

# Rock Lichen data from Sunset Crater

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April 23, 2021

## Data Summary

- This is an analysis of the effect of Pinyon Pine tree traits on the saxicole (lichen and moss) community on rocks under the canopy of the trees.
- Trees were sampled in a pairwise design in which pairs were comprised of one tree that is susceptible to the herbivory of a stem boring moth (*Diorictria abietella*) and an adjacent tree that is resistant to the moth.
- As tree resistance to the moth is genetically based, pairwise sampling was conducted in order to isolate this genetic effect.
- Some trees that were sampled were dead, these trees were removed from the analysis.
- Plant data were observed by R. Michalet
  - Vegetation.xlsx
  - Light penetration.xls
  - light\_&\_litter(1).xls

## Main Results

- Rock epiphyte communities were adequately sampled, based on species accumulation curves, with moth resistant trees accumulating slightly more lichen species.
- Several tree variables, including light availability, leaf litter abundance and rock abundance, were impacted by moth susceptibility, creating strong differences in sub-canopy conditions.
- Saxicole community abundance, richness, diversity, composition were significantly, generally negatively, affected by moth herbivory.
- Correlation analysis supported an indirect link between genetically based moth susceptibility and impacts on lichen communities via decreasing rock (i.e. habitat) availability through increased leaf abscission and accumulation on rocks under trees.

## Analysis and Results

Analyses were conducted in the **R** statistical programming language. The following section loads dependencies and custom functions used in the analysis.

### Dependencies

```
cran.pkgs <- c("reshape2", "vegan", "ecodist", "xtable", "knitr",  
              "semPlot", "lavaan", "piecewiseSEM", "distantia",  
              "tidySEM", "readxl", "psych")  
  
## install packages that are not installed  
if (any(!(cran.pkgs %in% installed.packages()[, 1]))) {
```

```

sapply(cran.pkgs[which(!(cran.pkgs %in%
                        installed.packages()[, 1]))],
       install.packages,
       dependencies = TRUE,
       repos = 'http://cran.us.r-project.org')
}

## Load libraries
sapply(cran.pkgs, library, quietly = TRUE, character.only = TRUE)

## Custom Functions

## se: Calculate the standard error of a variable.
se <- function(x){sd(x) / sqrt(length(x))}

```

## Load Data

The following are variable descriptions (Variable, Type, Range, Definition):

- Moth,categorical,0 or 1,Was the tree susceptible (0) or resistant (1) to moth attack
- Live/Dead,categorical,0 or 1,Was the tree dead (0) or alive (1)
- Litter %,continuous,0 to 100,Percent cover inside quadrat
- Rocks > 3cm %,continuous,0 to 100,Percent cover of rocks > 3cm? inside quadrat
- Rocks < 3cm %,continuous,0 to 100,Percent cover of rocks < 3cm? inside quadrat
- Shrubs %,continuous,0 to 100,Percent cover of shrubs inside quadrat
- Grass %,continuous,0 to 100,Percent cover of grass inside quadrat
- Branches %,continuous,0 to 100,Percent cover of branches on ground inside quadrat
- Distance,continuous,0 to 100,“Distance from main trunk, converted to percent of crown radius at that azimuth”
- Azimuth,continuous,0 to 360,Compass direction from main trunk
- Slope,continuous,0 to 90,Topographical steepness
- Aspect,continuous,0 to 360,Compass direction of slope
- Light,continuous,,Amount of light available to epiliths

```

## Data are in ../data/scrl
l.dat <- read.csv("../data/spp_env_combined.csv")

## Fix species names
colnames(l.dat)[colnames(l.dat) == "Acasup"] <- "Acaame"

## Summary of data
summary(l.dat)

## remove dead trees
l.dat <- l.dat[l.dat[, "Live.Dead"] != 0, ]

## Lichen species list
spp.l <- c("Acacon", "Acaame", "Acaobp", "Sterile.sp", "Brown.cr",
"Lobalp", "Canros", "Calare", "Phydub", "Rhichr", "Xanlin", "Xanpli",
"Xanele", "GrBr.cr", "Gray.cr")
spp.moss <- c("Synrur", "Cerpur.Bryarg")

## Create a community matrix
com <- l.dat[, colnames(l.dat) %in% c(spp.l, spp.moss)]

```

```

com.moss <- l.dat[, colnames(l.dat) %in% spp.moss]

## Add the tree labels to the rownames
rownames(com) <- paste(l.dat[, "Moth"], l.dat[, "Tree.pairs"], sep = "_")
rownames(com.moss) <- paste(l.dat[, "Moth"], l.dat[, "Tree.pairs"], sep = "_")
rownames(l.dat) <- paste(l.dat[, "Moth"], l.dat[, "Tree.pairs"], sep = "_")

## Paired environmental differences
total.rocks <- apply(l.dat[, c("Big.rocks..", "Small.rocks..")], 1, sum)
env <- l.dat[, c("Litter..", "Big.rocks..", "Small.rocks..",
                "Shrubs..", "Grass..", "Branches..",
                "Light...N", "Light...S", "Light...average")]
env <- cbind(env, total.rocks)
env.dif <- apply(env, 2, function(x, p) tapply(x, p, diff), p = l.dat[, "Tree.pairs"])

```

## Saxicole communities were sufficiently sampled

```

spa.all <- specaccum(com, method = "exact")
spa.res <- specaccum(com[l.dat[, "Moth"] == 1, ], method = "exact")
spa.sus <- specaccum(com[l.dat[, "Moth"] == 0, ], method = "exact")

plot(spa.all,
     ylim = c(0, 20),
     xlab = "Cumulative Trees Sampled",
     ylab = "Species Observed",
     col = "grey", ci.col = 'lightgrey', ci.type = "poly", ci.lty = 0)
plot(spa.res, ci.col = "black", ci.type = "bar", lty = 1, add = TRUE, ci.lty = 1)
plot(spa.sus, ci.col = "black", ci.type = "bar", lty = 3, add = TRUE, ci.lty = 3)
legend("bottomright",
     legend = c("All", "Resistant", "Susceptible"),
     lty = c(1, 1, 3), lwd = c(5, 2, 2), col = c("lightgrey", "black", "black"))

