [1] 3
## [1] 4
## [1] 5
## [1] 6
## [1] 7
## [1] 8
## [1] 9
## [1] 10
## [1] 11
## [1] 12
## [1] 13
## [1] 14
## [1] 15
## [1] 16
## [1] 17
## [1] 18
## [1] 19
## [1] 20
## [1] 21
## [1] 22
## [1] 23
## [1] 24
## [1] 25
```

```
##                                         V1
## 1          hanging from branches and leaves
## 2                          hanging from grass
## 3             laying on branches and leaves
## 4  laying on leaf litter, logs, bark, trunk
## 5                      laying on palm leaves
## 6          hanging from branches and leaves
## 7                          hanging from grass
## 8             laying on branches and leaves
## 9  laying on leaf litter, logs, bark, trunk
## 10                     laying on palm leaves
## 11         hanging from branches and leaves
## 12                         hanging from grass
## 13            laying on branches and leaves
## 14 laying on leaf litter, logs, bark, trunk
## 15                     laying on palm leaves
## 16         hanging from branches and leaves
## 17                         hanging from grass
## 18            laying on branches and leaves
## 19 laying on leaf litter, logs, bark, trunk
## 20                     laying on palm leaves
## 21         hanging from branches and leaves
## 22                         hanging from grass
## 23            laying on branches and leaves
## 24 laying on leaf litter, logs, bark, trunk
## 25                     laying on palm leaves
##                                         V2    port_prod  vol_V1_prod
## 1          hanging from branches and leaves 1.000000e+00 8.026471e-02
## 2          hanging from branches and leaves 2.440322e-05 6.373489e-06
## 3          hanging from branches and leaves 9.552701e-02 2.708696e-02
## 4          hanging from branches and leaves 3.985398e-02 9.275388e-03
## 5          hanging from branches and leaves 0.000000e+00 6.429999e-05
## 6                          hanging from grass 3.411457e-01 8.026471e-02
## 7                          hanging from grass 1.000000e+00 6.373489e-06
## 8                          hanging from grass 5.028213e-02 2.708696e-02
## 9                          hanging from grass 0.000000e+00 9.275388e-03
## 10                         hanging from grass 0.000000e+00 6.429999e-05
## 11            laying on branches and leaves 2.377482e-01 8.026471e-02
## 12            laying on branches and leaves 8.395322e-06 6.373489e-06
## 13            laying on branches and leaves 1.000000e+00 2.708696e-02
## 14            laying on branches and leaves 8.144047e-02 9.275388e-03
## 15            laying on branches and leaves 2.329100e-04 6.429999e-05
## 16 laying on leaf litter, logs, bark, trunk 3.149566e-01 8.026471e-02
## 17 laying on leaf litter, logs, bark, trunk 0.000000e+00 6.373489e-06
## 18 laying on leaf litter, logs, bark, trunk 2.559732e-01 2.708696e-02
## 19 laying on leaf litter, logs, bark, trunk 1.000000e+00 9.275388e-03
## 20 laying on leaf litter, logs, bark, trunk 2.242259e-05 6.429999e-05
## 21                     laying on palm leaves 0.000000e+00 8.026471e-02
## 22                     laying on palm leaves 0.000000e+00 6.373489e-06
## 23                     laying on palm leaves 1.256811e-01 2.708696e-02
## 24                     laying on palm leaves 6.106268e-03 9.275388e-03
## 25                     laying on palm leaves 1.000000e+00 6.429999e-05
##     vol_V2_prod
## 1  8.026471e-02
```

```
## 2  8.026471e-02
## 3  8.026471e-02
## 4  8.026471e-02
## 5  8.026471e-02
## 6  6.373489e-06
## 7  6.373489e-06
## 8  6.373489e-06
## 9  6.373489e-06
## 10 6.373489e-06
## 11 2.708696e-02
## 12 2.708696e-02
## 13 2.708696e-02
## 14 2.708696e-02
## 15 2.708696e-02
## 16 9.275388e-03
## 17 9.275388e-03
## 18 9.275388e-03
## 19 9.275388e-03
## 20 9.275388e-03
## 21 6.429999e-05
## 22 6.429999e-05
## 23 6.429999e-05
## 24 6.429999e-05
## 25 6.429999e-05
```

```
rc$result
```

```
##                                       V1
## 1          hanging from branches and leaves
## 2                        hanging from grass
## 3             laying on branches and leaves
## 4  laying on leaf litter, logs, bark, trunk
## 5                     laying on palm leaves
## 6          hanging from branches and leaves
## 7                        hanging from grass
## 8             laying on branches and leaves
## 9  laying on leaf litter, logs, bark, trunk
## 10                    laying on palm leaves
## 11         hanging from branches and leaves
## 12                       hanging from grass
## 13            laying on branches and leaves
## 14 laying on leaf litter, logs, bark, trunk
## 15                    laying on palm leaves
## 16         hanging from branches and leaves
## 17                       hanging from grass
## 18            laying on branches and leaves
## 19 laying on leaf litter, logs, bark, trunk
## 20                    laying on palm leaves
## 21         hanging from branches and leaves
## 22                       hanging from grass
## 23            laying on branches and leaves
## 24 laying on leaf litter, logs, bark, trunk
## 25                    laying on palm leaves
##                                       V2    port_prod port_mean port_gmean
```

```
## 1          hanging from branches and leaves 1.000000e+00 1.0000000 1.00000000
## 2          hanging from branches and leaves 2.440322e-05 0.2785816 0.13636491
## 3          hanging from branches and leaves 9.552701e-02 0.7055622 0.68074627
## 4          hanging from branches and leaves 3.985398e-02 0.6805866 0.56350439
## 5          hanging from branches and leaves 0.000000e+00 0.3491063 0.00000000
## 6                       hanging from grass 3.411457e-01 0.8905466 0.52079172
## 7                       hanging from grass 1.000000e+00 1.0000000 1.00000000
## 8                       hanging from grass 5.028213e-02 0.6071049 0.38025652
## 9                       hanging from grass 0.000000e+00 0.7916137 0.00000000
## 10                      hanging from grass 0.000000e+00 0.4176534 0.00000000
## 11           laying on branches and leaves 2.377482e-01 0.7929074 0.76188259
## 12           laying on branches and leaves 8.395322e-06 0.2022186 0.11357210
## 13           laying on branches and leaves 1.000000e+00 1.0000000 1.00000000
## 14           laying on branches and leaves 8.144047e-02 0.6704278 0.66073281
## 15           laying on branches and leaves 2.329100e-04 0.3734930 0.18744212
## 16 laying on leaf litter, logs, bark, trunk 3.149566e-01 0.8730048 0.75080560
## 17 laying on leaf litter, logs, bark, trunk 0.000000e+00 0.3390452 0.00000000
## 18 laying on leaf litter, logs, bark, trunk 2.559732e-01 0.7884876 0.78182337
## 19 laying on leaf litter, logs, bark, trunk 1.000000e+00 1.0000000 1.00000000
## 20 laying on leaf litter, logs, bark, trunk 2.242259e-05 0.3216908 0.07940308
## 21                    laying on palm leaves 0.000000e+00 0.8509387 0.00000000
## 22                    laying on palm leaves 0.000000e+00 0.3071580 0.00000000
## 23                    laying on palm leaves 1.256811e-01 0.8178359 0.44802457
## 24                    laying on palm leaves 6.106268e-03 0.5905056 0.17040009
## 25                    laying on palm leaves 1.000000e+00 1.0000000 1.00000000
##     vol_V1_prod vol_V1_mean vol_V1_gmean  vol_V2_prod vol_V2_mean vol_V2_gmean
## 1  8.026471e-02   0.9664312    0.9626571 8.026471e-02   0.9664312    0.9626571
## 2  6.373489e-06   0.4744041    0.4397935 8.026471e-02   0.9664312    0.9626571
## 3  2.708696e-02   0.9111737    0.9103507 8.026471e-02   0.9664312    0.9626571
## 4  9.275388e-03   0.8471250    0.8335036 8.026471e-02   0.9664312    0.9626571
## 5  6.429999e-05   0.5704378    0.5544605 8.026471e-02   0.9664312    0.9626571
## 6  8.026471e-02   0.9664312    0.9626571 6.373489e-06   0.4744041    0.4397935
## 7  6.373489e-06   0.4744041    0.4397935 6.373489e-06   0.4744041    0.4397935
## 8  2.708696e-02   0.9111737    0.9103507 6.373489e-06   0.4744041    0.4397935
## 9  9.275388e-03   0.8471250    0.8335036 6.373489e-06   0.4744041    0.4397935
## 10 6.429999e-05   0.5704378    0.5544605 6.373489e-06   0.4744041    0.4397935
## 11 8.026471e-02   0.9664312    0.9626571 2.708696e-02   0.9111737    0.9103507
## 12 6.373489e-06   0.4744041    0.4397935 2.708696e-02   0.9111737    0.9103507
## 13 2.708696e-02   0.9111737    0.9103507 2.708696e-02   0.9111737    0.9103507
## 14 9.275388e-03   0.8471250    0.8335036 2.708696e-02   0.9111737    0.9103507
## 15 6.429999e-05   0.5704378    0.5544605 2.708696e-02   0.9111737    0.9103507
## 16 8.026471e-02   0.9664312    0.9626571 9.275388e-03   0.8471250    0.8335036
## 17 6.373489e-06   0.4744041    0.4397935 9.275388e-03   0.8471250    0.8335036
## 18 2.708696e-02   0.9111737    0.9103507 9.275388e-03   0.8471250    0.8335036
## 19 9.275388e-03   0.8471250    0.8335036 9.275388e-03   0.8471250    0.8335036
## 20 6.429999e-05   0.5704378    0.5544605 9.275388e-03   0.8471250    0.8335036
## 21 8.026471e-02   0.9664312    0.9626571 6.429999e-05   0.5704378    0.5544605
## 22 6.373489e-06   0.4744041    0.4397935 6.429999e-05   0.5704378    0.5544605
## 23 2.708696e-02   0.9111737    0.9103507 6.429999e-05   0.5704378    0.5544605
## 24 9.275388e-03   0.8471250    0.8335036 6.429999e-05   0.5704378    0.5544605
## 25 6.429999e-05   0.5704378    0.5544605 6.429999e-05   0.5704378    0.5544605
```

```
rc2 <- dynRB_VPa(Xrb2)
```

```
## [1] 1
## [1] 2
## [1] 3
## [1] 4
## [1] 5
## [1] 6
## [1] 7
## [1] 8
## [1] 9
## [1] 10
## [1] 11
## [1] 12
## [1] 13
## [1] 14
## [1] 15
## [1] 16
## [1] 17
## [1] 18
## [1] 19
## [1] 20
## [1] 21
## [1] 22
## [1] 23
## [1] 24
## [1] 25
##                                         V1
## 1          hanging from branches and leaves
## 2                          hanging from grass
## 3             laying on branches and leaves
## 4  laying on leaf litter, logs, bark, trunk
## 5                       laying on palm leaves
## 6          hanging from branches and leaves
## 7                          hanging from grass
## 8             laying on branches and leaves
## 9  laying on leaf litter, logs, bark, trunk
## 10                      laying on palm leaves
## 11         hanging from branches and leaves
## 12                         hanging from grass
## 13            laying on branches and leaves
## 14 laying on leaf litter, logs, bark, trunk
## 15                      laying on palm leaves
## 16         hanging from branches and leaves
## 17                         hanging from grass
## 18            laying on branches and leaves
## 19 laying on leaf litter, logs, bark, trunk
## 20                      laying on palm leaves
## 21         hanging from branches and leaves
## 22                         hanging from grass
## 23            laying on branches and leaves
## 24 laying on leaf litter, logs, bark, trunk
## 25                      laying on palm leaves
##                                         V2    port_prod  vol_V1_prod
## 1          hanging from branches and leaves 1.000000e+00 8.877607e-02
## 2          hanging from branches and leaves 1.382038e-05 5.543901e-06
```

```
## 3          hanging from branches and leaves 1.923441e-02 6.701998e-03
## 4          hanging from branches and leaves 1.696952e-02 5.606689e-03
## 5          hanging from branches and leaves 2.304337e-04 4.538380e-05
## 6                       hanging from grass 1.875653e-01 8.877607e-02
## 7                       hanging from grass 1.000000e+00 5.543901e-06
## 8                       hanging from grass 4.870423e-02 6.701998e-03
## 9                       hanging from grass 0.000000e+00 5.606689e-03
## 10                      hanging from grass 0.000000e+00 4.538380e-05
## 11            laying on branches and leaves 2.408277e-01 8.877607e-02
## 12            laying on branches and leaves 2.766688e-05 5.543901e-06
## 13            laying on branches and leaves 1.000000e+00 6.701998e-03
## 14            laying on branches and leaves 8.185961e-02 5.606689e-03
## 15            laying on branches and leaves 0.000000e+00 4.538380e-05
## 16 laying on leaf litter, logs, bark, trunk 3.121606e-01 8.877607e-02
## 17 laying on leaf litter, logs, bark, trunk 0.000000e+00 5.543901e-06
## 18 laying on leaf litter, logs, bark, trunk 1.170634e-01 6.701998e-03
## 19 laying on leaf litter, logs, bark, trunk 1.000000e+00 5.606689e-03
## 20 laying on leaf litter, logs, bark, trunk 2.701403e-04 4.538380e-05
## 21                    laying on palm leaves 3.318853e-01 8.877607e-02
## 22                    laying on palm leaves 0.000000e+00 5.543901e-06
## 23                    laying on palm leaves 0.000000e+00 6.701998e-03
## 24                    laying on palm leaves 3.877847e-02 5.606689e-03
## 25                    laying on palm leaves 1.000000e+00 4.538380e-05
##     vol_V2_prod
## 1  8.877607e-02
## 2  8.877607e-02
## 3  8.877607e-02
## 4  8.877607e-02
## 5  8.877607e-02
## 6  5.543901e-06
## 7  5.543901e-06
## 8  5.543901e-06
## 9  5.543901e-06
## 10 5.543901e-06
## 11 6.701998e-03
## 12 6.701998e-03
## 13 6.701998e-03
## 14 6.701998e-03
## 15 6.701998e-03
## 16 5.606689e-03
## 17 5.606689e-03
## 18 5.606689e-03
## 19 5.606689e-03
## 20 5.606689e-03
## 21 4.538380e-05
## 22 4.538380e-05
## 23 4.538380e-05
## 24 4.538380e-05
## 25 4.538380e-05
```

```
rc2$result
```

```
##                                         V1
## 1          hanging from branches and leaves
```

```
## 2                        hanging from grass
## 3             laying on branches and leaves
## 4  laying on leaf litter, logs, bark, trunk
## 5                      laying on palm leaves
## 6           hanging from branches and leaves
## 7                        hanging from grass
## 8             laying on branches and leaves
## 9  laying on leaf litter, logs, bark, trunk
## 10                     laying on palm leaves
## 11          hanging from branches and leaves
## 12                       hanging from grass
## 13            laying on branches and leaves
## 14 laying on leaf litter, logs, bark, trunk
## 15                     laying on palm leaves
## 16          hanging from branches and leaves
## 17                       hanging from grass
## 18            laying on branches and leaves
## 19 laying on leaf litter, logs, bark, trunk
## 20                     laying on palm leaves
## 21          hanging from branches and leaves
## 22                       hanging from grass
## 23            laying on branches and leaves
## 24 laying on leaf litter, logs, bark, trunk
## 25                     laying on palm leaves
##                                         V2    port_prod port_mean port_gmean
## 1           hanging from branches and leaves 1.000000e+00 1.0000000  1.0000000
## 2           hanging from branches and leaves 1.382038e-05 0.2564344  0.2272034
## 3           hanging from branches and leaves 1.923441e-02 0.6055165  0.5974303
## 4           hanging from branches and leaves 1.696952e-02 0.6202517  0.5540875
## 5           hanging from branches and leaves 2.304337e-04 0.3904977  0.3413156
## 6                        hanging from grass 1.875653e-01 0.7827245  0.7212464
## 7                        hanging from grass 1.000000e+00 1.0000000  1.0000000
## 8                        hanging from grass 4.870423e-02 0.6666597  0.4102019
## 9                        hanging from grass 0.000000e+00 0.5909686  0.0000000
## 10                       hanging from grass 0.000000e+00 0.3781358  0.0000000
## 11            laying on branches and leaves 2.408277e-01 0.8020534  0.8055643
## 12            laying on branches and leaves 2.766688e-05 0.2937828  0.1675191
## 13            laying on branches and leaves 1.000000e+00 1.0000000  1.0000000
## 14            laying on branches and leaves 8.185961e-02 0.7000857  0.7069830
## 15            laying on branches and leaves 0.000000e+00 0.4302223  0.0000000
## 16 laying on leaf litter, logs, bark, trunk 3.121606e-01 0.8620425  0.7963066
## 17 laying on leaf litter, logs, bark, trunk 0.000000e+00 0.2665596  0.0000000
## 18 laying on leaf litter, logs, bark, trunk 1.170634e-01 0.7402571  0.7487617
## 19 laying on leaf litter, logs, bark, trunk 1.000000e+00 1.0000000  1.0000000
## 20 laying on leaf litter, logs, bark, trunk 2.701403e-04 0.4792061  0.2312780
## 21                     laying on palm leaves 3.318853e-01 0.8460962  0.8289590
## 22                     laying on palm leaves 0.000000e+00 0.2772102  0.0000000
## 23                     laying on palm leaves 0.000000e+00 0.6999329  0.0000000
## 24                     laying on palm leaves 3.877847e-02 0.7564975  0.4149414
## 25                     laying on palm leaves 1.000000e+00 1.0000000  1.0000000
##     vol_V1_prod vol_V1_mean vol_V1_gmean  vol_V2_prod vol_V2_mean vol_V2_gmean
## 1  8.877607e-02   0.9791447    0.9778563 8.877607e-02   0.9791447    0.9778563
## 2  5.543901e-06   0.5211603    0.5146444 8.877607e-02   0.9791447    0.9778563
## 3  6.701998e-03   0.8751410    0.8631182 8.877607e-02   0.9791447    0.9778563
```