```



```
pdf("./results/srcl_spp-accum.pdf", width = 5, height = 5)
plot(spa.all,
     ylim = c(0, 20),
     xlab = "Cumulative Trees Sampled",
     ylab = "Species Observed",
     col = "grey", ci.col = 'lightgrey', ci.type = "poly", ci.lty = 0)
plot(spa.res, ci.col = "black", ci.type = "bar", lty = 1, add = TRUE, ci.lty = 1)
plot(spa.sus, ci.col = "black", ci.type = "bar", lty = 3, add = TRUE, ci.lty = 3)
legend("bottomright",
     legend = c("All", "Resistant", "Susceptible"),
     lty = c(1, 1, 3), lwd = c(5, 2, 2), col = c("lightgrey", "black", "black"))
dev.off()
```

```
## pdf
## 2
```

## Moth trees have different microenvironments

```
env.test.l <- apply(env.dif, 2, t.test)
env.test.l <- lapply(env.test.l, unlist)
env.test.tab <- do.call(rbind, env.test.l)
env.test.tab <- env.test.tab[, c(1, 2, 3, 6, 4, 5)]
env.test.tab <- apply(env.test.tab, 2, as.numeric)
rownames(env.test.tab) <- names(env.test.l)
colnames(env.test.tab) <- c("t", "df", "p-value", "Mean Difference", "Lower CI 95%", "Upper CI 95%")
kable(env.test.tab, digits = 4)
```

|                 | t       | df | p-value | Mean Difference | Lower CI 95% | Upper CI 95% |
|-----------------|---------|----|---------|-----------------|--------------|--------------|
| Litter..        | 2.8665  | 29 | 0.0077  | 15.0700         | 4.3178       | 25.8222      |
| Big. rocks..    | -2.4617 | 29 | 0.0200  | -9.6837         | -17.7289     | -1.6384      |
| Small. rocks..  | -2.0792 | 29 | 0.0466  | -4.9750         | -9.8688      | -0.0812      |
| Shrubs..        | -1.7605 | 29 | 0.0889  | -0.5147         | -1.1126      | 0.0832       |
| Grass..         | -1.0000 | 29 | 0.3256  | -0.0493         | -0.1502      | 0.0516       |
| Branches..      | 1.0000  | 29 | 0.3256  | 0.1420          | -0.1484      | 0.4324       |
| Light...N       | -8.0191 | 29 | 0.0000  | -15.9767        | -20.0514     | -11.9019     |
| Light...S       | -7.5187 | 29 | 0.0000  | -14.2900        | -18.1772     | -10.4028     |
| Light...average | -9.2728 | 29 | 0.0000  | -15.1333        | -18.4712     | -11.7955     |
| total.rocks     | -2.8178 | 29 | 0.0086  | -14.6587        | -25.2983     | -4.0190      |

## Moth trees have different lichen communities

```
abun <- apply(com, 1, sum)
rich <- apply(com, 1, function(x) sum(sign(x)))
shan <- apply(com, 1, diversity, index = "shannon")
tt.a <- t.test(tapply(abun, l.dat[, "Tree.pairs"], diff))
tt.r <- t.test(tapply(rich, l.dat[, "Tree.pairs"], diff))
tt.h <- t.test(tapply(shan, l.dat[, "Tree.pairs"], diff))
tt.arh <- do.call(rbind,
     list(a = unlist(tt.a),
          r = unlist(tt.r),
          h = unlist(tt.h)))
tt.arh <- apply(tt.arh[, 1:6], 2, as.numeric)
```

```

ard.mu <- rbind(tapply(abun, l.dat[, "Moth"], mean),
               tapply(rich, l.dat[, "Moth"], mean),
               tapply(shan, l.dat[, "Moth"], mean))
ard.se <- rbind(tapply(abun, l.dat[, "Moth"], se),
               tapply(rich, l.dat[, "Moth"], se),
               tapply(shan, l.dat[, "Moth"], se))
ard.tab <- cbind(ard.mu[, "0"], ard.se[, "0"],
               ard.mu[, "1"], ard.se[, "1"])
colnames(ard.tab) <- c("Susceptible Mean", "Susceptible SE",
                     "Resistant Mean", "Resistant SE")
rownames(ard.tab) <- c("Abundance", "Richness", "Diversity (Shannon)")

kable(ard.tab, digits = 3)

```

|                     | Susceptible Mean | Susceptible SE | Resistant Mean | Resistant SE |
|---------------------|------------------|----------------|----------------|--------------|
| Abundance           | 1.210            | 0.351          | 2.754          | 0.567        |
| Richness            | 3.500            | 0.542          | 6.033          | 0.662        |
| Diversity (Shannon) | 0.707            | 0.119          | 1.144          | 0.125        |

```
kable(tt.arh, digits = 3)
```

| statistic.t | parameter.df | p.value | conf.int1 | conf.int2 | estimate.mean of x |
|-------------|--------------|---------|-----------|-----------|--------------------|
| -2.249      | 29           | 0.032   | -2.948    | -0.140    | -1.544             |
| -2.955      | 29           | 0.006   | -4.287    | -0.780    | -2.533             |
| -2.447      | 29           | 0.021   | -0.802    | -0.072    | -0.437             |

Composition is different (PERMANOVA, in text and supplement)

```

com.ds <- cbind(com, ds = rep(0.0001, nrow(com)))
com.ds.rel <- apply(com, 2, function(x) x/max(x))
com.ds.rel <- cbind(com.ds.rel, ds = rep(0.0001, nrow(com)))
com.ds.rel[is.na(com.ds.rel)] <- 0

set.seed(123)
ptab.moth <- adonis2(com.ds ~ Moth, data = l.dat,
                    strata = l.dat[, "Tree.pairs"],
                    by = "margin", nperm = 100000)

set.seed(123)
ptab.moth.rel <- adonis2(com.ds.rel ~ Moth, data = l.dat,
                        strata = l.dat[, "Tree.pairs"],
                        by = "margin", nperm = 100000)

kable(ptab.moth)

```

|          | Df | SumOfSqs   | R2        | F        | Pr(>F) |
|----------|----|------------|-----------|----------|--------|
| Moth     | 1  | 0.8329281  | 0.0389768 | 2.352343 | 0.023  |
| Residual | 58 | 20.5368939 | 0.9610232 | NA       | NA     |
| Total    | 59 | 21.3698219 | 1.0000000 | NA       | NA     |

```
kable(ptab.moth.rel)
```

|          | Df | SumOfSqs   | R2        | F        | Pr(>F) |
|----------|----|------------|-----------|----------|--------|
| Moth     | 1  | 0.8791695  | 0.0405034 | 2.448363 | 0.021  |
| Residual | 58 | 20.8269063 | 0.9594966 | NA       | NA     |
| Total    | 59 | 21.7060758 | 1.0000000 | NA       | NA     |

three main species were reduced by moths (FDR paired t-tests, in text + supplement)

```
ind.spp <- apply(com, 2, function(x, p) t.test(tapply(x, p, diff)), p = l.dat[, "Tree.pairs"])
isp <- apply(do.call(rbind, lapply(ind.spp, unlist)), 2, as.numeric)
```

```
## Warning in apply(do.call(rbind, lapply(ind.spp, unlist)), 2, as.numeric): NAs
## introduced by coercion
```

```
## Warning in apply(do.call(rbind, lapply(ind.spp, unlist)), 2, as.numeric): NAs
## introduced by coercion
```

```
## Warning in apply(do.call(rbind, lapply(ind.spp, unlist)), 2, as.numeric): NAs
## introduced by coercion
```

```
rownames(isp) <- names(ind.spp)
isp[, "p.value"] <- p.adjust(isp[, "p.value"], method = "fdr")
isp.all <- isp[, !(apply(isp, 2, function(x) all(is.na(x))))]
isp <- isp[order(isp[, "p.value"]), ]
```

```
isp.all <- isp.all[, c(1, 2, 3, 6, 4, 5)]
colnames(isp.all) <- c("t", "df", "p-value", "Mean Difference", "Lower CI 95%", "Upper CI 95%")
kable(isp.all, digits = 4)
```

|               | t       | df | p-value | Mean Difference | Lower CI 95% | Upper CI 95% |
|---------------|---------|----|---------|-----------------|--------------|--------------|
| Aacon         | -3.3776 | 29 | 0.0159  | -0.0447         | -0.0717      | -0.0176      |
| Acaame        | -3.2421 | 29 | 0.0159  | -0.1607         | -0.2620      | -0.0593      |
| Acaobp        | -1.0747 | 29 | 0.4341  | -0.2860         | -0.8303      | 0.2583       |
| Sterile.sp    | -1.0000 | 29 | 0.4341  | -0.0020         | -0.0061      | 0.0021       |
| Brown.cr      | NaN     | 29 | NaN     | 0.0000          | NaN          | NaN          |
| Lobalp        | -2.0414 | 29 | 0.2016  | -0.0047         | -0.0093      | 0.0000       |
| Canros        | -3.5819 | 29 | 0.0159  | -0.3837         | -0.6027      | -0.1646      |
| Calare        | -1.6076 | 29 | 0.2563  | -0.0307         | -0.0697      | 0.0083       |
| Phydub        | -1.9226 | 29 | 0.2061  | -0.1053         | -0.2174      | 0.0067       |
| Rhichr        | -1.5803 | 29 | 0.2563  | -0.2310         | -0.5300      | 0.0680       |
| Xanlin        | -0.6170 | 29 | 0.6672  | -0.2267         | -0.9781      | 0.5247       |
| Xanpli        | -0.2598 | 29 | 0.8500  | -0.0277         | -0.2455      | 0.1901       |
| Xanele        | -1.5662 | 29 | 0.2563  | -0.0473         | -0.1091      | 0.0145       |
| GrBr.cr       | 1.0000  | 29 | 0.4341  | 0.0013          | -0.0014      | 0.0041       |
| Gray.cr       | 0.1093  | 29 | 0.9137  | 0.0003          | -0.0059      | 0.0066       |
| Synrur        | 0.3628  | 29 | 0.8221  | 0.0220          | -0.1020      | 0.1460       |
| Cerpur.Bryarg | -1.2357 | 29 | 0.4027  | -0.0173         | -0.0460      | 0.0114       |

```
write.csv(round(isp.all, 5), file = "results/scrl_isp_table.csv")
```

Calculate the average abundances of the indicators

```
isp.names <- as.character(na.omit(rownames(isp[isp[, "p.value"] < 0.05, ])))
isp.com <- com[,colnames(com) %in% isp.names]
isp.dif <- apply(isp.com, 2, function(x,y) tapply(x, y, diff), y = 1.dat[, "Tree.pairs"])
```

Create a multi-bar plot figure for the community.

```
isp.dat <- melt(isp.dif)
colnames(isp.dat) <- c("Tree.pairs", "Species", "diff")
isp.mu <- tapply(isp.dat[, "diff"], isp.dat[, "Species"], mean)
isp.se <- tapply(isp.dat[, "diff"], isp.dat[, "Species"], se)
ard.dif <- cbind(tapply(abun, 1.dat[, "Tree.pairs"], diff),
                tapply(rich, 1.dat[, "Tree.pairs"], diff),
                tapply(shan, 1.dat[, "Tree.pairs"], diff))
colnames(ard.dif) <- c("Abundance", "Richness", "Diversity")
ard.dat <- melt(ard.dif)
colnames(ard.dat) <- c("Tree.pairs", "Stat", "diff")
ard.mu <- tapply(ard.dat[, "diff"], ard.dat[, "Stat"], mean)
ard.se <- tapply(ard.dat[, "diff"], ard.dat[, "Stat"], se)

pdf(file = "./results/scrl_isp_ard.pdf", width = 9, height = 5)

par(mfrow = c(1,2))
bp.out <- barplot(ard.mu, col = "darkgrey", ylim = c(-5, 0),
                  ylab = "Difference (S - R)", border = "NA")
segments(bp.out[, 1], ard.mu + ard.se,
         bp.out[, 1], ard.mu - ard.se,
         lwd = 1.5)
bp.out <- barplot(isp.mu, col = "darkgrey", ylim = c(-0.5, 0),
                  ylab = "Difference (S - R)", border = "NA",
                  axisnames = TRUE,
                  names.arg = sapply(names(isp.mu),
                                     function(x)
                                         paste(c(substr(x, 1, 1),
                                                substr(x, 4, 4)), collapse = "")))
segments(bp.out[, 1], isp.mu + isp.se,
         bp.out[, 1], isp.mu - isp.se,
         lwd = 1.5)
dev.off()
```

```
## pdf
## 2
```