```
## 4  5.606689e-03   0.8616857    0.8449887 8.877607e-02   0.9791447    0.9778563
## 5  4.538380e-05   0.6545858    0.6121191 8.877607e-02   0.9791447    0.9778563
## 6  8.877607e-02   0.9791447    0.9778563 5.543901e-06   0.5211603    0.5146444
## 7  5.543901e-06   0.5211603    0.5146444 5.543901e-06   0.5211603    0.5146444
## 8  6.701998e-03   0.8751410    0.8631182 5.543901e-06   0.5211603    0.5146444
## 9  5.606689e-03   0.8616857    0.8449887 5.543901e-06   0.5211603    0.5146444
## 10 4.538380e-05   0.6545858    0.6121191 5.543901e-06   0.5211603    0.5146444
## 11 8.877607e-02   0.9791447    0.9778563 6.701998e-03   0.8751410    0.8631182
## 12 5.543901e-06   0.5211603    0.5146444 6.701998e-03   0.8751410    0.8631182
## 13 6.701998e-03   0.8751410    0.8631182 6.701998e-03   0.8751410    0.8631182
## 14 5.606689e-03   0.8616857    0.8449887 6.701998e-03   0.8751410    0.8631182
## 15 4.538380e-05   0.6545858    0.6121191 6.701998e-03   0.8751410    0.8631182
## 16 8.877607e-02   0.9791447    0.9778563 5.606689e-03   0.8616857    0.8449887
## 17 5.543901e-06   0.5211603    0.5146444 5.606689e-03   0.8616857    0.8449887
## 18 6.701998e-03   0.8751410    0.8631182 5.606689e-03   0.8616857    0.8449887
## 19 5.606689e-03   0.8616857    0.8449887 5.606689e-03   0.8616857    0.8449887
## 20 4.538380e-05   0.6545858    0.6121191 5.606689e-03   0.8616857    0.8449887
## 21 8.877607e-02   0.9791447    0.9778563 4.538380e-05   0.6545858    0.6121191
## 22 5.543901e-06   0.5211603    0.5146444 4.538380e-05   0.6545858    0.6121191
## 23 6.701998e-03   0.8751410    0.8631182 4.538380e-05   0.6545858    0.6121191
## 24 5.606689e-03   0.8616857    0.8449887 4.538380e-05   0.6545858    0.6121191
## 25 4.538380e-05   0.6545858    0.6121191 4.538380e-05   0.6545858    0.6121191
```

```
rc3 <- dynRB_VPa(Xrb3)
```

```
## [1] 1
## [1] 2
## [1] 3
## [1] 4
## [1] 5
## [1] 6
## [1] 7
## [1] 8
## [1] 9
## [1] 10
## [1] 11
## [1] 12
## [1] 13
## [1] 14
## [1] 15
## [1] 16
## [1] 17
## [1] 18
## [1] 19
## [1] 20
## [1] 21
## [1] 22
## [1] 23
## [1] 24
## [1] 25
##                                       V1
## 1          hanging from branches and leaves
## 2                       hanging from grass
## 3             laying on branches and leaves
```

```
## 4  laying on leaf litter, logs, bark, trunk
## 5                      laying on palm leaves
## 6           hanging from branches and leaves
## 7                          hanging from grass
## 8              laying on branches and leaves
## 9  laying on leaf litter, logs, bark, trunk
## 10                     laying on palm leaves
## 11          hanging from branches and leaves
## 12                         hanging from grass
## 13             laying on branches and leaves
## 14 laying on leaf litter, logs, bark, trunk
## 15                     laying on palm leaves
## 16          hanging from branches and leaves
## 17                         hanging from grass
## 18             laying on branches and leaves
## 19 laying on leaf litter, logs, bark, trunk
## 20                     laying on palm leaves
## 21          hanging from branches and leaves
## 22                         hanging from grass
## 23             laying on branches and leaves
## 24 laying on leaf litter, logs, bark, trunk
## 25                     laying on palm leaves
##                                         V2    port_prod  vol_V1_prod
## 1           hanging from branches and leaves 1.000000e+00 0.1598451684
## 2           hanging from branches and leaves 1.681771e-04 0.0001222903
## 3           hanging from branches and leaves 3.748854e-02 0.0240751823
## 4           hanging from branches and leaves 1.658536e-02 0.0092887460
## 5           hanging from branches and leaves 2.585288e-03 0.0005412556
## 6                          hanging from grass 2.455953e-01 0.1598451684
## 7                          hanging from grass 1.000000e+00 0.0001222903
## 8                          hanging from grass 7.442070e-02 0.0240751823
## 9                          hanging from grass 7.164497e-04 0.0092887460
## 10                         hanging from grass 0.000000e+00 0.0005412556
## 11             laying on branches and leaves 2.251331e-01 0.1598451684
## 12             laying on branches and leaves 3.220762e-04 0.0001222903
## 13             laying on branches and leaves 1.000000e+00 0.0240751823
## 14             laying on branches and leaves 1.396384e-01 0.0092887460
## 15             laying on branches and leaves 3.227660e-03 0.0005412556
## 16 laying on leaf litter, logs, bark, trunk 2.712031e-01 0.1598451684
## 17 laying on leaf litter, logs, bark, trunk 6.065730e-06 0.0001222903
## 18 laying on leaf litter, logs, bark, trunk 3.639053e-01 0.0240751823
## 19 laying on leaf litter, logs, bark, trunk 1.000000e+00 0.0092887460
## 20 laying on leaf litter, logs, bark, trunk 2.761694e-04 0.0005412556
## 21                     laying on palm leaves 5.878160e-01 0.1598451684
## 22                     laying on palm leaves 0.000000e+00 0.0001222903
## 23                     laying on palm leaves 1.751566e-01 0.0240751823
## 24                     laying on palm leaves 8.466414e-03 0.0092887460
## 25                     laying on palm leaves 1.000000e+00 0.0005412556
##     vol_V2_prod
## 1  0.1598451684
## 2  0.1598451684
## 3  0.1598451684
## 4  0.1598451684
## 5  0.1598451684
```

```
## 6  0.0001222903
## 7  0.0001222903
## 8  0.0001222903
## 9  0.0001222903
## 10 0.0001222903
## 11 0.0240751823
## 12 0.0240751823
## 13 0.0240751823
## 14 0.0240751823
## 15 0.0240751823
## 16 0.0092887460
## 17 0.0092887460
## 18 0.0092887460
## 19 0.0092887460
## 20 0.0092887460
## 21 0.0005412556
## 22 0.0005412556
## 23 0.0005412556
## 24 0.0005412556
## 25 0.0005412556
```

```
rc3$result
```

```
##                                         V1
## 1          hanging from branches and leaves
## 2                        hanging from grass
## 3             laying on branches and leaves
## 4  laying on leaf litter, logs, bark, trunk
## 5                      laying on palm leaves
## 6          hanging from branches and leaves
## 7                        hanging from grass
## 8             laying on branches and leaves
## 9  laying on leaf litter, logs, bark, trunk
## 10                     laying on palm leaves
## 11         hanging from branches and leaves
## 12                       hanging from grass
## 13            laying on branches and leaves
## 14 laying on leaf litter, logs, bark, trunk
## 15                     laying on palm leaves
## 16         hanging from branches and leaves
## 17                       hanging from grass
## 18            laying on branches and leaves
## 19 laying on leaf litter, logs, bark, trunk
## 20                     laying on palm leaves
## 21         hanging from branches and leaves
## 22                       hanging from grass
## 23            laying on branches and leaves
## 24 laying on leaf litter, logs, bark, trunk
## 25                     laying on palm leaves
##                                         V2    port_prod port_mean port_gmean
## 1          hanging from branches and leaves 1.000000e+00 1.0000000 1.00000000
## 2          hanging from branches and leaves 1.681771e-04 0.2644282 0.17585220
## 3          hanging from branches and leaves 3.748854e-02 0.5902280 0.55012460
## 4          hanging from branches and leaves 1.658536e-02 0.5395237 0.44322494
```

```
## 5          hanging from branches and leaves 2.585288e-03 0.4302638 0.35592400
## 6                        hanging from grass 2.455953e-01 0.7770595 0.57382187
## 7                        hanging from grass 1.000000e+00 1.0000000 1.00000000
## 8                        hanging from grass 7.442070e-02 0.5338428 0.45632362
## 9                        hanging from grass 7.164497e-04 0.3707744 0.09240878
## 10                       hanging from grass 0.000000e+00 0.5122723 0.00000000
## 11           laying on branches and leaves 2.251331e-01 0.7623472 0.72675461
## 12           laying on branches and leaves 3.220762e-04 0.2323698 0.18875065
## 13           laying on branches and leaves 1.000000e+00 1.0000000 1.00000000
## 14           laying on branches and leaves 1.396384e-01 0.7018413 0.70004036
## 15           laying on branches and leaves 3.227660e-03 0.4348383 0.34078969
## 16 laying on leaf litter, logs, bark, trunk 2.712031e-01 0.8020086 0.69366503
## 17 laying on leaf litter, logs, bark, trunk 6.065730e-06 0.1883817 0.04213101
## 18 laying on leaf litter, logs, bark, trunk 3.639053e-01 0.8256921 0.82582207
## 19 laying on leaf litter, logs, bark, trunk 1.000000e+00 1.0000000 1.00000000
## 20 laying on leaf litter, logs, bark, trunk 2.761694e-04 0.4269285 0.09729556
## 21                    laying on palm leaves 5.878160e-01 0.9281819 0.85773836
## 22                    laying on palm leaves 0.000000e+00 0.4123846 0.00000000
## 23                    laying on palm leaves 1.751566e-01 0.7537908 0.63674571
## 24                    laying on palm leaves 8.466414e-03 0.6269661 0.16974714
## 25                    laying on palm leaves 1.000000e+00 1.0000000 1.00000000
##     vol_V1_prod vol_V1_mean vol_V1_gmean  vol_V2_prod vol_V2_mean vol_V2_gmean
## 1  0.1598451684   0.9825744    0.9814757 0.1598451684   0.9825744    0.9814757
## 2  0.0001222903   0.5218075    0.5039255 0.1598451684   0.9825744    0.9814757
## 3  0.0240751823   0.8735418    0.8677168 0.1598451684   0.9825744    0.9814757
## 4  0.0092887460   0.8183300    0.7917287 0.1598451684   0.9825744    0.9814757
## 5  0.0005412556   0.6320294    0.5979652 0.1598451684   0.9825744    0.9814757
## 6  0.1598451684   0.9825744    0.9814757 0.0001222903   0.5218075    0.5039255
## 7  0.0001222903   0.5218075    0.5039255 0.0001222903   0.5218075    0.5039255
## 8  0.0240751823   0.8735418    0.8677168 0.0001222903   0.5218075    0.5039255
## 9  0.0092887460   0.8183300    0.7917287 0.0001222903   0.5218075    0.5039255
## 10 0.0005412556   0.6320294    0.5979652 0.0001222903   0.5218075    0.5039255
## 11 0.1598451684   0.9825744    0.9814757 0.0240751823   0.8735418    0.8677168
## 12 0.0001222903   0.5218075    0.5039255 0.0240751823   0.8735418    0.8677168
## 13 0.0240751823   0.8735418    0.8677168 0.0240751823   0.8735418    0.8677168
## 14 0.0092887460   0.8183300    0.7917287 0.0240751823   0.8735418    0.8677168
## 15 0.0005412556   0.6320294    0.5979652 0.0240751823   0.8735418    0.8677168
## 16 0.1598451684   0.9825744    0.9814757 0.0092887460   0.8183300    0.7917287
## 17 0.0001222903   0.5218075    0.5039255 0.0092887460   0.8183300    0.7917287
## 18 0.0240751823   0.8735418    0.8677168 0.0092887460   0.8183300    0.7917287
## 19 0.0092887460   0.8183300    0.7917287 0.0092887460   0.8183300    0.7917287
## 20 0.0005412556   0.6320294    0.5979652 0.0092887460   0.8183300    0.7917287
## 21 0.1598451684   0.9825744    0.9814757 0.0005412556   0.6320294    0.5979652
## 22 0.0001222903   0.5218075    0.5039255 0.0005412556   0.6320294    0.5979652
## 23 0.0240751823   0.8735418    0.8677168 0.0005412556   0.6320294    0.5979652
## 24 0.0092887460   0.8183300    0.7917287 0.0005412556   0.6320294    0.5979652
## 25 0.0005412556   0.6320294    0.5979652 0.0005412556   0.6320294    0.5979652
```

```
result1 <- rc$result
result2 <- rc2$result
result3 <- rc3$result

vol <- as.data.frame(matrix(nrow = 5, ncol = 2))
colnames(vol) <- c("volume", "habitat")
```

```
vol$habitat <- c("hanging from branches and leaves", "hanging from grass",
    "laying on branches and leaves", "laying on leaf litter, logs, bark, trunk",
    "laying on palm leaves")

vol1 <- vol
vol2 <- vol
vol3 <- vol

# product
vol1[, 1] <- c(result1[1:5, 6])
vol2[, 1] <- c(result2[1:5, 6])
vol3[, 1] <- c(result3[1:5, 6])

pl1 <- ggplot(vol1, aes(x = habitat, y = volume)) + geom_bar(aes(fill = habitat),
    stat = "identity", width = 0.8) + scale_fill_manual(values = c("darkseagreen",
    "gold", "darkorange", "darkred", "dodgerblue")) + ylab("Niche hypervolume size") +
    # xlab('')+
coord_cartesian(ylim = c(-1e-04, 0.1)) + labs(title = "Mixed PCA - Size correction",
    subtitle = "Dynamic range boxes - Product") + scale_x_discrete(labels = NULL,
    breaks = NULL) + guides(fill = F) + theme_classic()

pl2 <- ggplot(vol2, aes(x = habitat, y = volume)) + geom_bar(aes(fill = habitat),
    stat = "identity", width = 0.8) + scale_fill_manual(values = c("darkseagreen",
    "gold", "darkorange", "darkred", "dodgerblue")) + ylab("Niche hypervolume size") +
    # xlab('')+
coord_cartesian(ylim = c(-1e-04, 0.1)) + labs(title = "Phylogenetic PCA - Size correction",
    subtitle = "Dynamic range boxes - Product") + scale_x_discrete(labels = NULL,
    breaks = NULL) + guides(fill = F) + theme_classic()

pl3 <- ggplot(vol3, aes(x = habitat, y = volume)) + geom_bar(aes(fill = habitat),
    stat = "identity", width = 0.8) + scale_fill_manual(values = c("darkseagreen",
    "gold", "darkorange", "darkred", "dodgerblue")) + ylab("Niche hypervolume size") +
    # xlab('')+
coord_cartesian(ylim = c(-1e-04, 0.1)) + labs(title = "Phylogenetic PCA - No size correction",
    subtitle = "Dynamic range boxes - Product") + scale_x_discrete(labels = NULL,
    breaks = NULL) + guides(fill = F) + theme_classic()
```

Using hypervolume package

```
# PCAmix - Size corrected

Xrb_litter = Xrb[Xrb$habitat == "laying on leaf litter, logs, bark, trunk",
    c("PC1", "PC2", "PC3", "PC4", "PC5", "PC6", "PC7")]
Xrb_hang = Xrb[Xrb$habitat == "hanging from branches and leaves",
    c("PC1", "PC2", "PC3", "PC4", "PC5", "PC6", "PC7")]
Xrb_branch = Xrb[Xrb$habitat == "laying on branches and leaves",
    c("PC1", "PC2", "PC3", "PC4", "PC5", "PC6", "PC7")]
Xrb_grass = Xrb[Xrb$habitat == "hanging from grass", c("PC1",
    "PC2", "PC3", "PC4", "PC5", "PC6", "PC7")]
Xrb_palm = Xrb[Xrb$habitat == "laying on palm leaves", c("PC1",
    "PC2", "PC3", "PC4", "PC5", "PC6", "PC7")]
```

```r
hv1 = hypervolume_box(Xrb_litter, name = "litter")
```

```
##
## Building tree...
## done.
## Ball query...
##
## done.
## Binding random points... done.
## Beginning volume calculation... done.
```

```r
hv2 = hypervolume_box(Xrb_hang, name = "hang")
```

```
##
## Building tree...
## done.
## Ball query...
##
## done.
## Binding random points... done.
## Beginning volume calculation... done.
```

```r
hv3 = hypervolume_box(Xrb_branch, name = "branch")
```

```
##
## Building tree...
## done.
## Ball query...
##
## done.
## Binding random points... done.
## Beginning volume calculation... done.
```

```r
hv4 = hypervolume_box(Xrb_grass, name = "grass")
```

```
##
## Building tree...
## done.
## Ball query...
##
## done.
## Binding random points... done.
## Beginning volume calculation... done.
```

```r
hv5 = hypervolume_box(Xrb_palm, name = "palm")
```

```
##
## Building tree...
## done.
```

```
## Ball query...
##
## done.
## Binding random points... done.
## Beginning volume calculation... done.
```

```
values <- c(get_volume(hv2), get_volume(hv4), get_volume(hv3),
    get_volume(hv1), get_volume(hv5))
hyper <- data.frame(values, names(values))
colnames(hyper) <- c("volume", "habitat")
hyper$habitat <- factor(hyper$habitat, levels = hyper$habitat)

pl4 <- ggplot(hyper, aes(x = habitat, y = volume)) + geom_bar(aes(fill = habitat),
    stat = "identity", width = 0.8) + scale_fill_manual(values = c("darkseagreen",
    "gold", "darkorange", "darkred", "dodgerblue")) + ylab("Niche hypervolume size") +
    # xlab('')+
labs(title = "Mixed PCA - Size correction", subtitle = "Kernel density estimates") +
    scale_x_discrete(labels = NULL, breaks = NULL) + guides(fill = F) +
    theme_classic()


# Phylogenetic PCA - Size corrected

Xrb2_litter = Xrb2[Xrb2$habitat == "laying on leaf litter, logs, bark, trunk",
    c("PC1", "PC2", "PC3", "PC4", "PC5", "PC6", "PC7", "PC8")]
Xrb2_hang = Xrb2[Xrb2$habitat == "hanging from branches and leaves",
    c("PC1", "PC2", "PC3", "PC4", "PC5", "PC6", "PC7", "PC8")]
Xrb2_branch = Xrb2[Xrb2$habitat == "laying on branches and leaves",
    c("PC1", "PC2", "PC3", "PC4", "PC5", "PC6", "PC7", "PC8")]
Xrb2_grass = Xrb2[Xrb2$habitat == "hanging from grass", c("PC1",
    "PC2", "PC3", "PC4", "PC5", "PC6", "PC7", "PC8")]
Xrb2_palm = Xrb2[Xrb2$habitat == "laying on palm leaves", c("PC1",
    "PC2", "PC3", "PC4", "PC5", "PC6", "PC7", "PC8")]

hv12 = hypervolume_box(Xrb2_litter, name = "litter")
```

```
##
## Building tree...
## done.
## Ball query...
##
## done.
## Binding random points... done.
## Beginning volume calculation... done.
```

```
hv22 = hypervolume_box(Xrb2_hang, name = "hang")
```

```
##
## Building tree...
## done.
## Ball query...
##
## done.
```

```
## Binding random points... done.
## Beginning volume calculation... done.
```

```
hv32 = hypervolume_box(Xrb2_branch, name = "branch")
```

```
##
## Building tree...
## done.
## Ball query...
##
## done.
## Binding random points... done.
## Beginning volume calculation... done.
```

```
hv42 = hypervolume_box(Xrb2_grass, name = "grass")
```

```
##
## Building tree...
## done.
## Ball query...
##
## done.
## Binding random points... done.
## Beginning volume calculation... done.
```

```
hv52 = hypervolume_box(Xrb2_palm, name = "palm")
```

```
##
## Building tree...
## done.
## Ball query...
##
## done.
## Binding random points... done.
## Beginning volume calculation... done.
```

```
values2 <- c(get_volume(hv22), get_volume(hv42), get_volume(hv32),
    get_volume(hv12), get_volume(hv52))
hyper2 <- data.frame(values2, names(values2))
colnames(hyper2) <- c("volume", "habitat")
hyper2$habitat <- factor(hyper2$habitat, levels = hyper2$habitat)

pl5 <- ggplot(hyper2, aes(x = habitat, y = volume)) + geom_bar(aes(fill = habitat),
    stat = "identity", width = 0.8) + scale_fill_manual(values = c("darkseagreen",
    "gold", "darkorange", "darkred", "dodgerblue")) + ylab("Niche hypervolume size") +
    # xlab('')+
labs(title = "Phylogenetic PCA - Size correction", subtitle = "Kernel density estimates") +
    scale_x_discrete(labels = NULL, breaks = NULL) + guides(fill = F) +
    theme_classic()

# Phylogenetic PCA - No size correction
```

```
Xrb3_litter = Xrb3[Xrb3$habitat == "laying on leaf litter, logs, bark, trunk",
    c("PC1", "PC2", "PC3", "PC4", "PC5", "PC6")]
Xrb3_hang = Xrb3[Xrb3$habitat == "hanging from branches and leaves",
    c("PC1", "PC2", "PC3", "PC4", "PC5", "PC6")]
Xrb3_branch = Xrb3[Xrb3$habitat == "laying on branches and leaves",
    c("PC1", "PC2", "PC3", "PC4", "PC5", "PC6")]
Xrb3_grass = Xrb3[Xrb3$habitat == "hanging from grass", c("PC1",
    "PC2", "PC3", "PC4", "PC5", "PC6")]
Xrb3_palm = Xrb3[Xrb3$habitat == "laying on palm leaves", c("PC1",
    "PC2", "PC3", "PC4", "PC5", "PC6")]

hv13 = hypervolume_box(Xrb3_litter, name = "litter")
```

```
##
## Building tree...
## done.
## Ball query...
##
## done.
## Binding random points... done.
## Beginning volume calculation... done.
```

```
hv23 = hypervolume_box(Xrb3_hang, name = "hang")
```

```
##
## Building tree...
## done.
## Ball query...
##
## done.
## Binding random points... done.
## Beginning volume calculation... done.
```

```
hv33 = hypervolume_box(Xrb3_branch, name = "branch")
```

```
##
## Building tree...
## done.
## Ball query...
##
## done.
## Binding random points... done.
## Beginning volume calculation... done.
```

```
hv43 = hypervolume_box(Xrb3_grass, name = "grass")
```

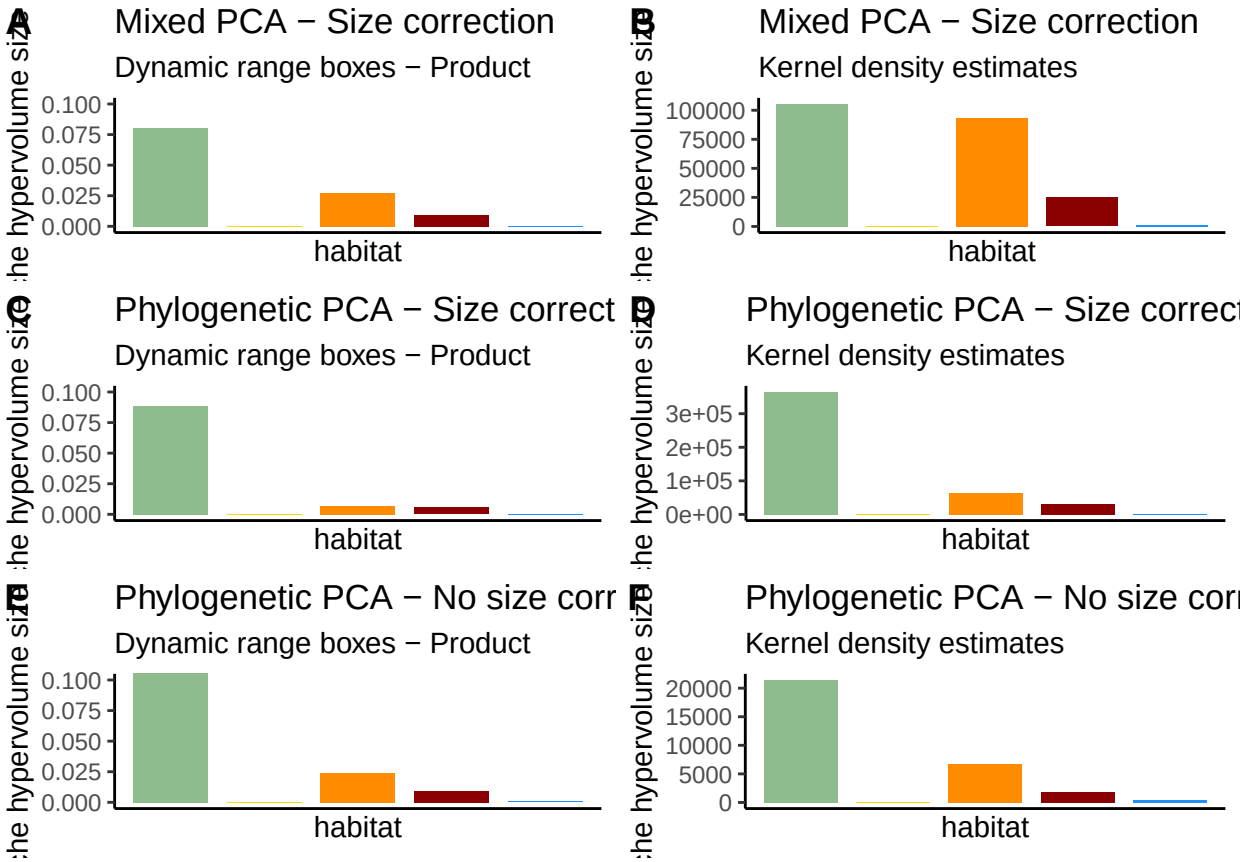
```
##
## Building tree...
## done.
## Ball query...
```

```
##
## done.
## Binding random points... done.
## Beginning volume calculation... done.
```

```
hv53 = hypervolume_box(Xrb3_palm, name = "palm")
```

```
##
## Building tree...
## done.
## Ball query...
##
## done.
## Binding random points... done.
## Beginning volume calculation... done.
```

```
values3 <- c(get_volume(hv23), get_volume(hv43), get_volume(hv33),
    get_volume(hv13), get_volume(hv53))
hyper3 <- data.frame(values3, names(values3))
colnames(hyper3) <- c("volume", "habitat")
hyper3$habitat <- factor(hyper3$habitat, levels = hyper3$habitat)

pl6 <- ggplot(hyper3, aes(x = habitat, y = volume)) + geom_bar(aes(fill = habitat),
    stat = "identity", width = 0.8) + scale_fill_manual(values = c("darkseagreen",
    "gold", "darkorange", "darkred", "dodgerblue")) + ylab("Niche hypervolume size") +
    # xlab('')+
labs(title = "Phylogenetic PCA - No size correction", subtitle = "Kernel density estimates") +
    scale_x_discrete(labels = NULL, breaks = NULL) + guides(fill = F) +
    theme_classic()


plot_grid(pl1, pl4, pl2, pl5, pl3, pl6, ncol = 2, labels = "AUTO")
```



Predicting habitat (Random forests - PCA mix + residuals)

Can habitat be predicted by morphology? tutorial: https://towardsdatascience.com/random-forest-in-r-f66adf80ec9

Prepare dataset

```
XX <- X[, -1]
XX <- XX[, -c(16:52)]  #only keep morpho data and habitat use
XX <- subset(XX, is.na(XX$habitat2) == F)
XX$habitat2 <- as.factor(XX$habitat2)

head(XX)
```

```
##                             pca_mix_dim1 pca_mix_dim2 pca_mix_dim3 pca_mix_dim4
## Acanthoxyla_geisovii_AXG1     -1.3759671  0.085671079   -1.0824179    1.6197692
## Clitarchus_hookeri_CLH1       -2.8740381  1.369276215    0.4360864   -0.4345218
## Argosarchus_horridus_ARG      -3.9956566  0.005241395   -1.2947459    0.5195014
## Micrarchus_hystriculeus_MIH    0.9150644 -0.267091036   -1.7022573    0.4727771
## Canachus_alligator_CAN1        4.1915667  1.030433904   -0.6096281    1.5343849
## Canachus_sp._CAN2              4.6060583  1.649304906   -0.3693754    1.6917260
##                             pca_mix_dim5 pca_mix_dim6 pca_mix_dim7 pca_mix_dim8
```

```
## Acanthoxyla_geisovii_AXG1     -0.7840636   -0.7307814   -0.5069875   -0.7024527
## Clitarchus_hookeri_CLH1        0.7347754    0.1038844    0.2192024    0.4229190
## Argosarchus_horridus_ARG      -3.0610214   -0.6666210    0.8030136   -0.7137576
## Micrarchus_hystriculeus_MIH   -1.8435060   -0.2895571   -0.1021009   -0.2832688
## Canachus_alligator_CAN1        0.4317944    1.0413946   -0.2469166    0.1280258
## Canachus_sp._CAN2              1.2429044    1.2574744    0.1902168    0.1216815
##                            pca_mix_dim9 pca_mix_dim10 pca_mix_dim11
## Acanthoxyla_geisovii_AXG1    -0.9431956   -0.18055995     0.3234469
## Clitarchus_hookeri_CLH1      -0.3051649   -0.43393416    -0.2500117
## Argosarchus_horridus_ARG     -0.1101320   -0.52138089     0.3056898
## Micrarchus_hystriculeus_MIH  -0.5014256    0.24502244     0.4049826
## Canachus_alligator_CAN1       0.3904848    0.03806992    -0.1937711
## Canachus_sp._CAN2             0.9825112    0.41346075    -0.2189815
##                            pca_mix_dim12 pca_mix_dim13 pca_mix_dim14
## Acanthoxyla_geisovii_AXG1     -0.3701815    -0.1146489  -0.245664320
## Clitarchus_hookeri_CLH1       -0.4065280     0.7680544  -0.284338664
## Argosarchus_horridus_ARG      -0.6794614    -0.1720579   0.177054919
## Micrarchus_hystriculeus_MIH    0.0448744    -0.1112182  -0.001549396
## Canachus_alligator_CAN1       -0.7539665    -0.2374013  -0.247930234
## Canachus_sp._CAN2             -0.4920160     0.0377261  -0.136942420
##                            pca_mix_dim15
## Acanthoxyla_geisovii_AXG1     -0.2092843
## Clitarchus_hookeri_CLH1       -0.3350510
## Argosarchus_horridus_ARG      -0.4757940
## Micrarchus_hystriculeus_MIH    0.3703019
## Canachus_alligator_CAN1       -0.1688248
## Canachus_sp._CAN2             -0.2384600
##                                                      habitat2
## Acanthoxyla_geisovii_AXG1           hanging from branches and leaves
## Clitarchus_hookeri_CLH1             hanging from branches and leaves
## Argosarchus_horridus_ARG            hanging from branches and leaves
## Micrarchus_hystriculeus_MIH laying on leaf litter, logs, bark, trunk
## Canachus_alligator_CAN1     laying on leaf litter, logs, bark, trunk
## Canachus_sp._CAN2           laying on leaf litter, logs, bark, trunk
```

##Run randomforest

Null accuracy

Predict the most frequent habitat in the training set for the test set.

```
a <- NULL
acc <- NULL

# Define training dataset with always the same proportions
# of species from each habitat
trainIndex1 <- createDataPartition(XX$habitat2, p = 3/4, list = FALSE,
    times = 1)
train <- XX[trainIndex1, ]
# Test dataset
test <- subset(XX, !(rownames(XX) %in% rownames(train)))
# Most frequent habitat in test dataset
h <- names(which.max(table(train$habitat2)))
```

```
# Prediction = always the most frequent habitat
pred <- rep(h, length(test$habitat2))
pred <- as.factor(pred)
test2 <- test[, dim(test)[2]]
cm <- table(pred, test2)
cm2 <- prop.table(cm, 1) * 100
null <- cm2[2]
null
```

```
## [1] 53.06122
```

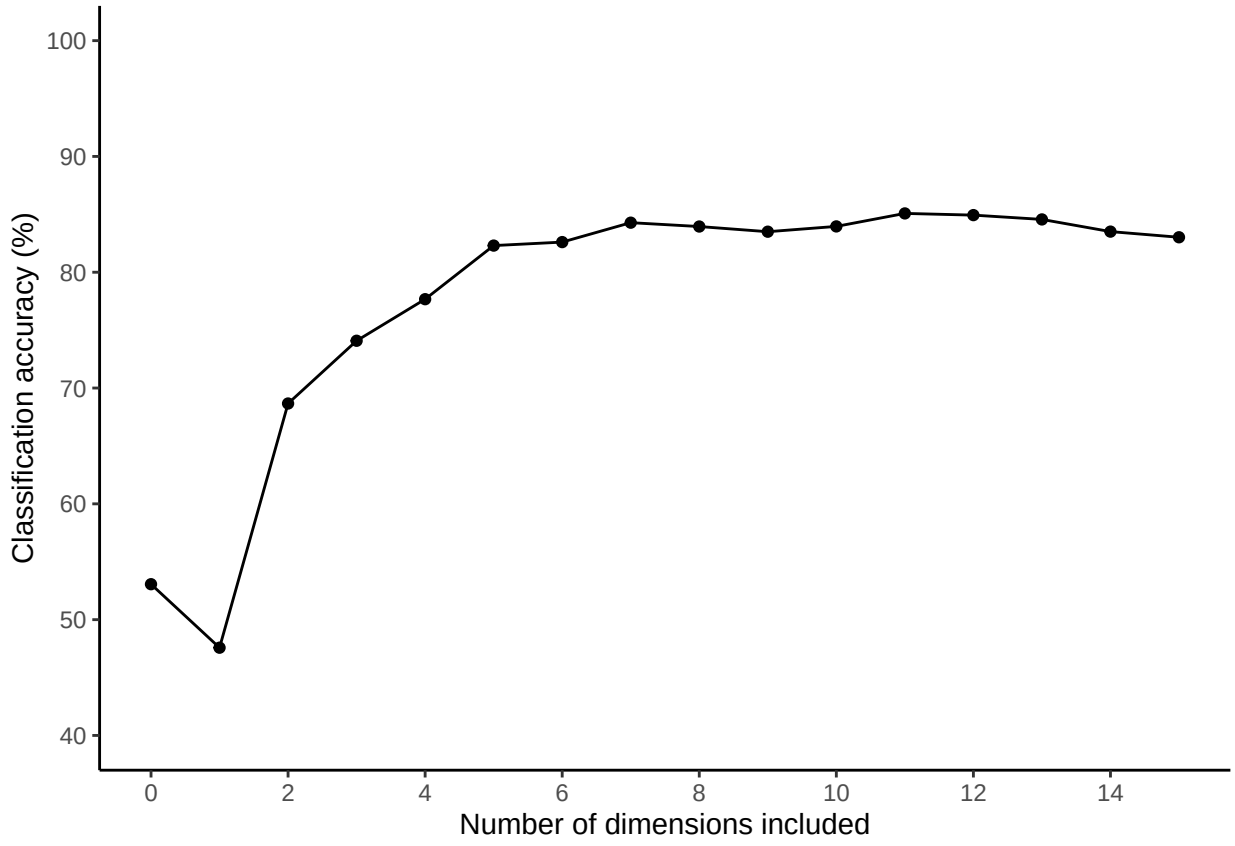
Training and prediction with morphological data

Adding one PC at a time (repeat each step 1000 times)