Create a plot of the two most indicative species

```
pdf(file = "./results/scrl_complot.pdf", width = 7, height = 7)
plot(com[, c("Acaame", "Canros")], pch = 1.dat[, "Moth"] + 1, cex = 3, col = 1.dat[, "Moth"] + 1)
legend("topleft", title = "Tree Type", legend = c("Resistant", "Susceptible"), pch = c(2, 1), col = c(2, 1))
dev.off()
```

```
## pdf
## 2
```

Create plot with indicator taxa

```
pdf(file = "./results/scrl_pdif.pdf", width = 7, height = 7)
plot(melt(isp.dif)[-1], xlab = "Species", ylab = "Abundance Reduction")
dev.off()
```

```
## pdf
## 2
```

## Litter covering rocks was the main driver

Although light did significantly explain variation in the lichen community, this was not significant once the variation in litter was controlled for.

There was high correlation among environmental variables.

```
heatmap(abs(round(cor(env.dif), 3)))
```



```
set.seed(123)
ptab.env <- adonis2(com.ds ~ Litter.. + Light...average, data = l.dat,
  strata = l.dat[, "Tree.pairs"],
  by = "margin", nperm = 100000)
kable(ptab.env)
```

|                 | Df | SumOfSqs   | R2        | F        | Pr(>F) |
|-----------------|----|------------|-----------|----------|--------|
| Litter..        | 1  | 1.0035484  | 0.0469610 | 2.972456 | 0.007  |
| Light...average | 1  | 0.4114619  | 0.0192543 | 1.218728 | 0.243  |
| Residual        | 57 | 19.2441042 | 0.9005271 | NA       | NA     |
| Total           | 59 | 21.3698219 | 1.0000000 | NA       | NA     |

```
set.seed(123)
ptab.env <- adonis2(com.ds ~ Light...average + Litter.., data = l.dat,
```



```

strata = l.dat[, "Tree.pairs"],
by = "margin", nperm = 100000)
kable(ptab.env)

```

|                 | Df | SumOfSqs   | R2        | F        | Pr(>F) |
|-----------------|----|------------|-----------|----------|--------|
| Light...average | 1  | 0.4114619  | 0.0192543 | 1.218728 | 0.243  |
| Litter..        | 1  | 1.0035484  | 0.0469610 | 2.972456 | 0.007  |
| Residual        | 57 | 19.2441042 | 0.9005271 | NA       | NA     |
| Total           | 59 | 21.3698219 | 1.0000000 | NA       | NA     |

```

set.seed(123)
ptab.env <- adonis2(com.ds ~ Litter.. + Light...average + Litter.. * Light...average, data = l.dat,
strata = l.dat[, "Tree.pairs"],
by = "margin", nperm = 100000)
kable(ptab.env)

```

|                          | Df | SumOfSqs   | R2        | F        | Pr(>F) |
|--------------------------|----|------------|-----------|----------|--------|
| Litter...Light...average | 1  | 0.6021127  | 0.0281758 | 1.808729 | 0.077  |
| Residual                 | 56 | 18.6419916 | 0.8723513 | NA       | NA     |
| Total                    | 59 | 21.3698219 | 1.0000000 | NA       | NA     |

```

set.seed(123)
ptab.env <- adonis2(com.ds ~ total.rocks ,
strata = l.dat[, "Tree.pairs"],
by = "term", nperm = 100000)
kable(ptab.env)

```

|             | Df | SumOfSqs  | R2        | F        | Pr(>F) |
|-------------|----|-----------|-----------|----------|--------|
| total.rocks | 1  | 1.664876  | 0.0779078 | 4.900435 | 0.002  |
| Residual    | 58 | 19.704946 | 0.9220922 | NA       | NA     |
| Total       | 59 | 21.369822 | 1.0000000 | NA       | NA     |

```

set.seed(123)
ptab.env <- adonis2(com.ds ~ Big.rocks.. , data = l.dat,
strata = l.dat[, "Tree.pairs"],
by = "term", nperm = 100000)
kable(ptab.env)

```

|             | Df | SumOfSqs  | R2        | F        | Pr(>F) |
|-------------|----|-----------|-----------|----------|--------|
| Big.rocks.. | 1  | 2.428473  | 0.1136403 | 7.436188 | 0.001  |
| Residual    | 58 | 18.941349 | 0.8863597 | NA       | NA     |
| Total       | 59 | 21.369822 | 1.0000000 | NA       | NA     |

```

set.seed(123)
ptab.env <- adonis2(com.ds ~ Small.rocks.. , data = l.dat,

```

```
strata = l.dat[, "Tree.pairs"],
by = "term", nperm = 100000)
kable(ptab.env)
```

|               | Df | SumOfSqs   | R2        | F        | Pr(>F) |
|---------------|----|------------|-----------|----------|--------|
| Small.rocks.. | 1  | 0.2204425  | 0.0103156 | 0.604541 | 0.782  |
| Residual      | 58 | 21.1493794 | 0.9896844 | NA       | NA     |
| Total         | 59 | 21.3698219 | 1.0000000 | NA       | NA     |

```
set.seed(123)
ptab.env <- adonis2(com.ds ~ Litter.. , data = l.dat,
strata = l.dat[, "Tree.pairs"],
by = "term", nperm = 100000)
kable(ptab.env)
```

|          | Df | SumOfSqs  | R2        | F        | Pr(>F) |
|----------|----|-----------|-----------|----------|--------|
| Litter.. | 1  | 1.714256  | 0.0802185 | 5.058457 | 0.002  |
| Residual | 58 | 19.655566 | 0.9197815 | NA       | NA     |
| Total    | 59 | 21.369822 | 1.0000000 | NA       | NA     |

Because light was significantly, negatively correlated with litter and large rocks.

```
cor.test(env.dif[, "Big.rocks.."], env.dif[, "Litter.."])
```

```
##
## Pearson's product-moment correlation
##
## data: env.dif[, "Big.rocks.."] and env.dif[, "Litter.."]
## t = -11.106, df = 28, p-value = 9.054e-12
## alternative hypothesis: true correlation is not equal to 0
## 95 percent confidence interval:
## -0.9530598 -0.8039735
## sample estimates:
## cor
## -0.9027609
```

```
pdf("./results/scrl_litterVbigrocks.pdf", width = 5, height = 5)
dev.off()
```

```
## pdf
## 2
```

```
par(mfrow = c(1,3))
plot(density(tapply(l.dat[, "Litter.."], l.dat[, "Tree.pairs"], diff)),
main = "", xlab = "Litter Difference (S - R)")
abline(v = mean(tapply(l.dat[, "Litter.."], l.dat[, "Tree.pairs"], diff)),
lwd = 0.5)
plot(env.dif[, "Big.rocks.."] ~ env.dif[, "Litter.."],
xlab = "Litter Difference (S - R)", ylab = "Rock Cover (size >3 cm) Difference (S - R)",
pch = 19, cex = 1.5)
abline(lm(env.dif[, "Big.rocks.."] ~ env.dif[, "Litter.."]))
plot(tapply(l.dat[, "Litter.."], l.dat[, "Tree.pairs"], diff),
```

```
tapply(l.dat[, "Light...average"], l.dat[, "Tree.pairs"], diff),
xlab = "Litter Difference (S - R)", ylab = "Light Difference (S - R)",
pch = 19, cex = 1.5)
```



```
pdf("./results/scrl_litter_effects.pdf", width = 10, height = 5)
par(mfrow = c(1,3))
plot(density(tapply(l.dat[, "Litter.."], l.dat[, "Tree.pairs"], diff)),
     main = "", xlab = "Litter Difference (S - R)")
abline(v = mean(tapply(l.dat[, "Litter.."], l.dat[, "Tree.pairs"], diff)),
       lwd = 0.5)
plot(env.dif[, "Big.rock.."] ~ env.dif[, "Litter.."],
     xlab = "Litter Difference (S - R)", ylab = "Rock Cover (size >3 cm) Difference (S - R)",
     pch = 19, cex = 1.5)
abline(lm(env.dif[, "Big.rock.."] ~ env.dif[, "Litter.."]))
plot(tapply(l.dat[, "Litter.."], l.dat[, "Tree.pairs"], diff),
     tapply(l.dat[, "Light...average"], l.dat[, "Tree.pairs"], diff),
     xlab = "Litter Difference (S - R)", ylab = "Light Difference (S - R)",
     pch = 19, cex = 1.5)
dev.off()
```

```
## pdf
## 2
```

```
nmds.out <- nmds(vegdist(com.ds), 2, 2)
ord <- nmds.min(nmds.out, dims = 2)
```

```
## Minimum stress for given dimensionality: 0.2169355
## r^2 for minimum stress configuration: 0.6416469
```

```
ord.pch <- c("R", "S")[(l.dat[, "Moth"] + 1)]
plot(X2~ X1, data = ord, pch = ord.pch)
```



Litter not light was correlated with large rocks (dist cor, in text). Thus, higher amounts of litter under trees was not related to the penetration of light under the tree canopy.

```
cor.test(tapply(l.dat[, "Big.rock.."], l.dat[, "Tree.pairs"], diff),
         tapply(l.dat[, "Litter.."], l.dat[, "Tree.pairs"], diff))
```

```
##
## Pearson's product-moment correlation
##
## data:  tapply(l.dat[, "Big.rock.."], l.dat[, "Tree.pairs"], diff) and tapply(l.dat[, "Litter.."], l.dat[, "Tree.pairs"], diff)
## t = -11.106, df = 28, p-value = 9.054e-12
## alternative hypothesis: true correlation is not equal to 0
## 95 percent confidence interval:
## -0.9530598 -0.8039735
## sample estimates:
##      cor
## -0.9027609
```

```
cor.test(tapply(l.dat[, "Big.rock.."], l.dat[, "Tree.pairs"], diff),
         tapply(l.dat[, "Light...average"], l.dat[, "Tree.pairs"], diff))
```

```
##
## Pearson's product-moment correlation
##
## data:  tapply(l.dat[, "Big.rock.."], l.dat[, "Tree.pairs"], diff) and tapply(l.dat[, "Light...average"], l.dat[, "Tree.pairs"], diff)
## t = 0.71624, df = 28, p-value = 0.4798
## alternative hypothesis: true correlation is not equal to 0
## 95 percent confidence interval:
## -0.2376184 0.4716125
## sample estimates:
##      cor
## 0.1341335
```

```
cor.test(tapply(l.dat[, "Litter.."], l.dat[, "Tree.pairs"], diff),
         tapply(l.dat[, "Light...average"], l.dat[, "Tree.pairs"], diff))

##
## Pearson's product-moment correlation
##
## data:  tapply(l.dat[, "Litter.."], l.dat[, "Tree.pairs"], diff) and tapply(l.dat[, "Light...average"],
## t = -0.92053, df = 28, p-value = 0.3652
## alternative hypothesis: true correlation is not equal to 0
## 95 percent confidence interval:
## -0.5007401  0.2013096
## sample estimates:
##          cor
## -0.1713898

cor.test(tapply(l.dat[, "Small.rocks.."], l.dat[, "Tree.pairs"], diff),
         tapply(l.dat[, "Litter.."], l.dat[, "Tree.pairs"], diff))

##
## Pearson's product-moment correlation
##
## data:  tapply(l.dat[, "Small.rocks.."], l.dat[, "Tree.pairs"], diff) and tapply(l.dat[, "Litter.."],
## t = -4.994, df = 28, p-value = 2.819e-05
## alternative hypothesis: true correlation is not equal to 0
## 95 percent confidence interval:
## -0.8391386 -0.4332285
## sample estimates:
##          cor
## -0.6863699
```