```
r <- vector(mode = "list", length = 15)
aa <- vector(mode = "list", length = 15)
racc <- NULL
a <- NULL
for (i in c(1:15)) {
    dat <- XX[, c(1:i, 16)]
    dat$habitat2 <- as.factor(dat$habitat2)
    acc <- NULL
    if (i == 1) {
        mtry = 1
    }
    if (i != 1) {
        mtry = 2
    }
    for (j in c(1:1000)) {
        trainIndex1 <- createDataPartition(XX$habitat2, p = 3/4,
            list = FALSE, times = 1)
        train <- dat[trainIndex1, ]
        test <- subset(dat, !(rownames(dat) %in% rownames(train)))
        test2 <- test[, dim(test)[2]]
        rf <- randomForest(habitat2 ~ ., data = train, mtry = mtry,
            maxnodes = 50)
        pred = as.factor(predict(rf, newdata = test))
        cm = table(pred, test2)
        a <- rbind(a, prop.table(cm, 1) * 100)
        acc <- cbind(acc, mean(pred == test2))
    }
    aa[[i]] <- a
    r[[i]] <- acc  #store all accuracy results
    racc <- cbind(racc, mean(acc))  #mean accuracy results
    a <- NULL
}
```

Plot overall prediction accuracy

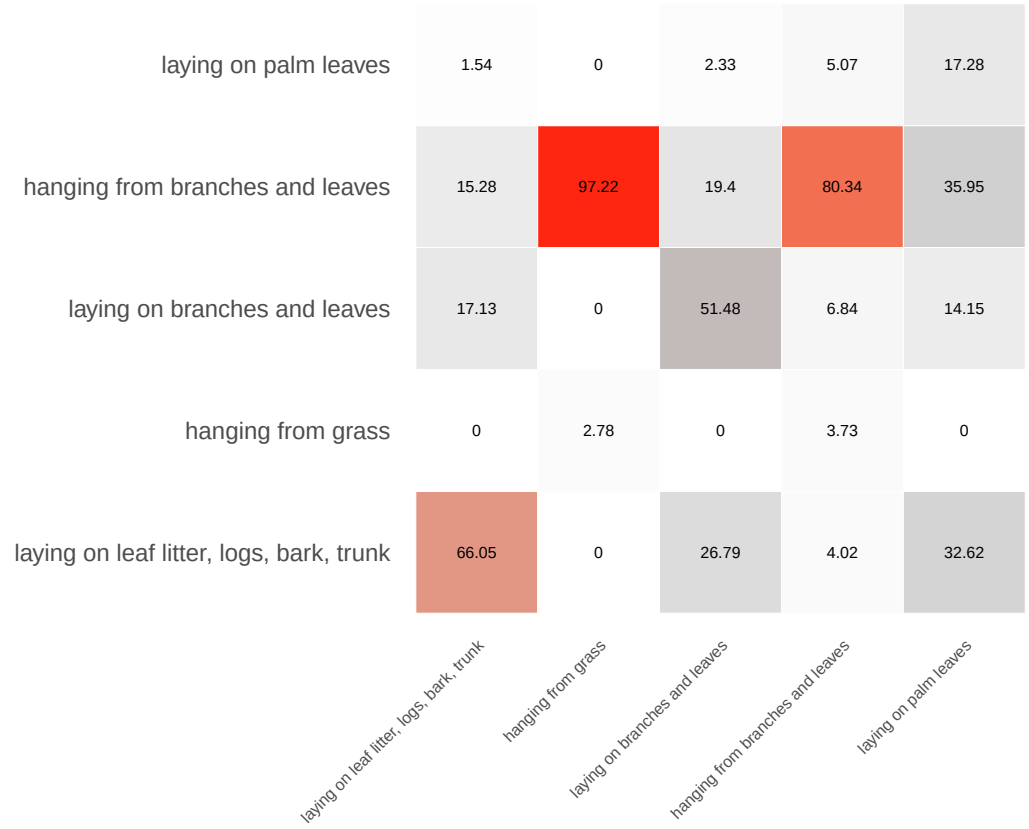
```
accu <- cbind(c(1:15), as.vector(racc * 100))
colnames(accu) <- c("var", "accur")
accu <- as.data.frame(accu)
accu <- rbind(accu, c(0, null))
ggplot(accu, aes(x = var, y = accur)) + geom_point() + geom_line() +
    scale_x_continuous(name = "Number of dimensions included",
        limits = c(0, 15), breaks = seq(0, 15, 2)) + scale_y_continuous(name = "Classification accuracy
    limits = c(40, 100), breaks = seq(40, 100, 10)) + theme_classic()
```



Prediction accuracy for 2 dimensions

```
d <- aa[[2]]
mean2 <- function(x) {
    mean(x, na.rm = T)
}
b <- aggregate(d, list(row.names(d)), mean2)
bb <- melt(b)
bb$variable <- factor(bb$variable, levels = c("laying on leaf litter, logs, bark, trunk",
    "hanging from grass", "laying on branches and leaves", "hanging from branches and leaves",
    "laying on palm leaves"))
bb$Group.1 <- factor(bb$Group.1, levels = c("laying on leaf litter, logs, bark, trunk",
    "hanging from grass", "laying on branches and leaves", "hanging from branches and leaves",
    "laying on palm leaves"))
```

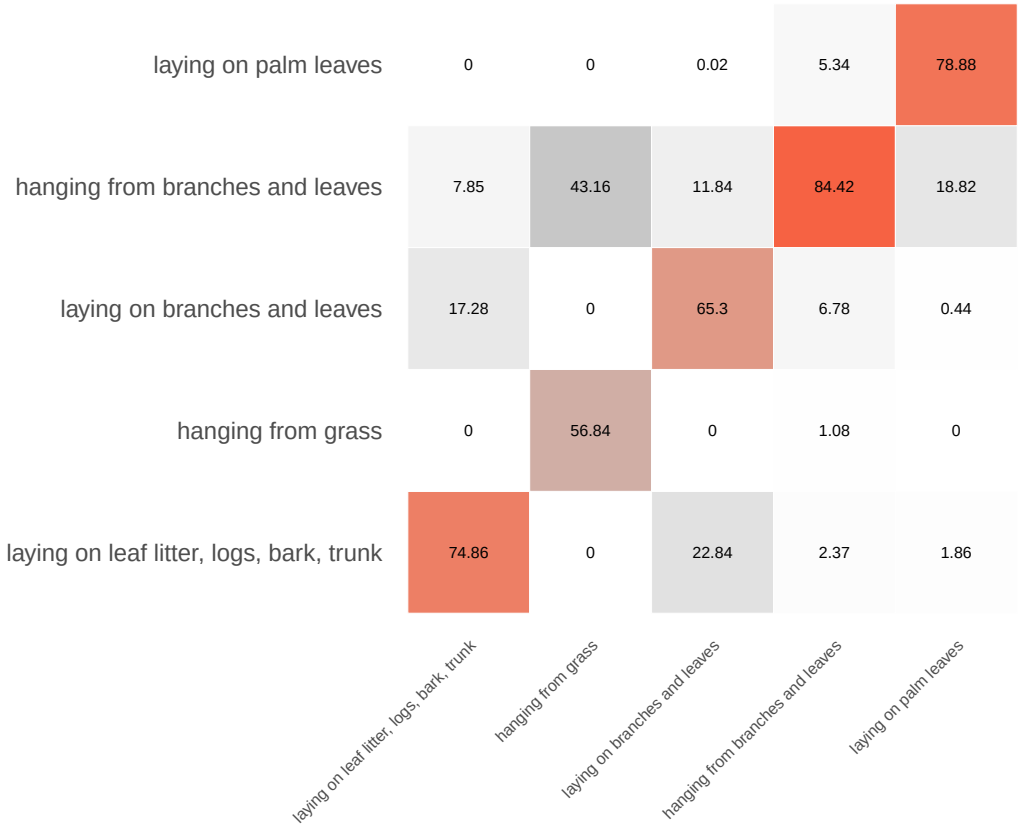
```
bb <- bb %>%
    arrange(Group.1, variable)

p2 <- ggplot(data = bb, aes(x = Group.1, y = variable, fill = value)) +
    geom_tile(color = "white") + scale_fill_gradient2(low = "white",
    high = "red", mid = "grey", midpoint = 50, limit = c(0, 100),
    space = "Lab", name = "% of classified species") + theme_minimal() +
    theme(axis.text.x = element_text(angle = 45, vjust = 1, size = 6,
        hjust = 1)) + coord_fixed() + geom_text(aes(x = Group.1,
    y = variable, label = round(value, digits = 2)), color = "black",
    size = 2) + theme(axis.title.x = element_blank(), axis.title.y = element_blank(),
    panel.grid.major = element_blank(), panel.border = element_blank(),
    panel.background = element_blank(), axis.ticks = element_blank(),
    legend.position = "none")
p2
```




```
p22 <- ggplot(data = bb, aes(x = Group.1, y = variable, fill = value)) +
    geom_tile(color = "white") + scale_fill_gradient2(low = "white",
    high = "red", mid = "grey", midpoint = 50, limit = c(0, 100),
    space = "Lab", name = "% of classified species") + theme_minimal() +
    labs(title = "2 dimensions") + theme(axis.text.x = element_text(angle = 45,
    vjust = 1, size = 6, hjust = 1)) + coord_fixed() + theme(axis.title.x = element_blank(),
    axis.title.y = element_blank(), panel.grid.major = element_blank(),
    panel.border = element_blank(), panel.background = element_blank(),
    axis.ticks = element_blank(), legend.position = "none")
```

Prediction accuracy for 3 dimensions

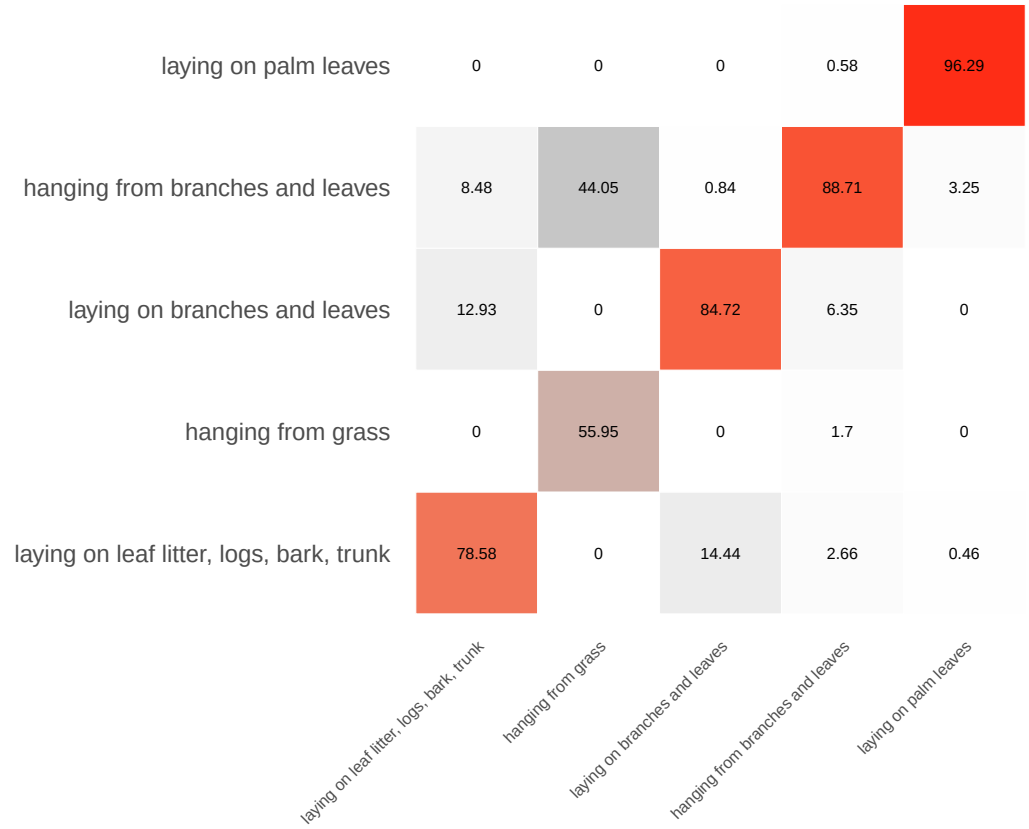
```
d <- aa[[4]]
b <- aggregate(d, list(row.names(d)), mean2)
bb <- melt(b)
bb$variable <- factor(bb$variable, levels = c("laying on leaf litter, logs, bark, trunk",
    "hanging from grass", "laying on branches and leaves", "hanging from branches and leaves",
    "laying on palm leaves"))
bb$Group.1 <- factor(bb$Group.1, levels = c("laying on leaf litter, logs, bark, trunk",
    "hanging from grass", "laying on branches and leaves", "hanging from branches and leaves",
    "laying on palm leaves"))
bb <- bb %>%
    arrange(Group.1, variable)

p4 <- ggplot(data = bb, aes(x = Group.1, y = variable, fill = value)) +
    geom_tile(color = "white") + scale_fill_gradient2(low = "white",
    high = "red", mid = "grey", midpoint = 50, limit = c(0, 100),
    space = "Lab", name = "% of classified species") + theme_minimal() +
    theme(axis.text.x = element_text(angle = 45, vjust = 1, size = 6,
        hjust = 1)) + coord_fixed() + geom_text(aes(x = Group.1,
    y = variable, label = round(value, digits = 2)), color = "black",
    size = 2) + theme(axis.title.x = element_blank(), axis.title.y = element_blank(),
    panel.grid.major = element_blank(), panel.border = element_blank(),
    panel.background = element_blank(), axis.ticks = element_blank(),
    legend.position = "none")
p4
```



Prediction accuracy for 7 dimensions

```
d <- aa[[7]]
b <- aggregate(d, list(row.names(d)), mean2)
bb <- melt(b)
bb$variable <- factor(bb$variable, levels = c("laying on leaf litter, logs, bark, trunk",
    "hanging from grass", "laying on branches and leaves", "hanging from branches and leaves",
    "laying on palm leaves"))
bb$Group.1 <- factor(bb$Group.1, levels = c("laying on leaf litter, logs, bark, trunk",
    "hanging from grass", "laying on branches and leaves", "hanging from branches and leaves",
    "laying on palm leaves"))
bb <- bb %>%
    arrange(Group.1, variable)

p7 <- ggplot(data = bb, aes(x = Group.1, y = variable, fill = value)) +
    geom_tile(color = "white") + scale_fill_gradient2(low = "white",
    high = "red", mid = "grey", midpoint = 50, limit = c(0, 100),
    space = "Lab", name = "% of classified species") + theme_minimal() +
    theme(axis.text.x = element_text(angle = 45, vjust = 1, size = 6,
        hjust = 1)) + coord_fixed() + geom_text(aes(x = Group.1,
    y = variable, label = round(value, digits = 2)), color = "black",
    size = 2) + theme(axis.title.x = element_blank(), axis.title.y = element_blank(),
    panel.grid.major = element_blank(), panel.border = element_blank(),
    panel.background = element_blank(), axis.ticks = element_blank(),
```

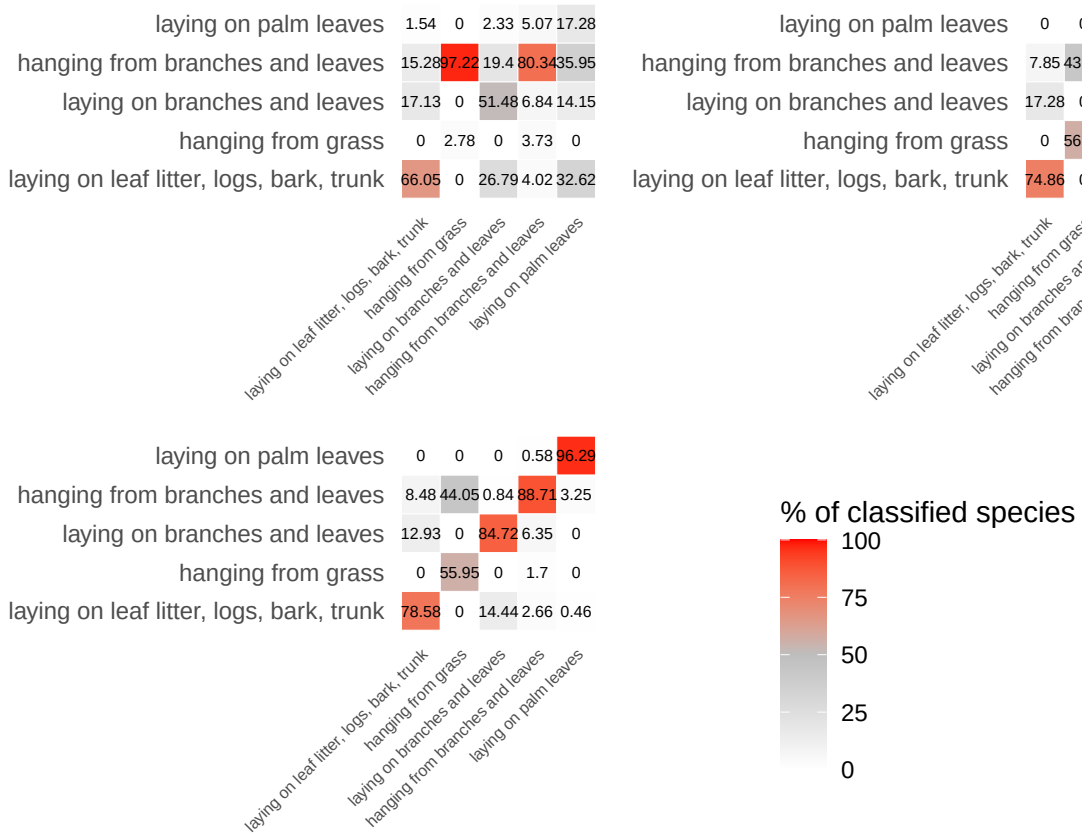
```
    legend.position = "none")
p7
```




```
p77 <- ggplot(data = bb, aes(x = Group.1, y = variable, fill = value)) +
    geom_tile(color = "white") + scale_fill_gradient2(low = "white",
    high = "red", mid = "grey", midpoint = 50, limit = c(0, 100),
    space = "Lab", name = "% of classified species") + theme_minimal() +
    theme(axis.text.x = element_text(angle = 45, vjust = 1, size = 6,
        hjust = 1)) + labs(title = "7 dimensions") + coord_fixed() +
    theme(axis.title.x = element_blank(), axis.title.y = element_blank(),
        panel.grid.major = element_blank(), panel.border = element_blank(),
        panel.background = element_blank(), axis.ticks = element_blank(),
        legend.position = "none")
```

```
ppp <- ggplot(data = bb, aes(x = Group.1, y = variable, fill = value)) +
    geom_tile(color = "white") + scale_fill_gradient2(low = "white",
    high = "red", mid = "grey", midpoint = 50, limit = c(0, 100),
    space = "Lab", name = "% of classified species") + theme_minimal() +
    theme(axis.text.x = element_text(angle = 45, vjust = 1, size = 6,
        hjust = 1)) + coord_fixed() + theme(axis.title.x = element_blank(),
    axis.title.y = element_blank(), panel.grid.major = element_blank(),
    panel.border = element_blank(), panel.background = element_blank(),
    axis.ticks = element_blank())
legend <- cowplot::get_legend(ppp)
```

```
l <- as_ggplot(legend)
plot_grid(p2, p4, p7, l, ncol = 2)
```




```
# plot for figure
plot_grid(p22, p77, l, nrow = 1)
```

Predicting habitat (Random forests - phylogenetic PCA + residuals)

Prepare dataset

```
XX <- X[, -1]
XX <- XX[, -c(1:15, 31:52)]  #only keep morpho data and habitat use
XX <- subset(XX, is.na(XX$habitat2) == F)
XX$habitat2 <- as.factor(XX$habitat2)

head(XX)
```

```
##                            pPCA_sizecorr_dim1 pPCA_sizecorr_dim2
## Acanthoxyla_geisovii_AXG1           4.5965581         -0.9060956
## Clitarchus_hookeri_CLH1             5.6814708         -1.6982495
## Argosarchus_horridus_ARG            7.3635322          0.8738964
## Micrarchus_hystriculeus_MIH         2.3296265          0.9535926
## Canachus_alligator_CAN1            -0.9045619         -0.9779065
## Canachus_sp._CAN2                  -1.3483295         -1.4074393
##                            pPCA_sizecorr_dim3 pPCA_sizecorr_dim4
## Acanthoxyla_geisovii_AXG1           0.8293949         -1.4687452
## Clitarchus_hookeri_CLH1             1.5277214          0.7039254
```

```
## Argosarchus_horridus_ARG             1.2545787         -0.9043370
## Micrarchus_hystriculeus_MIH          0.6438192         -1.0963965
## Canachus_alligator_CAN1              0.5615505          0.6987421
## Canachus_sp._CAN2                    0.8543314          1.5526521
##                            pPCA_sizecorr_dim5 pPCA_sizecorr_dim6
## Acanthoxyla_geisovii_AXG1           0.3568420          0.6291487
## Clitarchus_hookeri_CLH1             0.2780851          0.7978928
## Argosarchus_horridus_ARG            1.9344974          1.2439369
## Micrarchus_hystriculeus_MIH         0.9093774          0.9242074
## Canachus_alligator_CAN1            -1.2264691          1.1462574
## Canachus_sp._CAN2                  -1.8703784          0.8670012
##                            pPCA_sizecorr_dim7 pPCA_sizecorr_dim8
## Acanthoxyla_geisovii_AXG1           1.1675522         -0.1531384
## Clitarchus_hookeri_CLH1             0.6326144         -0.5988136
## Argosarchus_horridus_ARG            0.3868782         -0.2810615
## Micrarchus_hystriculeus_MIH         0.8438302         -0.2567734
## Canachus_alligator_CAN1             1.0873844         -1.1727578
## Canachus_sp._CAN2                   0.6937075         -1.2800386
##                            pPCA_sizecorr_dim9 pPCA_sizecorr_dim10
## Acanthoxyla_geisovii_AXG1          0.18208679        -0.001994741
## Clitarchus_hookeri_CLH1           -0.11390874        -0.240364319
## Argosarchus_horridus_ARG           0.32395784        -0.927072097
## Micrarchus_hystriculeus_MIH       -0.09634414         0.398199140
## Canachus_alligator_CAN1           -0.08718907        -0.448264921
## Canachus_sp._CAN2                 -0.42310522        -0.335930235
##                            pPCA_sizecorr_dim11 pPCA_sizecorr_dim12
## Acanthoxyla_geisovii_AXG1          -0.04498002          0.03350272
## Clitarchus_hookeri_CLH1             0.45783251          0.59178603
## Argosarchus_horridus_ARG           -0.18201816         -0.01935252
## Micrarchus_hystriculeus_MIH        -0.25486309         -0.01741955
## Canachus_alligator_CAN1            -0.03944657         -0.50324673
## Canachus_sp._CAN2                   0.18174984         -0.47864899
##                            pPCA_sizecorr_dim13 pPCA_sizecorr_dim14
## Acanthoxyla_geisovii_AXG1           0.11396619       -0.0276691484
## Clitarchus_hookeri_CLH1             0.03104352        0.1022408958
## Argosarchus_horridus_ARG            0.32195802       -0.0003249141
## Micrarchus_hystriculeus_MIH         0.55626523        0.0099649626
## Canachus_alligator_CAN1            -0.22006626       -0.1982651632
## Canachus_sp._CAN2                  -0.12493447        0.0708690988
##                            pPCA_sizecorr_dim15
## Acanthoxyla_geisovii_AXG1          -0.06812651
## Clitarchus_hookeri_CLH1            -0.33770374
## Argosarchus_horridus_ARG           -0.57951647
## Micrarchus_hystriculeus_MIH        -0.18791475
## Canachus_alligator_CAN1            -0.18591290
## Canachus_sp._CAN2                  -0.26687417
##                                                                habitat2
## Acanthoxyla_geisovii_AXG1                  hanging from branches and leaves
## Clitarchus_hookeri_CLH1                    hanging from branches and leaves
## Argosarchus_horridus_ARG                   hanging from branches and leaves
## Micrarchus_hystriculeus_MIH laying on leaf litter, logs, bark, trunk
## Canachus_alligator_CAN1     laying on leaf litter, logs, bark, trunk
## Canachus_sp._CAN2           laying on leaf litter, logs, bark, trunk
```

##Run randomforest ### Null accuracy Predict the most frequent habitat in the training set for the test set.

```
a <- NULL
acc <- NULL

# Define training dataset with always the same proportions
# of species from each habitat
trainIndex1 <- createDataPartition(XX$habitat2, p = 3/4, list = FALSE,
    times = 1)
train <- XX[trainIndex1, ]
# Test dataset
test <- subset(XX, !(rownames(XX) %in% rownames(train)))
# Most frequent habitat in test dataset
h <- names(which.max(table(train$habitat2)))
# Prediction = always the most frequent habitat
pred <- rep(h, length(test$habitat2))
pred <- as.factor(pred)
test2 <- test[, dim(test)[2]]
cm <- table(pred, test2)
cm2 <- prop.table(cm, 1) * 100
null <- cm2[2]
null
```

```
## [1] 53.06122
```

Training and prediction with morphological data

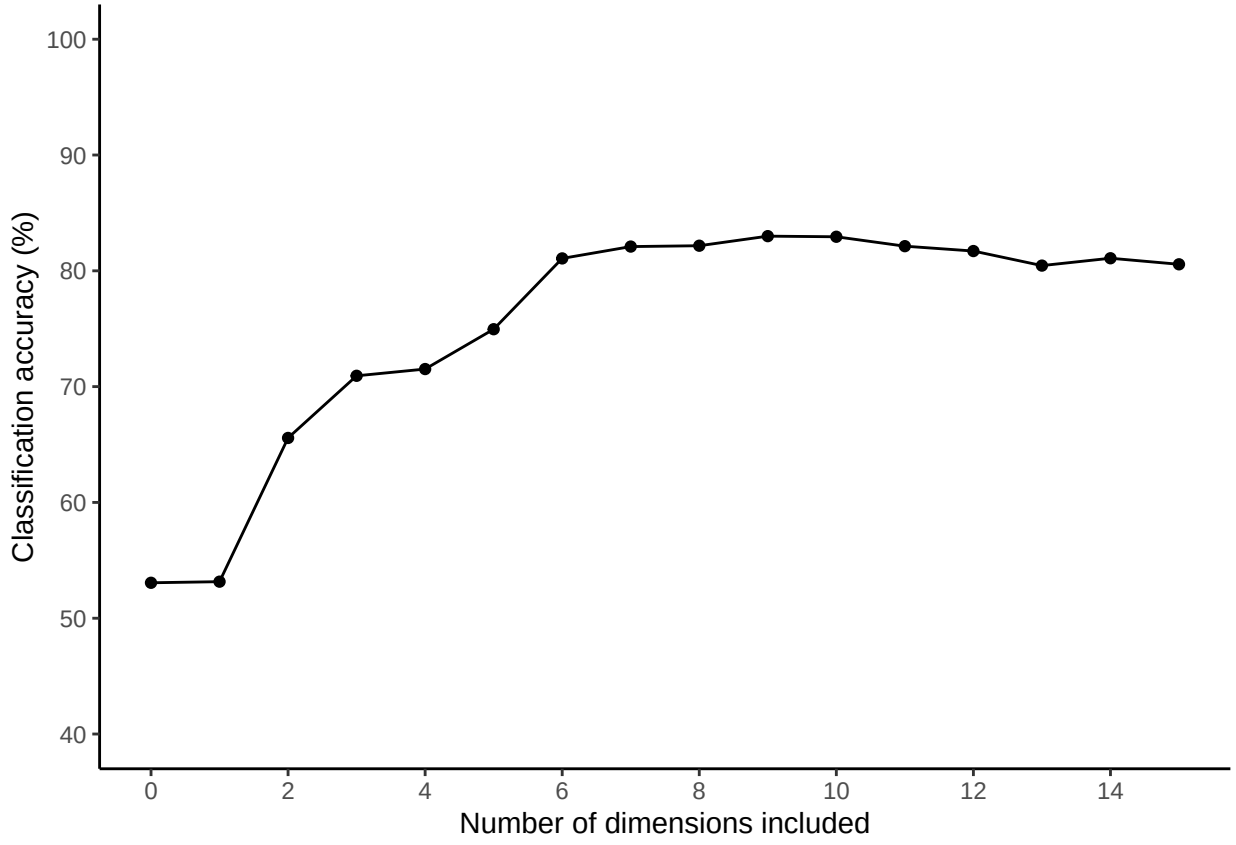
Adding one PC at a time (repeat each step 1000 times)

```
r <- vector(mode = "list", length = 15)
aa <- vector(mode = "list", length = 15)
racc <- NULL
a <- NULL
for (i in c(1:15)) {
    dat <- XX[, c(1:i, 16)]
    dat$habitat2 <- as.factor(dat$habitat2)
    acc <- NULL
    if (i == 1) {
        mtry = 1
    }
    if (i != 1) {
        mtry = 2
    }
    for (j in c(1:1000)) {
        trainIndex1 <- createDataPartition(XX$habitat2, p = 3/4,
            list = FALSE, times = 1)
        train <- dat[trainIndex1, ]
        test <- subset(dat, !(rownames(dat) %in% rownames(train)))
        test2 <- test[, dim(test)[2]]
        rf <- randomForest(habitat2 ~ ., data = train, mtry = mtry,
            maxnodes = 50)
        pred = as.factor(predict(rf, newdata = test))
```

```
        cm = table(pred, test2)
        a <- rbind(a, prop.table(cm, 1) * 100)
        acc <- cbind(acc, mean(pred == test2))
    }
    aa[[i]] <- a
    r[[i]] <- acc  #store all accuracy results
    racc <- cbind(racc, mean(acc))  #mean accuracy results
    a <- NULL
}
```

Plot overall prediction accuracy

```
accu <- cbind(c(1:15), as.vector(racc * 100))
colnames(accu) <- c("var", "accur")
accu <- as.data.frame(accu)
accu <- rbind(accu, c(0, null))
ggplot(accu, aes(x = var, y = accur)) + geom_point() + geom_line() +
    scale_x_continuous(name = "Number of dimensions included",
        limits = c(0, 15), breaks = seq(0, 15, 2)) + scale_y_continuous(name = "Classification accuracy
    limits = c(40, 100), breaks = seq(40, 100, 10)) + theme_classic()
```



Predicting habitat (Random forests - PCA mix + residuals)

Prepare dataset

```
XX <- X[, -1]
XX <- XX[, -c(1:30, 46:52)]  #only keep morpho data and habitat use
XX <- subset(XX, is.na(XX$habitat2) == F)
XX$habitat2 <- as.factor(XX$habitat2)

head(XX)
```

```
##                            pPCA_nocorr_dim1 pPCA_nocorr_dim2 pPCA_nocorr_dim3
## Acanthoxyla_geisovii_AXG1        -1.5414094       3.20842617       0.94624934
## Clitarchus_hookeri_CLH1           0.2617767       4.13404914       1.00254647
## Argosarchus_horridus_ARG         -1.9151226       5.20233387       1.68709400
## Micrarchus_hystriculeus_MIH       1.1451876       1.43071581       0.76552178
## Canachus_alligator_CAN1          -5.3362217       0.06605149       0.01476928
## Canachus_sp._CAN2                -4.5640696      -0.01438301      -0.22327286
##                            pPCA_nocorr_dim4 pPCA_nocorr_dim5 pPCA_nocorr_dim6
## Acanthoxyla_geisovii_AXG1        1.2365590      -0.07485868       0.06737058
## Clitarchus_hookeri_CLH1          1.3409043      -0.22156799       0.33548288
## Argosarchus_horridus_ARG         0.7398764      -0.44336709       0.93946703
## Micrarchus_hystriculeus_MIH      0.1684776      -0.05225778       0.46512019
## Canachus_alligator_CAN1          0.4822347       0.13929531      -0.58727026
## Canachus_sp._CAN2                0.4178866       0.38068404      -0.73466778
##                            pPCA_nocorr_dim7 pPCA_nocorr_dim8 pPCA_nocorr_dim9
## Acanthoxyla_geisovii_AXG1        0.8176705       -0.1255503      -0.41020756
## Clitarchus_hookeri_CLH1          0.4052168        0.3392119       0.27337845
## Argosarchus_horridus_ARG         0.4008504       -0.1396918      -0.05718353
## Micrarchus_hystriculeus_MIH      0.5729816        0.2410431      -0.68546292
## Canachus_alligator_CAN1          0.7339198        0.8667493       0.21085913
## Canachus_sp._CAN2                0.3562099        1.0768221       0.25460004
##                            pPCA_nocorr_dim10 pPCA_nocorr_dim11
## Acanthoxyla_geisovii_AXG1        -0.37561675      -0.009681851
## Clitarchus_hookeri_CLH1          -0.29714039       0.205537860
## Argosarchus_horridus_ARG         -0.65896537      -0.399095170
## Micrarchus_hystriculeus_MIH      -0.16648291      -0.420959563
## Canachus_alligator_CAN1          -0.20142038       0.219005111
## Canachus_sp._CAN2                 0.01443039       0.373028722
##                            pPCA_nocorr_dim12 pPCA_nocorr_dim13
## Acanthoxyla_geisovii_AXG1        0.0580434945      -0.004448451
## Clitarchus_hookeri_CLH1         -0.1880016376      -0.187155253
## Argosarchus_horridus_ARG         0.3756427604      -0.489982351
## Micrarchus_hystriculeus_MIH      0.0007353492      -0.387099785
## Canachus_alligator_CAN1          0.2122434917      -0.247554869
## Canachus_sp._CAN2                0.2239732486      -0.383121375
##                            pPCA_nocorr_dim14 pPCA_nocorr_dim15
## Acanthoxyla_geisovii_AXG1         0.06315413       0.097492751
## Clitarchus_hookeri_CLH1           0.21265022      -0.224353459
## Argosarchus_horridus_ARG          0.22518677      -0.123065972
## Micrarchus_hystriculeus_MIH       0.23001976       0.002747999
## Canachus_alligator_CAN1          -0.05136293      -0.046606515
```

```
## Canachus_sp._CAN2                   0.09542549      -0.125398675
##                                                            habitat2
## Acanthoxyla_geisovii_AXG1           hanging from branches and leaves
## Clitarchus_hookeri_CLH1             hanging from branches and leaves
## Argosarchus_horridus_ARG            hanging from branches and leaves
## Micrarchus_hystriculeus_MIH laying on leaf litter, logs, bark, trunk
## Canachus_alligator_CAN1     laying on leaf litter, logs, bark, trunk
## Canachus_sp._CAN2           laying on leaf litter, logs, bark, trunk
```

##Run randomforest ### Null accuracy Predict the most frequent habitat in the training set for the test set.