## Vegetation Analysis

### Results Summary

- Both vegetation and light from the plant dataset respond to moth susceptibility (see t-tests below)
- Plant cover, richness and Shannon's diversity respond to moth susceptibility (see t-tests below)
- Plant community composition using Bray-Curtis dissimilarity and a PERMANOVA model that accounts for tree pairs is significantly affected by moth susceptibility (Tables 11-12)
- Using the light, litter and rock cover from the saxicole dataset, plant community composition is significantly correlated with light and litter but not rock cover. Light has a strong effect but the effect of litter is weak and is non-significant after controlling for the effect of light, suggesting that the effect of litter is due to the covariance between light and litter (Tables 13-16)
- Two main species of plant were indicators of moth susceptibility: Apache plume and *Asteraceae ovaes*. Both showed reduced cover under moth susceptible trees (Table 17)
- Saxicole and plant communities were not multivariately correlated based on Mantel Tests on both un-relativized and species max relativized cover (see Mantel Test below)

### From Richard Michalet

First sheet is the vegetation matrix with all relevés.

Second sheet are values of vegetation cover, rock cover and species richness in all replicates of all treatments + mean values of treatments and corresponding graphs.

From what I remember the methods were simple, quadrats of 1square meter in four treatments

with a full factorial design, exposure (north and south of the tree), mortality (alive vs dead shrubs), tree susceptibility (resistant vs susceptible) and tree presence (below the canopy or outside the canopy in open conditions at the close vicinity of the trees).

You can see that without stats results are obvious: strong effect of tree susceptibility only below the tree and in both exposure for both alive and dead trees.

```
veg <- readxl::read_xlsx("data/Vegetation.xlsx")
veg <- as.data.frame(veg)
l.raw <- read.csv("data/rawdata Sunset Crater for Matt.csv")
l.raw <- l.raw[!(grepl("cover", l.raw[,1])),]
le.raw <- read.csv("data/rawdata Sunset Crater for Matt_env.csv")
le.raw <- le.raw[!(grepl("cover", le.raw[,1])),]
le.raw <- na.omit(le.raw)
```

## Observation checks

Do the saxicole community and environment data match?

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

Are all of the trees in the saxicole dataset represented in the veg dataset?

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

## Coalesce datasets

```
l.d <- data.frame(le.raw[, -2:-3], l.raw[, -1:-3])
l.d <- split(l.d, l.d[, "Tree.ID"])
l.d <- l.d[names(l.d) %in% le.raw[, "Tree.ID"]]
l.d <- lapply(l.d, function(x) x[, -1])
l.d <- lapply(l.d, apply, 2, mean)
l.df <- do.call(rbind, l.d)
trt <- strsplit(rownames(l.df), "")
moth.alive <- lapply(trt, function(x) x[x %in% c(letters, LETTERS)][1:2])
moth.alive <- do.call(rbind, moth.alive)
tree <- lapply(trt, function(x) x[x %in% 0:9])
tree <- as.numeric(unlist(lapply(tree, paste, collapse = "")))
l.df <- data.frame(Tree.pairs = tree,
                  Moth = moth.alive[, 1],
                  Live.Dead = moth.alive[, 2],
                  l.df)
l.df <- l.df[l.df[, "Live.Dead"] == "A", ]
l.df[, "Moth"] <- as.character(l.df[, "Moth"])
l.df[l.df[, "Moth"] == "R", "Moth"] <- 1
l.df[l.df[, "Moth"] == "S", "Moth"] <- 0
moth.tree <- paste(l.df[, "Moth"], l.df[, "Tree.pairs"], sep = "_")
l.df <- l.df[match(rownames(l.dat), moth.tree), ]
```

Check that l.dat and l.df are correctly coalesced:

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

```
## [1] TRUE TRUE TRUE FALSE FALSE FALSE FALSE FALSE FALSE TRUE FALSE TRUE
## [13] TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE
## [25] TRUE TRUE
```

Check that the values of the variables match, excluding light:

The following vector should work to match-up the saxicoles with the veg data:

Checking the vegetation and rock cover correlations. We find that vegetation cover is significantly, but not strongly correlated with rock cover. Large rock cover measurements in the saxicole dataset is strongly correlated with total rock cover in the plant dataset.

Both vegetation and rock cover are strongly affected by moth susceptibility.

```
cor.test(v.dat[, "Vegetation.cover"], v.dat[, "Rock.cover"], alt = "greater")
```

```
##
## Pearson's product-moment correlation
##
## data: v.dat[, "Vegetation.cover"] and v.dat[, "Rock.cover"]
## t = 1.8835, df = 58, p-value = 0.03233
## alternative hypothesis: true correlation is greater than 0
## 95 percent confidence interval:
## 0.0269872 1.0000000
## sample estimates:
## cor
## 0.2400809
```

```
cor.test(l.dat[, "Big.rock.."], v.dat[, "Rock.cover"], alt = "greater")
```

```
##
## Pearson's product-moment correlation
##
## data: l.dat[, "Big.rock.."] and v.dat[, "Rock.cover"]
## t = 9.5342, df = 58, p-value = 8.816e-14
## alternative hypothesis: true correlation is greater than 0
## 95 percent confidence interval:
## 0.6809688 1.0000000
## sample estimates:
## cor
## 0.7813334
```

```
t.test(tapply(v.dat[, "Rock.cover"], v.dat[, "Tree.Pair"], diff))
```

```
##
## One Sample t-test
##
## data: tapply(v.dat[, "Rock.cover"], v.dat[, "Tree.Pair"], diff)
## t = -3.3582, df = 29, p-value = 0.002208
## alternative hypothesis: true mean is not equal to 0
## 95 percent confidence interval:
## -27.621617 -6.711716
## sample estimates:
## mean of x
## -17.16667
```

```
t.test(tapply(v.dat[, "Vegetation.cover"], v.dat[, "Tree.Pair"], diff))
```

```
##
## One Sample t-test
##
## data: tapply(v.dat[, "Vegetation.cover"], v.dat[, "Tree.Pair"], diff)
## t = -7.2026, df = 29, p-value = 6.269e-08
## alternative hypothesis: true mean is not equal to 0
```

```
## 95 percent confidence interval:
## -28.67505 -15.99162
## sample estimates:
## mean of x
## -22.33333
```