```
a <- NULL
acc <- NULL

# Define training dataset with always the same proportions
# of species from each habitat
trainIndex1 <- createDataPartition(XX$habitat2, p = 3/4, list = FALSE,
    times = 1)
train <- XX[trainIndex1, ]
# Test dataset
test <- subset(XX, !(rownames(XX) %in% rownames(train)))
# Most frequent habitat in test dataset
h <- names(which.max(table(train$habitat2)))
# Prediction = always the most frequent habitat
pred <- rep(h, length(test$habitat2))
pred <- as.factor(pred)
test2 <- test[, dim(test)[2]]
cm <- table(pred, test2)
cm2 <- prop.table(cm, 1) * 100
null <- cm2[2]
null
```

```
## [1] 53.06122
```

Training and prediction with morphological data

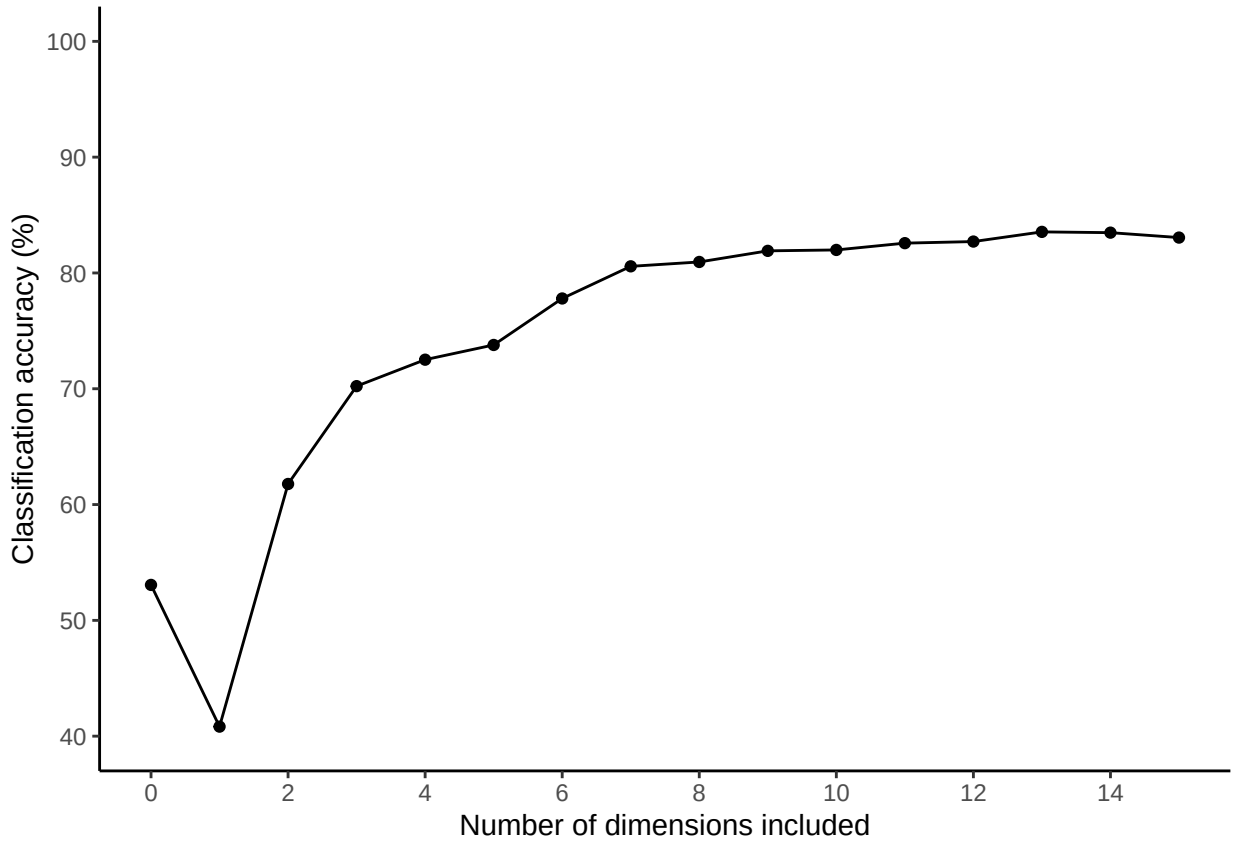
Adding one PC at a time (repeat each step 1000 times)

```
r <- vector(mode = "list", length = 15)
aa <- vector(mode = "list", length = 15)
racc <- NULL
a <- NULL
for (i in c(1:15)) {
    dat <- XX[, c(1:i, 16)]
    dat$habitat2 <- as.factor(dat$habitat2)
    acc <- NULL
    if (i == 1) {
        mtry = 1
    }
    if (i != 1) {
        mtry = 2
    }
```

```
    for (j in c(1:1000)) {
        trainIndex1 <- createDataPartition(XX$habitat2, p = 3/4,
            list = FALSE, times = 1)
        train <- dat[trainIndex1, ]
        test <- subset(dat, !(rownames(dat) %in% rownames(train)))
        test2 <- test[, dim(test)[2]]
        rf <- randomForest(habitat2 ~ ., data = train, mtry = mtry,
            maxnodes = 50)
        pred = as.factor(predict(rf, newdata = test))
        cm = table(pred, test2)
        a <- rbind(a, prop.table(cm, 1) * 100)
        acc <- cbind(acc, mean(pred == test2))
    }
    aa[[i]] <- a
    r[[i]] <- acc  #store all accuracy results
    racc <- cbind(racc, mean(acc))  #mean accuracy results
    a <- NULL
}
```

Plot overall prediction accuracy

```
accu <- cbind(c(1:15), as.vector(racc * 100))
colnames(accu) <- c("var", "accur")
accu <- as.data.frame(accu)
accu <- rbind(accu, c(0, null))
ggplot(accu, aes(x = var, y = accur)) + geom_point() + geom_line() +
    scale_x_continuous(name = "Number of dimensions included",
        limits = c(0, 15), breaks = seq(0, 15, 2)) + scale_y_continuous(name = "Classification accuracy
    limits = c(40, 100), breaks = seq(40, 100, 10)) + theme_classic()
```



Environment hypervolumes and overlaps

```
dd <- read_excel("DatasetS1.xlsx", sheet = "Habitat")
dd <- as.data.frame(dd)
row.names(dd) <- dd$ID_in_tree

d2 <- dd[, c(6, 23:38)]  #select environmental variables
row.names(d2) <- dd$ID_in_tree
d2 <- na.omit(d2)

# Replace vegetation layer by numerical variable (1:
# ground, 2: shrub, 3: canopy)
for (i in 1:length(d2$vegetation_layer)) {
    if (d2$vegetation_layer[i] == "ground/shrub") {
        d2$vegetation_layer[i] <- 1
    }
    if (d2$vegetation_layer[i] == "shrub/understory") {
        d2$vegetation_layer[i] <- 2
    }
    if (d2$vegetation_layer[i] == "understory/canopy") {
        d2$vegetation_layer[i] <- 3
    } else {
    }
```

```
}
d2$vegetation_layer <- as.numeric(d2$vegetation_layer)
d2 <- as.data.frame(scale(d2))

### Make phylogenetic tree match Cleaning both the data and
### the tree
cleaned_data <- clean.data(d2, ttree)
## Extracting the cleaned dataset and the cleaned tree
df <- cleaned_data$data
tttree <- cleaned_data$tree
name.check(tttree, df)
```

```
## [1] "OK"
```

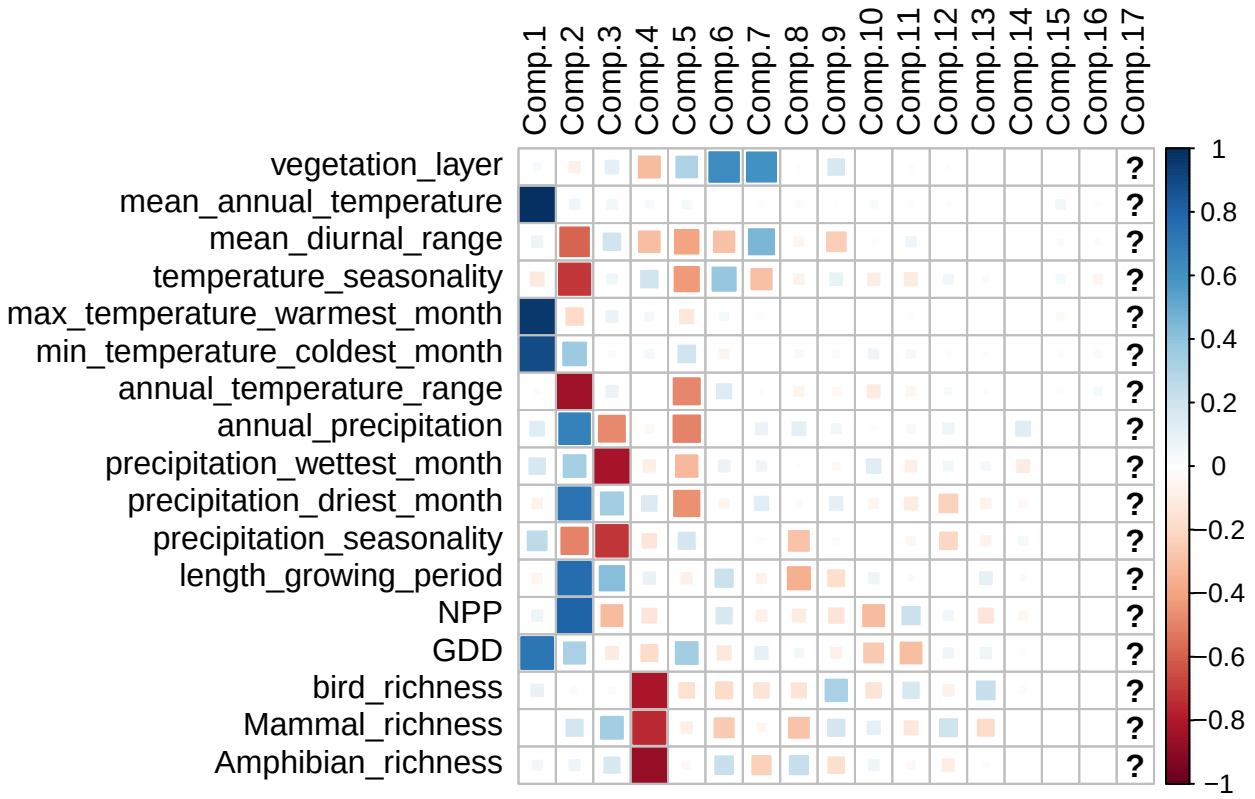
```
# reorder data to match the order of tips in tree
d2 <- ReorderData(tttree, df, taxa.names = "row names")
```

Climate PCA

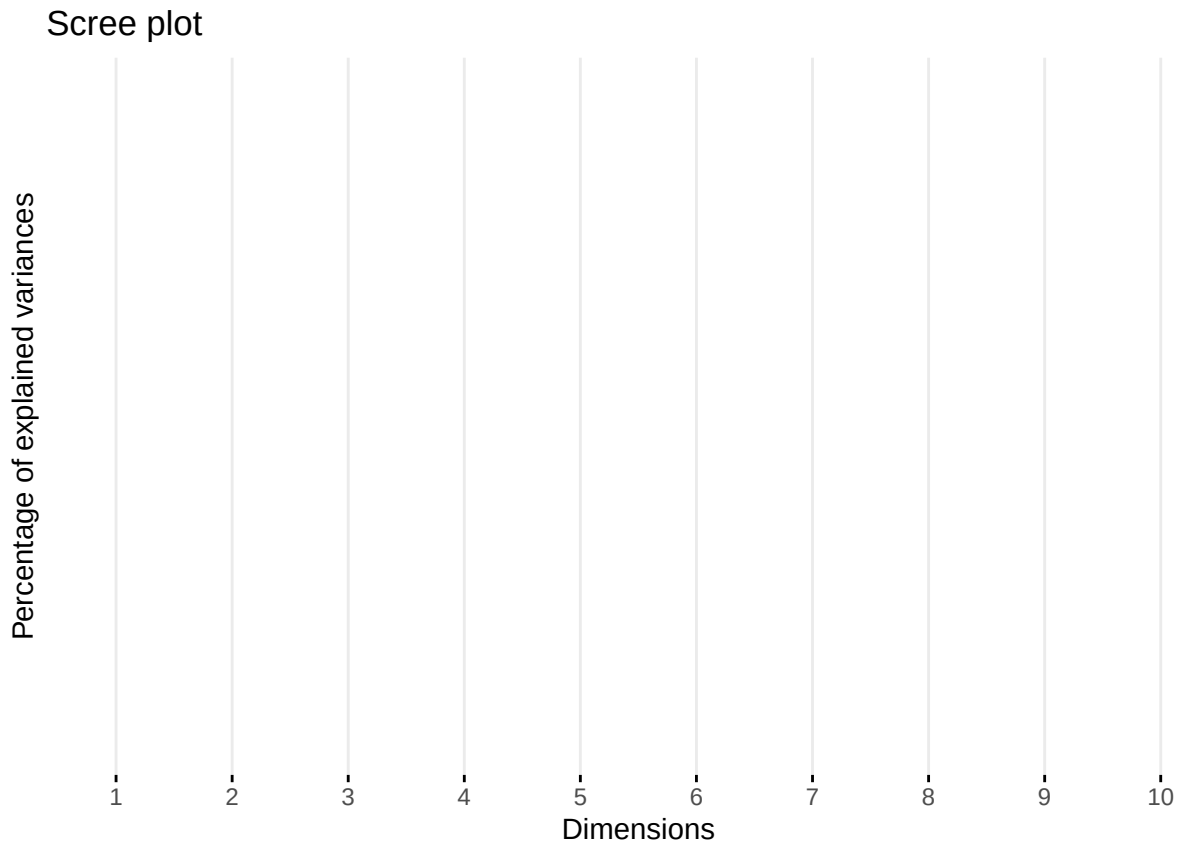
```
dpca <- d2
dpca <- na.omit(dpca)

pPCA <- phyl.pca(tttree, dpca, method = "BM")
summary(pPCA)
```

```
## Importance of components:
##                             PC1       PC2       PC3        PC4        PC5
## Standard deviation     0.5455323 0.3882250 0.2771509 0.25576341 0.22392173
## Proportion of Variance 0.4036433 0.2044202 0.1041812 0.08872247 0.06800632
## Cumulative Proportion  0.4036433 0.6080635 0.7122447 0.80096721 0.86897353
##                             PC6        PC7        PC8        PC9       PC10
## Standard deviation     0.15941376 0.15142607 0.11674505 0.09962367 0.08492155
## Proportion of Variance 0.03446739 0.03109984 0.01848561 0.01346114 0.00978121
## Cumulative Proportion  0.90344091 0.93454075 0.95302636 0.96648750 0.97626871
##                            PC11        PC12        PC13        PC14
## Standard deviation     0.080500684 0.075419421 0.057272677 0.036814134
## Proportion of Variance 0.008789333 0.007714773 0.004448891 0.001838171
## Cumulative Proportion  0.985058041 0.992772815 0.997221705 0.999059877
##                             PC15         PC16          PC17
## Standard deviation     0.0222658568 0.0140493045           NaN
## Proportion of Variance 0.0006724122 0.0002677111 -6.531736e-17
## Cumulative Proportion  0.9997322889 1.0000000000  1.000000e+00
```

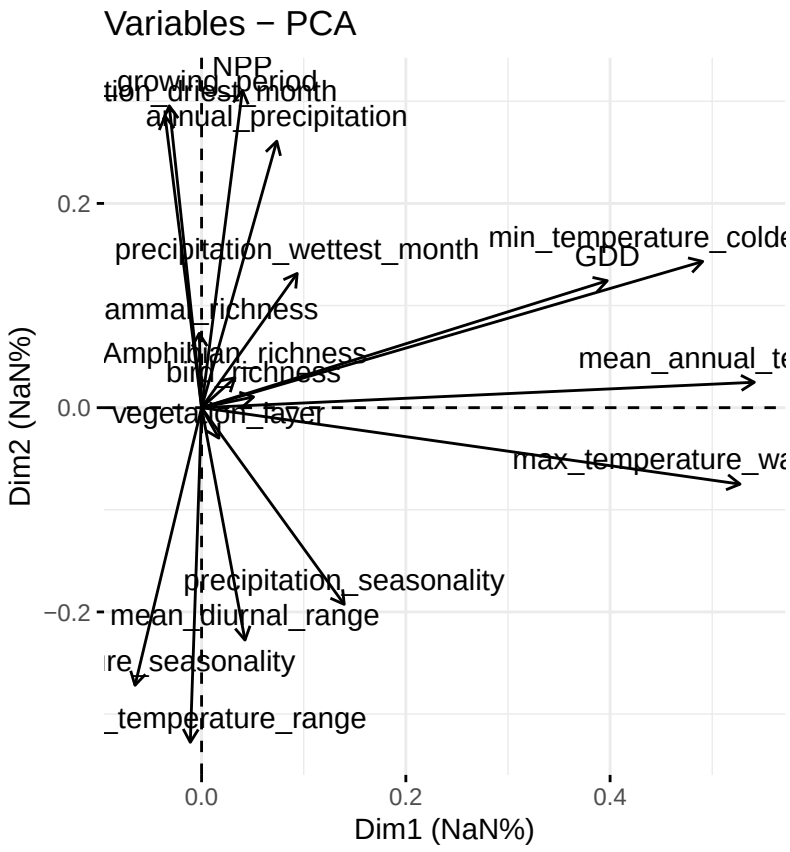
```
pPCA <- as.princomp(pPCA)

# Loadings correlation plot
corrplot(pPCA$loadings, method = "square", tl.col = "black")
```



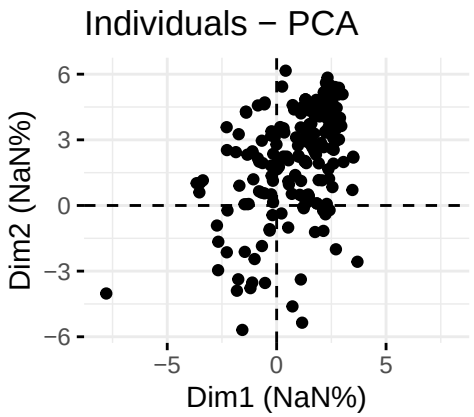

```
# Screeplot
fviz_screeplot(pPCA, addlabels = TRUE)
```

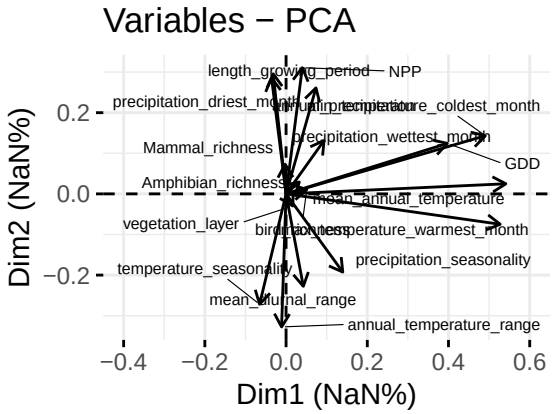



```
# Correlation circle
fviz_pca_var(pPCA, col.var = "black") + coord_fixed()
```

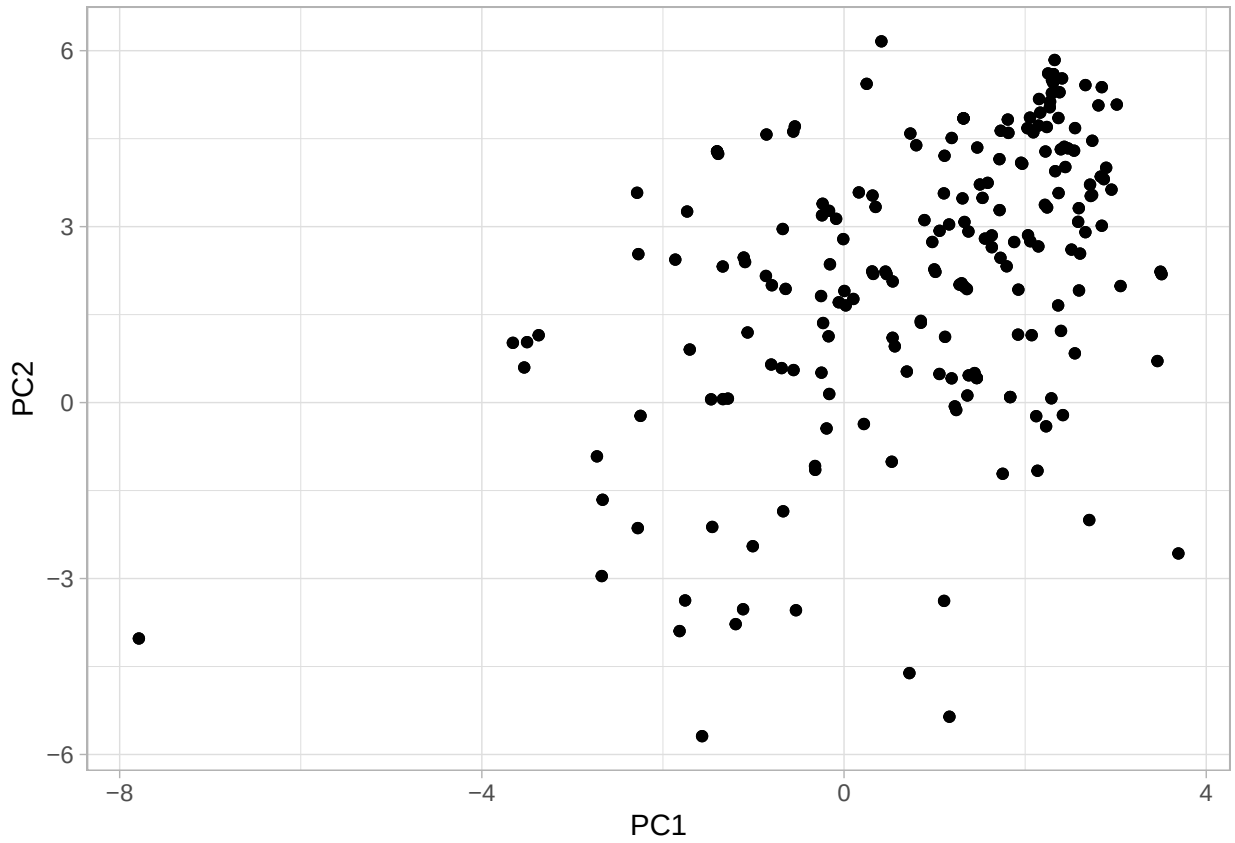



```
pp <- fviz_eig(pPCA)
pp2 <- fviz_pca_ind(pPCA, geom = c("point"), repel = TRUE)
pp2 <- pp2 + coord_fixed() + xlim(-8, 8)
pp3 <- fviz_pca_var(pPCA, repel = TRUE, labelsize = 2)
pp3 <- pp3 + coord_fixed() + xlim(-0.4, 0.6)
plot_grid(pp, pp2, pp3, nrow = 2)
```

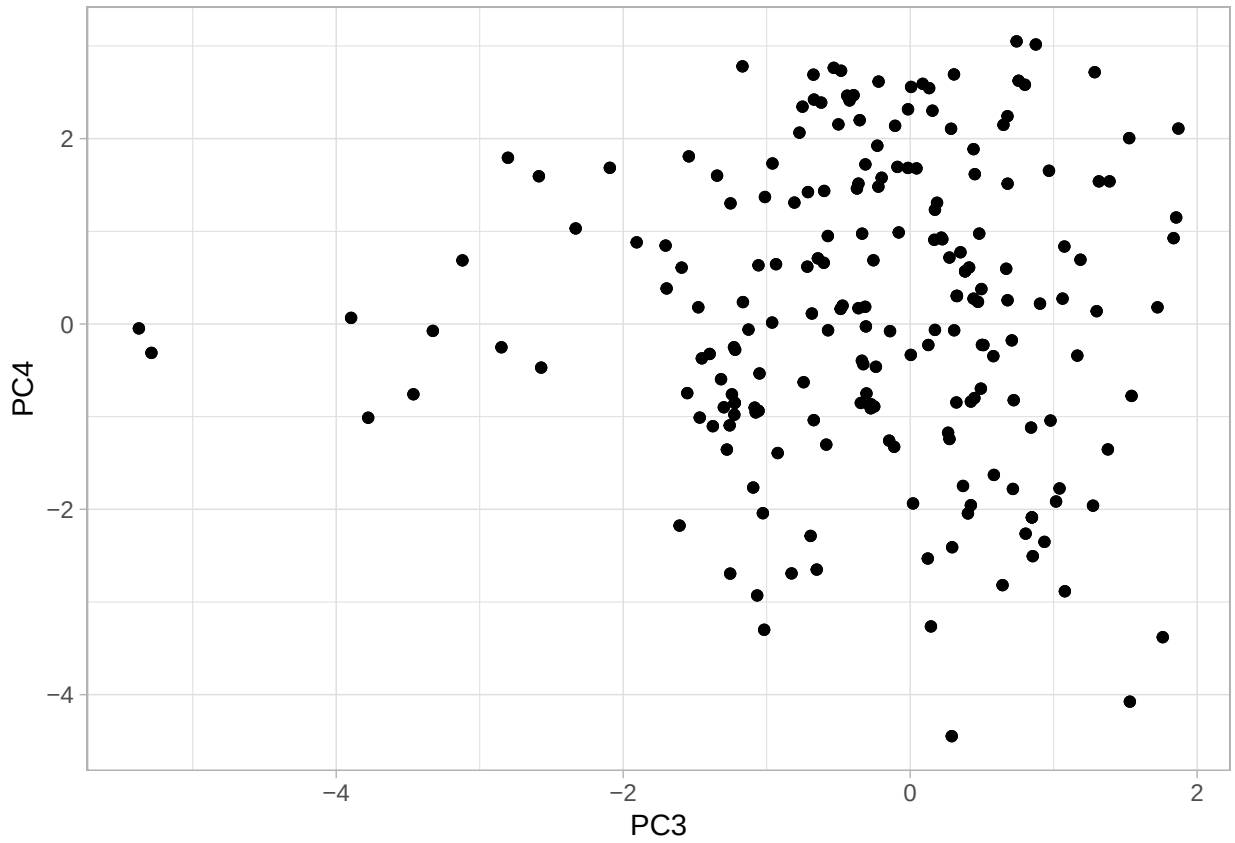





```
pcar <- as.data.frame(pPCA$scores)
ggplot(pcar, aes(x = Comp.1, y = Comp.2, label = rownames(pcar))) +
    geom_point() + #geom_text() + geom_point() +
    geom_point() + #geom_text() + #geom_text() +
xlab("PC1") + ylab("PC2") + theme_light()
```




```
ggplot(pcar, aes(x = Comp.3, y = Comp.4, label = rownames(pcar))) +
    geom_point() + #geom_text() + geom_point() +
    geom_point() + #geom_text() + #geom_text() +
xlab("PC3") + ylab("PC4") + theme_light()
```




```
# Take the first 6 dimensions (accounting for 90.3% of the
# variation)
denv <- as.data.frame(pcar[, 1:6])
colnames(denv) <- c("PC1", "PC2", "PC3", "PC4", "PC5", "PC6")
denv$species <- row.names(denv)

# Add habitat column
hab <- as.data.frame(dd$habitat)
hab$species <- row.names(dd)
colnames(hab) <- c("habitat", "species")
env_space <- merge(denv, hab, by = "species")
```

Hypervolume size

Kernel density estimates

```
# Create appropriate dataset with 6 first dimensions of
# morphospace
Xrb <- matrix(nrow = length(env_space$habitat), ncol = 7)
colnames(Xrb) <- c("habitat", "PC1", "PC2", "PC3", "PC4", "PC5",
    "PC6")
Xrb <- as.data.frame(Xrb)
Xrb$habitat <- as.character(env_space$habitat)
```

```
Xrb$PC1 <- as.numeric(env_space$PC1)
Xrb$PC2 <- as.numeric(env_space$PC2)
Xrb$PC3 <- as.numeric(env_space$PC3)
Xrb$PC4 <- as.numeric(env_space$PC4)
Xrb$PC5 <- as.numeric(env_space$PC5)
Xrb$PC6 <- as.numeric(env_space$PC6)

## Using hypervolume package
Xrb_litter = Xrb[Xrb$habitat == "laying on leaf litter, logs, bark, trunk",
    c("PC1", "PC2", "PC3", "PC4", "PC5", "PC6")]
Xrb_hang = Xrb[Xrb$habitat == "hanging from branches and leaves",
    c("PC1", "PC2", "PC3", "PC4", "PC5", "PC6")]
Xrb_branch = Xrb[Xrb$habitat == "laying on branches and leaves",
    c("PC1", "PC2", "PC3", "PC4", "PC5", "PC6")]
Xrb_grass = Xrb[Xrb$habitat == "hanging from grass", c("PC1",
    "PC2", "PC3", "PC4", "PC5", "PC6")]
Xrb_palm = Xrb[Xrb$habitat == "laying on palm leaves", c("PC1",
    "PC2", "PC3", "PC4", "PC5", "PC6")]


vol <- as.data.frame(matrix(nrow = 5, ncol = 2))
colnames(vol) <- c("volume", "habitat")
vol$habitat <- c("laying on leaf litter, logs, bark, trunk",
    "hanging from branches and leaves", "laying on branches and leaves",
    "hanging from grass", "laying on palm leaves")

hv1 = hypervolume_box(Xrb_litter, name = "litter")
```

```
##
## Building tree...
## done.
## Ball query...
##
## done.
## Binding random points... done.
## Beginning volume calculation... done.
```

```
hv2 = hypervolume_box(Xrb_hang, name = "hang")
```

```
##
## Building tree...
## done.
## Ball query...
##
## done.
## Binding random points... done.
## Beginning volume calculation... done.
```

```
hv3 = hypervolume_box(Xrb_branch, name = "branch")
```

```
##
```

```
## Building tree...
## done.
## Ball query...
##
## done.
## Binding random points... done.
## Beginning volume calculation... done.
```

```
hv4 = hypervolume_box(Xrb_grass, name = "grass")
```

```
##
## Building tree...
## done.
## Ball query...
##
## done.
## Binding random points... done.
## Beginning volume calculation... done.
```

```
hv5 = hypervolume_box(Xrb_palm, name = "palm")
```

```
##
## Building tree...
## done.
## Ball query...
##
## done.
## Binding random points... done.
## Beginning volume calculation... done.
```

```
vol[1, 1] <- get_volume(hv1)
vol[2, 1] <- get_volume(hv2)
vol[3, 1] <- get_volume(hv3)
vol[4, 1] <- get_volume(hv4)
vol[5, 1] <- get_volume(hv5)

p1 <- ggplot(vol, aes(x = habitat, y = volume, fill = habitat)) +
    geom_bar(position = "dodge", stat = "identity") + xlab("Habitat") +
    ylab("Hypervolume size") + scale_fill_manual(values = c("darkseagreen",
    "gold", "darkorange", "darkred", "dodgerblue")) + scale_x_discrete(labels = NULL,
    breaks = NULL) + labs(title = "Kernel density estimates") +
    theme_classic()
```

Dynamic range boxes

```
## Using dynRB Size and pairwise overlap
r <- dynRB_VPa(Xrb)
```

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

```
## [1] 3
## [1] 4
## [1] 5
## [1] 6
## [1] 7
## [1] 8
## [1] 9
## [1] 10
## [1] 11
## [1] 12
## [1] 13
## [1] 14
## [1] 15
## [1] 16
## [1] 17
## [1] 18
## [1] 19
## [1] 20
## [1] 21
## [1] 22
## [1] 23
## [1] 24
## [1] 25
##                                         V1
## 1          hanging from branches and leaves
## 2                          hanging from grass
## 3             laying on branches and leaves
## 4  laying on leaf litter, logs, bark, trunk
## 5                       laying on palm leaves
## 6          hanging from branches and leaves
## 7                          hanging from grass
## 8             laying on branches and leaves
## 9  laying on leaf litter, logs, bark, trunk
## 10                      laying on palm leaves
## 11         hanging from branches and leaves
## 12                         hanging from grass
## 13            laying on branches and leaves
## 14 laying on leaf litter, logs, bark, trunk
## 15                      laying on palm leaves
## 16         hanging from branches and leaves
## 17                         hanging from grass
## 18            laying on branches and leaves
## 19 laying on leaf litter, logs, bark, trunk
## 20                      laying on palm leaves
## 21         hanging from branches and leaves
## 22                         hanging from grass
## 23            laying on branches and leaves
## 24 laying on leaf litter, logs, bark, trunk
## 25                      laying on palm leaves
##                                         V2    port_prod vol_V1_prod
## 1          hanging from branches and leaves 1.0000000000 0.097187554
## 2          hanging from branches and leaves 0.0214109091 0.006420454
## 3          hanging from branches and leaves 0.3554436485 0.035481683
## 4          hanging from branches and leaves 0.3279836889 0.076003751
```

```
## 5          hanging from branches and leaves 0.0101317587 0.000720669
## 6                        hanging from grass 0.3018722223 0.097187554
## 7                        hanging from grass 1.0000000000 0.006420454
## 8                        hanging from grass 0.2190941799 0.035481683
## 9                        hanging from grass 0.4015063722 0.076003751
## 10                       hanging from grass 0.0002453835 0.000720669
## 11            laying on branches and leaves 0.7080513951 0.097187554
## 12            laying on branches and leaves 0.0382763788 0.006420454
## 13            laying on branches and leaves 1.0000000000 0.035481683
## 14            laying on branches and leaves 0.4618436884 0.076003751
## 15            laying on branches and leaves 0.0133699268 0.000720669
## 16 laying on leaf litter, logs, bark, trunk 0.4144429486 0.097187554
## 17 laying on leaf litter, logs, bark, trunk 0.0418683796 0.006420454
## 18 laying on leaf litter, logs, bark, trunk 0.2852640434 0.035481683
## 19 laying on leaf litter, logs, bark, trunk 1.0000000000 0.076003751
## 20 laying on leaf litter, logs, bark, trunk 0.0082480308 0.000720669
## 21                    laying on palm leaves 0.8145171129 0.097187554
## 22                    laying on palm leaves 0.0020736525 0.006420454
## 23                    laying on palm leaves 0.5699490799 0.035481683
## 24                    laying on palm leaves 0.5795862151 0.076003751
## 25                    laying on palm leaves 1.0000000000 0.000720669
##    vol_V2_prod
## 1  0.097187554
## 2  0.097187554
## 3  0.097187554
## 4  0.097187554
## 5  0.097187554
## 6  0.006420454
## 7  0.006420454
## 8  0.006420454
## 9  0.006420454
## 10 0.006420454
## 11 0.035481683
## 12 0.035481683
## 13 0.035481683
## 14 0.035481683
## 15 0.035481683
## 16 0.076003751
## 17 0.076003751
## 18 0.076003751
## 19 0.076003751
## 20 0.076003751
## 21 0.000720669
## 22 0.000720669
## 23 0.000720669
## 24 0.000720669
## 25 0.000720669
```

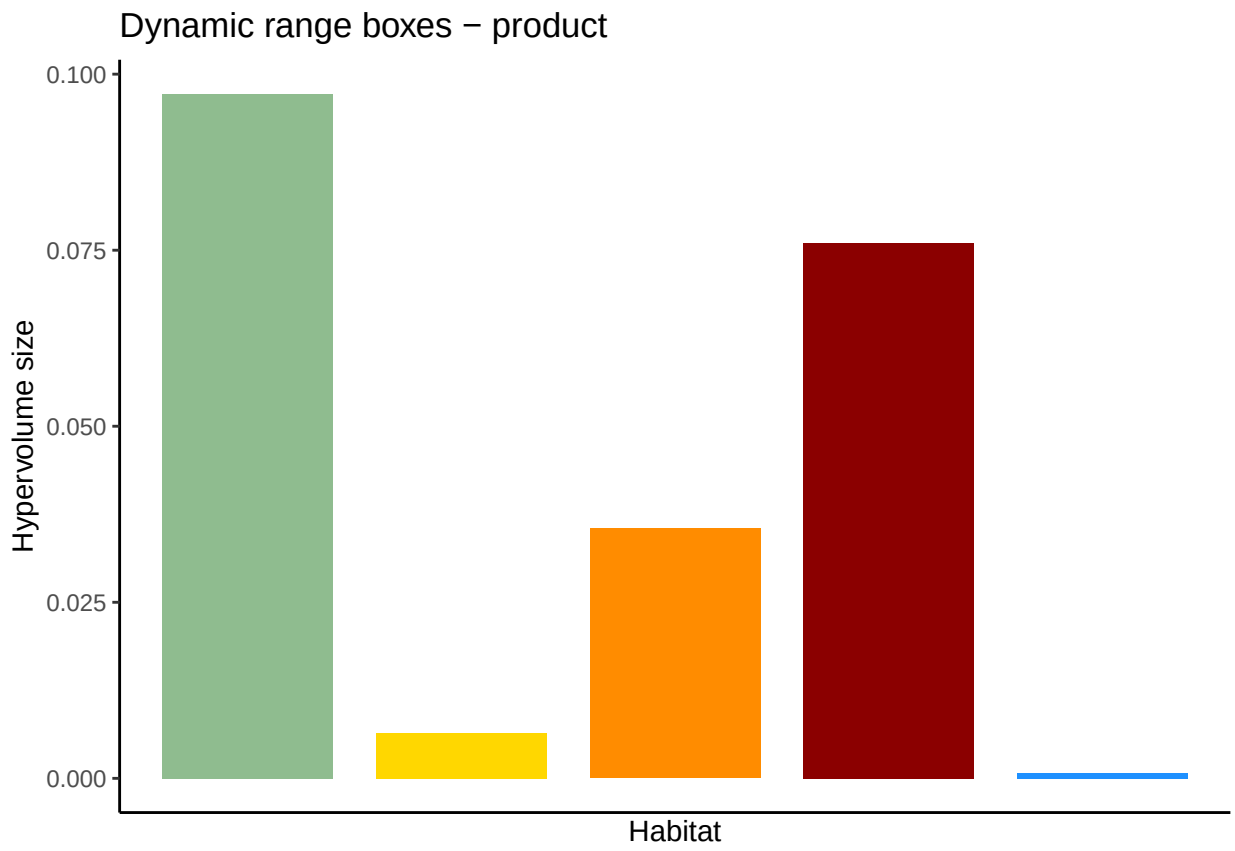
```
r$result
```