Both plant richness and Shannon's Diversity index were significantly affected by moth susceptibility.

```
v.abun <- v.dat[, "Vegetation.cover"]
v.rich <- apply(v.com, 1, function(x) sum(sign(x)))
v.shan <- apply(v.com, 1, diversity)

t.test(tapply(v.rich, l.dat[, "Tree.pairs"], diff))
```

```
##
## One Sample t-test
##
## data: tapply(v.rich, l.dat[, "Tree.pairs"], diff)
## t = -7.477, df = 29, p-value = 3.062e-08
## alternative hypothesis: true mean is not equal to 0
## 95 percent confidence interval:
## -1.6555988 -0.9444012
## sample estimates:
## mean of x
## -1.3
```

```
t.test(tapply(v.shan, l.dat[, "Tree.pairs"], diff))
```

```
##
## One Sample t-test
##
## data: tapply(v.shan, l.dat[, "Tree.pairs"], diff)
## t = -4.2192, df = 29, p-value = 0.00022
## alternative hypothesis: true mean is not equal to 0
## 95 percent confidence interval:
## -0.4386895 -0.1522394
## sample estimates:
## mean of x
## -0.2954645
```

```
v.ard.mu <- rbind(tapply(v.dat[, "Vegetation.cover"], l.dat[, "Moth"], mean),
                 tapply(rich, l.dat[, "Moth"], mean),
                 tapply(shan, l.dat[, "Moth"], mean))
v.ard.se <- rbind(tapply(v.dat[, "Vegetation.cover"], l.dat[, "Moth"], se),
                 tapply(rich, l.dat[, "Moth"], se),
                 tapply(shan, l.dat[, "Moth"], se))
v.ard.tab <- cbind(v.ard.mu[, "0"], v.ard.se[, "0"],
                  v.ard.mu[, "1"], v.ard.se[, "1"])
colnames(v.ard.tab) <- c("Susceptible Mean", "Susceptible SE",
                        "Resistant Mean", "Resistant SE")
rownames(v.ard.tab) <- c("Abundance", "Richness", "Diversity (Shannon)")

kable(v.ard.tab, digits = 3)
```

|           | Susceptible Mean | Susceptible SE | Resistant Mean | Resistant SE |
|-----------|------------------|----------------|----------------|--------------|
| Abundance | 3.733            | 1.511          | 26.067         | 2.758        |



|                     | Susceptible Mean | Susceptible SE | Resistant Mean | Resistant SE |
|---------------------|------------------|----------------|----------------|--------------|
| Richness            | 3.500            | 0.542          | 6.033          | 0.662        |
| Diversity (Shannon) | 0.707            | 0.119          | 1.144          | 0.125        |

This is a multivariate analysis of the plant community response to moth susceptibility (PERMANOVA). This analysis uses a modified Bray-Curtis Dissimilarity metric, which permits the inclusion of quadrats that had no plants in them. The analysis also accounts for the paired structure of the data (i.e. pairs of moth susceptible and resistant trees).

```
set.seed(123)
ptab.v.moth <- adonis2(v.com.ds ~ Moth, data = l.dat,
                      strata = v.dat[, "Tree.pairs"],
                      by = "margin", nperm = 100000)

set.seed(123)
ptab.v.moth.rel <- adonis2(v.com.ds.rel ~ Moth, data = l.dat,
                          strata = v.dat[, "Tree.pairs"],
                          by = "margin", nperm = 100000)
```

Here are the results of the multivariate plant community response.

```
kable(ptab.v.moth, caption = "PERMANOVA of plant community response to moth.")
```

Table 15: PERMANOVA of plant community response to moth.

|          | Df | SumOfSqs  | R2        | F        | Pr(>F) |
|----------|----|-----------|-----------|----------|--------|
| Moth     | 1  | 5.174376  | 0.3081168 | 25.82917 | 0.001  |
| Residual | 58 | 11.619181 | 0.6918832 | NA       | NA     |
| Total    | 59 | 16.793557 | 1.0000000 | NA       | NA     |

Here are the results of the multivariate plant community response after relativizing by species max.

Table 16: PERMANOVA of relativized plant community response to moth.

|          | Df | SumOfSqs  | R2       | F        | Pr(>F) |
|----------|----|-----------|----------|----------|--------|
| Moth     | 1  | 5.989174  | 0.288048 | 23.46617 | 0.001  |
| Residual | 58 | 14.803100 | 0.711952 | NA       | NA     |
| Total    | 59 | 20.792275 | 1.000000 | NA       | NA     |

Do light, litter or rock cover influence plant communities?

```
set.seed(123)
ptab.v.env <- adonis2(v.com.ds ~ Light...average + Litter.. + Big.rock...,
                    data = l.dat,
                    strata = l.dat[, "Tree.pairs"],
                    by = "margin", nperm = 100000)

set.seed(123)
ptab.v.env.total.rock <- adonis2(v.com.ds ~ Light...average + Litter.. + total.rock,
                                data = l.dat,
                                strata = l.dat[, "Tree.pairs"],
                                by = "margin", nperm = 100000)
```

```

set.seed(123)
ptab.v.env.rel <- adonis2(v.com.ds.rel ~ Light...average + Litter.. + total.rocks,
  data = l.dat,
  strata = l.dat[, "Tree.pairs"],
  by = "margin", nperm = 100000)

set.seed(123)
ptab.v.env.int <- adonis2(v.com.ds ~ Light...average + Litter.. + total.rocks +
  Light...average * Litter.. +
  Light...average * total.rocks +
  Litter.. * total.rocks,
  data = l.dat,
  strata = l.dat[, "Tree.pairs"],
  by = "margin", nperm = 100000)

set.seed(123)
ptab.v.env.rel.int <- adonis2(v.com.ds.rel ~ Light...average + Litter.. + total.rocks +
  Light...average * Litter.. +
  Light...average * total.rocks +
  Litter.. * total.rocks,
  data = l.dat,
  strata = l.dat[, "Tree.pairs"],
  by = "margin", nperm = 100000)

```

Light has a strong effect on the plant community. Litter also has an effect but it is small and marginally significant, either un-relativized or relativized, respectively.