```
##                                       V1
## 1          hanging from branches and leaves
## 2                        hanging from grass
## 3             laying on branches and leaves
```

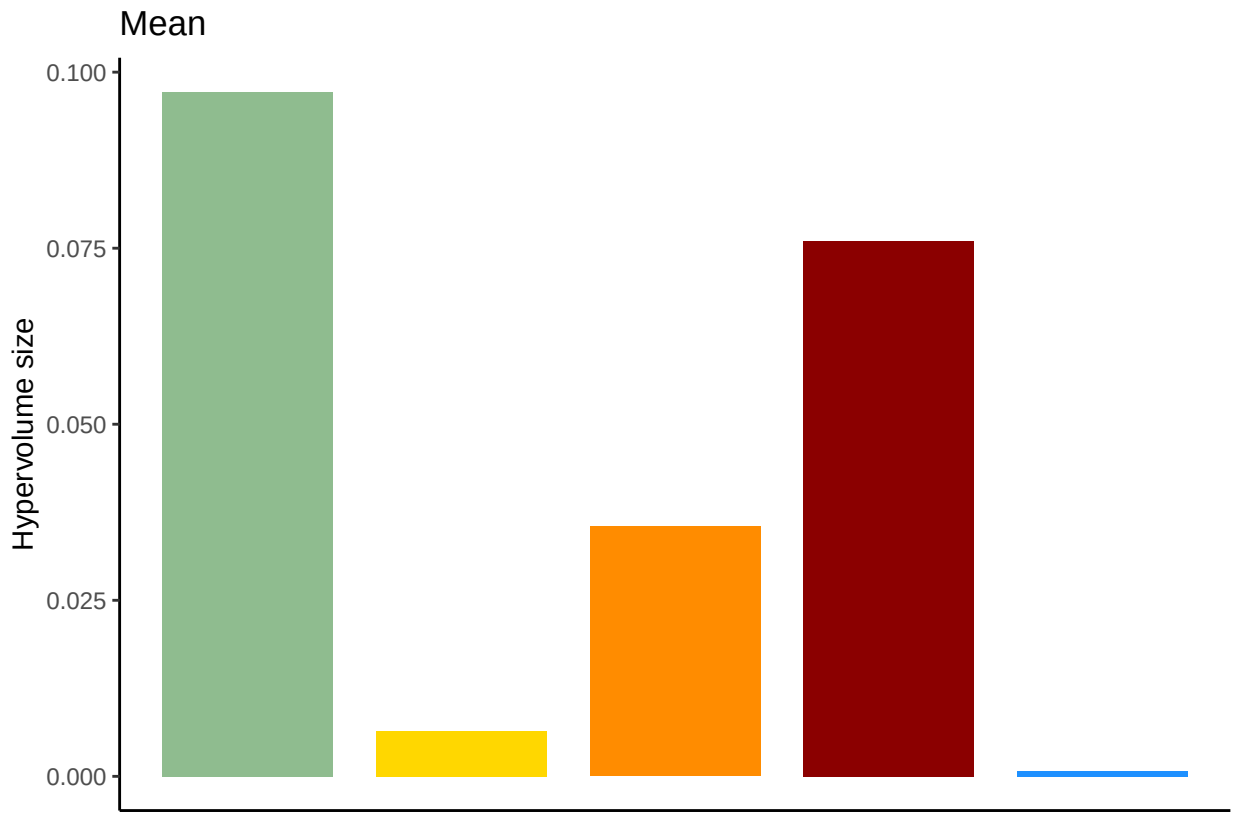
```
## 4  laying on leaf litter, logs, bark, trunk
## 5                      laying on palm leaves
## 6           hanging from branches and leaves
## 7                          hanging from grass
## 8              laying on branches and leaves
## 9  laying on leaf litter, logs, bark, trunk
## 10                     laying on palm leaves
## 11          hanging from branches and leaves
## 12                         hanging from grass
## 13             laying on branches and leaves
## 14 laying on leaf litter, logs, bark, trunk
## 15                     laying on palm leaves
## 16          hanging from branches and leaves
## 17                         hanging from grass
## 18             laying on branches and leaves
## 19 laying on leaf litter, logs, bark, trunk
## 20                     laying on palm leaves
## 21          hanging from branches and leaves
## 22                         hanging from grass
## 23             laying on branches and leaves
## 24 laying on leaf litter, logs, bark, trunk
## 25                     laying on palm leaves
##                                         V2    port_prod port_mean port_gmean
## 1           hanging from branches and leaves 1.0000000000 1.0000000 1.00000000
## 2           hanging from branches and leaves 0.0214109091 0.4995906 0.43277356
## 3           hanging from branches and leaves 0.3554436485 0.8393246 0.83565413
## 4           hanging from branches and leaves 0.3279836889 0.8326677 0.82049163
## 5           hanging from branches and leaves 0.0101317587 0.4601335 0.44319774
## 6                          hanging from grass 0.3018722223 0.7210752 0.64644967
## 7                          hanging from grass 1.0000000000 1.0000000 1.00000000
## 8                          hanging from grass 0.2190941799 0.6873573 0.59145444
## 9                          hanging from grass 0.4015063722 0.8037271 0.67871730
## 10                         hanging from grass 0.0002453835 0.3676887 0.06811329
## 11             laying on branches and leaves 0.7080513951 0.9352841 0.93707532
## 12             laying on branches and leaves 0.0382763788 0.5344836 0.45329544
## 13             laying on branches and leaves 1.0000000000 1.0000000 1.00000000
## 14             laying on branches and leaves 0.4618436884 0.8655839 0.86686431
## 15             laying on branches and leaves 0.0133699268 0.4790873 0.45321769
## 16 laying on leaf litter, logs, bark, trunk 0.4144429486 0.8574291 0.85156034
## 17 laying on leaf litter, logs, bark, trunk 0.0418683796 0.5626040 0.47487859
## 18 laying on leaf litter, logs, bark, trunk 0.2852640434 0.8055650 0.80159596
## 19 laying on leaf litter, logs, bark, trunk 1.0000000000 1.0000000 1.00000000
## 20 laying on leaf litter, logs, bark, trunk 0.0082480308 0.4318278 0.38420358
## 21                     laying on palm leaves 0.8145171129 0.9561271 0.93438447
## 22                     laying on palm leaves 0.0020736525 0.5203652 0.09723164
## 23                     laying on palm leaves 0.5699490799 0.8924510 0.85201334
## 24                     laying on palm leaves 0.5795862151 0.8844649 0.78094260
## 25                     laying on palm leaves 1.0000000000 1.0000000 1.00000000
##    vol_V1_prod vol_V1_mean vol_V1_gmean vol_V2_prod vol_V2_mean vol_V2_gmean
## 1  0.097187554   0.9592122    0.9550130 0.097187554   0.9592122    0.9550130
## 2  0.006420454   0.7795008    0.7737219 0.097187554   0.9592122    0.9550130
## 3  0.035481683   0.8938553    0.8856993 0.097187554   0.9592122    0.9550130
## 4  0.076003751   0.9453340    0.9382550 0.097187554   0.9592122    0.9550130
## 5  0.000720669   0.6204625    0.6183855 0.097187554   0.9592122    0.9550130
```

```
## 6  0.097187554   0.9592122    0.9550130 0.006420454   0.7795008    0.7737219
## 7  0.006420454   0.7795008    0.7737219 0.006420454   0.7795008    0.7737219
## 8  0.035481683   0.8938553    0.8856993 0.006420454   0.7795008    0.7737219
## 9  0.076003751   0.9453340    0.9382550 0.006420454   0.7795008    0.7737219
## 10 0.000720669   0.6204625    0.6183855 0.006420454   0.7795008    0.7737219
## 11 0.097187554   0.9592122    0.9550130 0.035481683   0.8938553    0.8856993
## 12 0.006420454   0.7795008    0.7737219 0.035481683   0.8938553    0.8856993
## 13 0.035481683   0.8938553    0.8856993 0.035481683   0.8938553    0.8856993
## 14 0.076003751   0.9453340    0.9382550 0.035481683   0.8938553    0.8856993
## 15 0.000720669   0.6204625    0.6183855 0.035481683   0.8938553    0.8856993
## 16 0.097187554   0.9592122    0.9550130 0.076003751   0.9453340    0.9382550
## 17 0.006420454   0.7795008    0.7737219 0.076003751   0.9453340    0.9382550
## 18 0.035481683   0.8938553    0.8856993 0.076003751   0.9453340    0.9382550
## 19 0.076003751   0.9453340    0.9382550 0.076003751   0.9453340    0.9382550
## 20 0.000720669   0.6204625    0.6183855 0.076003751   0.9453340    0.9382550
## 21 0.097187554   0.9592122    0.9550130 0.000720669   0.6204625    0.6183855
## 22 0.006420454   0.7795008    0.7737219 0.000720669   0.6204625    0.6183855
## 23 0.035481683   0.8938553    0.8856993 0.000720669   0.6204625    0.6183855
## 24 0.076003751   0.9453340    0.9382550 0.000720669   0.6204625    0.6183855
## 25 0.000720669   0.6204625    0.6183855 0.000720669   0.6204625    0.6183855
```

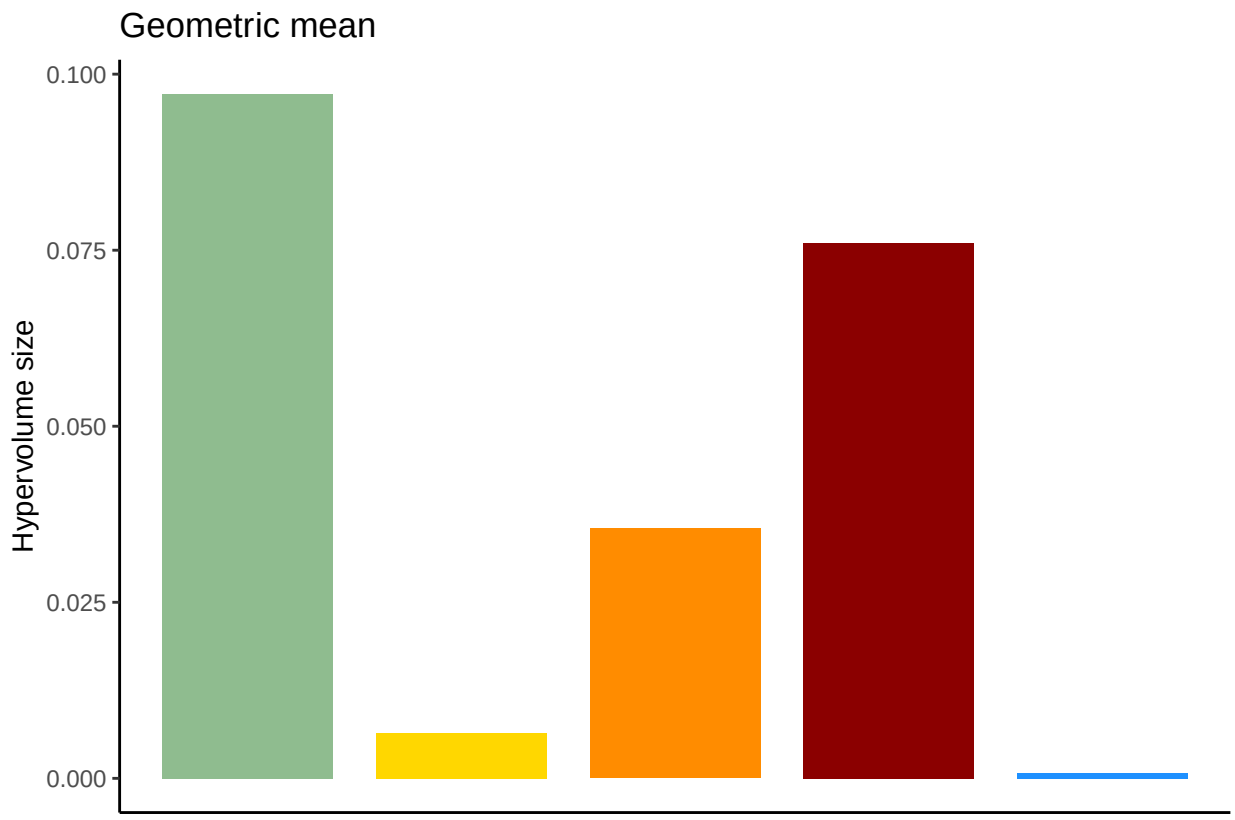
```
# Plot full hypervolume size
result <- r$result
voll <- as.data.frame(matrix(nrow = 5, ncol = 2))
colnames(voll) <- c("volume", "habitat")
voll$habitat <- c("hanging from branches and leaves", "hanging from grass",
    "laying on branches and leaves", "laying on leaf litter, logs, bark, trunk",
    "laying on palm leaves")
# product
voll[, 1] <- c(result[1:5, 6])
p2 <- ggplot(voll, aes(x = habitat, y = volume)) + xlab("Habitat") +
    ylab("Hypervolume size") + geom_bar(aes(fill = habitat),
    stat = "identity", width = 0.8) + scale_fill_manual(values = c("darkseagreen",
    "gold", "darkorange", "darkred", "dodgerblue")) + ylab("Hypervolume size") +
    # xlab('')+
labs(title = "Dynamic range boxes - product") + scale_x_discrete(labels = NULL,
    breaks = NULL) + guides(fill = F) + theme_classic()
p2
```



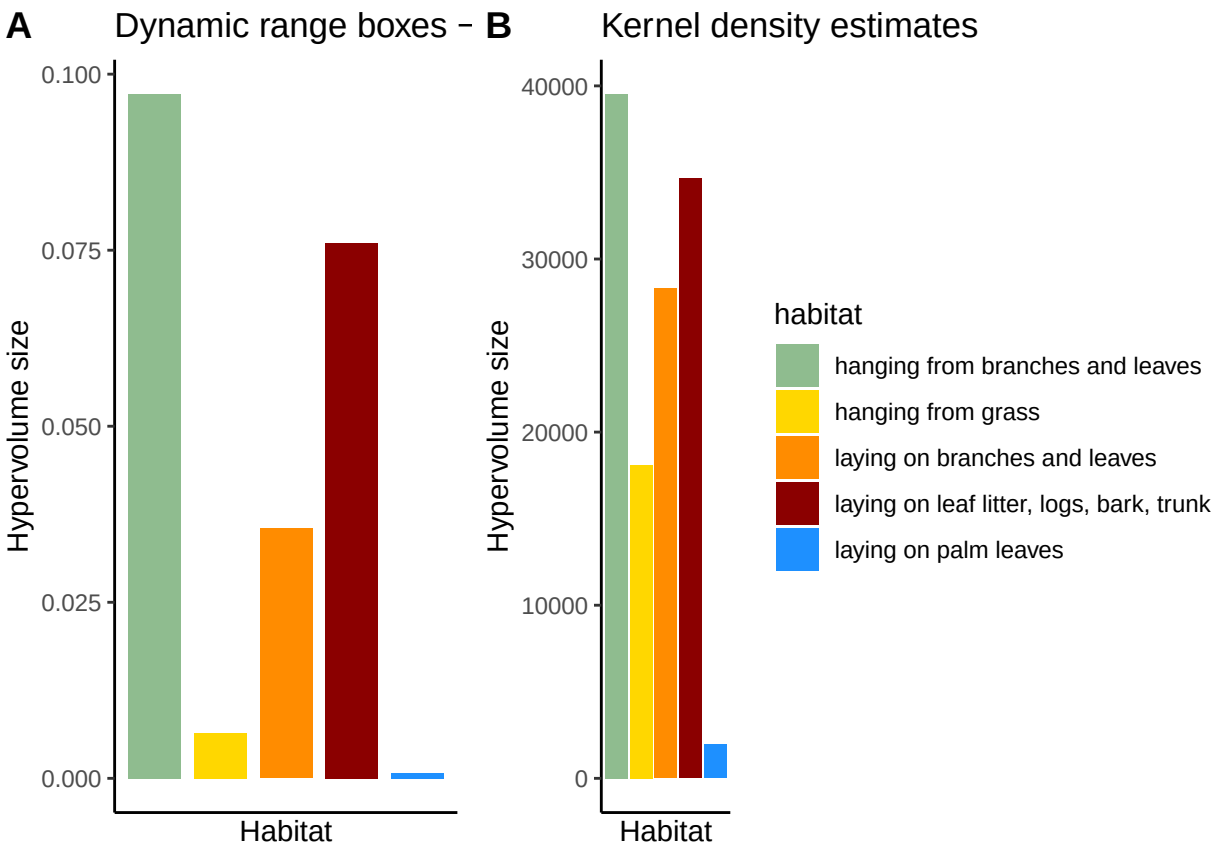

```
# mean
vol[, 1] <- c(result[1:5, 7])
ggplot(voll, aes(x = habitat, y = volume)) + geom_bar(aes(fill = habitat),
    stat = "identity", width = 0.8) + scale_fill_manual(values = c("darkseagreen",
    "gold", "darkorange", "darkred", "dodgerblue")) + ylab("Full niche hypervolume") +
    ylab("Hypervolume size") + xlab("") + labs(title = "Mean") +
    scale_x_discrete(labels = NULL, breaks = NULL) + guides(fill = F) +
    theme_classic()
```




```
# gmean
vol[, 1] <- c(result[1:5, 8])
ggplot(voll, aes(x = habitat, y = volume)) + geom_bar(aes(fill = habitat),
    stat = "identity", width = 0.8) + scale_fill_manual(values = c("darkseagreen",
    "gold", "darkorange", "darkred", "dodgerblue")) + ylab("Full niche hypervolume") +
    ylab("Hypervolume size") + xlab("") + labs(title = "Geometric mean") +
    scale_x_discrete(labels = NULL, breaks = NULL) + guides(fill = F) +
    theme_classic()
```




```
# Final
plot_grid(p2, p1, nrow = 1, rel_widths = c(1, 1.6), labels = "AUTO")
```


A
Dynamic range boxes
B
Kernel density estimates
Hypervolume size
0.100
0.075
0.050
0.025
0.000
Habitat
40000
30000
20000
10000
0
habitat
hanging from branches and leaves
hanging from grass
laying on branches and leaves
laying on leaf litter, logs, bark, trunk
laying on palm leaves