Table 17: PERMANOVA of plant community response to several environmental variables.

|                 | Df | SumOfSqs   | R2        | F         | Pr(>F) |
|-----------------|----|------------|-----------|-----------|--------|
| Light...average | 1  | 2.8692870  | 0.1708564 | 12.696810 | 0.001  |
| Litter..        | 1  | 0.6890028  | 0.0410278 | 3.048889  | 0.049  |
| Big.rocks..     | 1  | 0.3621592  | 0.0215654 | 1.602582  | 0.189  |
| Residual        | 56 | 12.6551530 | 0.7535719 | NA        | NA     |
| Total           | 59 | 16.7935571 | 1.0000000 | NA        | NA     |

Table 18: PERMANOVA of relativized plant community response to several environmental variables.

|                 | Df | SumOfSqs   | R2        | F         | Pr(>F) |
|-----------------|----|------------|-----------|-----------|--------|
| Light...average | 1  | 3.4724258  | 0.1670056 | 12.245941 | 0.001  |
| Litter..        | 1  | 0.3437323  | 0.0165317 | 1.212215  | 0.291  |
| total.rocks     | 1  | 0.3501066  | 0.0168383 | 1.234694  | 0.282  |
| Residual        | 56 | 15.8792084 | 0.7637071 | NA        | NA     |
| Total           | 59 | 20.7922745 | 1.0000000 | NA        | NA     |

```

set.seed(123)
ptab.v.env.seq <- adonis2(v.com.ds ~ Light...average + Litter.. + total.rocks,
  data = l.dat,
  strata = l.dat[, "Tree.pairs"],
  by = "term", nperm = 100000)

set.seed(123)

```

```
ptab.v.env.rel.seq <- adonis2(v.com.ds.rel ~ Light...average + Litter.. + total.rocks,
                             data = l.dat,
                             strata = l.dat[, "Tree.pairs"],
                             by = "term", nperm = 100000)
```

After controlling for the effect of light, the effect of litter is no longer significant, un-relativized or relativized, respectively.

Table 19: Sequential PERMANOVA of plant community response to several environmental variables. Variance is explained sequentially by factors entered into the model from top to bottom.

|                 | Df | SumOfSqs   | R2        | F         | Pr(>F) |
|-----------------|----|------------|-----------|-----------|--------|
| Light...average | 1  | 3.2765116  | 0.1951053 | 14.567808 | 0.001  |
| Litter..        | 1  | 0.4997333  | 0.0297574 | 2.221881  | 0.098  |
| total.rocks     | 1  | 0.4220991  | 0.0251346 | 1.876709  | 0.128  |
| Residual        | 56 | 12.5952131 | 0.7500027 | NA        | NA     |
| Total           | 59 | 16.7935571 | 1.0000000 | NA        | NA     |

Table 20: Sequential PERMANOVA of relativized plant community response to several environmental variables. Variance is explained sequentially by factors entered into the model from top to bottom.

|                 | Df | SumOfSqs   | R2        | F         | Pr(>F) |
|-----------------|----|------------|-----------|-----------|--------|
| Light...average | 1  | 3.8762571  | 0.1864278 | 13.670102 | 0.001  |
| Litter..        | 1  | 0.6867025  | 0.0330268 | 2.421742  | 0.060  |
| total.rocks     | 1  | 0.3501066  | 0.0168383 | 1.234694  | 0.282  |
| Residual        | 56 | 15.8792084 | 0.7637071 | NA        | NA     |
| Total           | 59 | 20.7922745 | 1.0000000 | NA        | NA     |

- Indicator species

```
## Warning in apply(do.call(rbind, lapply(ind.spp.v, unlist))), 2, as.numeric): NAs
## introduced by coercion
```

```
## Warning in apply(do.call(rbind, lapply(ind.spp.v, unlist))), 2, as.numeric): NAs
## introduced by coercion
```

```
## Warning in apply(do.call(rbind, lapply(ind.spp.v, unlist))), 2, as.numeric): NAs
## introduced by coercion
```

There are two species that are responding to moth susceptibility, Apache plume and *Asteraceae ovaes*.

Table 21: Indicator Species Analysis using False Discovery Rate (FDR) adjusted p-values from t-tests of paired differences between resistant and susceptible trees (Resistant - Susceptible).

|                  | t       | df | p-value | Mean Difference | Lower CI 95% | Upper CI 95% |
|------------------|---------|----|---------|-----------------|--------------|--------------|
| Apache.plume     | -4.6010 | 29 | 0.0007  | -10.2667        | -14.8304     | -5.7029      |
| Asteraceae.ovaes | -3.9581 | 29 | 0.0020  | -8.1333         | -12.3360     | -3.9307      |
| Rhus.trilobata   | -1.8410 | 29 | 0.1869  | -3.1667         | -6.6847      | 0.3514       |
| Rabbit.brush     | -1.0000 | 29 | 0.3256  | -0.6667         | -2.0302      | 0.6968       |

|                           | t       | df | p-value | Mean Difference | Lower CI 95% | Upper CI 95% |
|---------------------------|---------|----|---------|-----------------|--------------|--------------|
| Avena                     | -1.7951 | 29 | 0.1869  | -0.2000         | -0.4279      | 0.0279       |
| Juniperus.monosperma      | -1.0000 | 29 | 0.3256  | -0.1667         | -0.5075      | 0.1742       |
| Plante.grise.allongée     | -1.0000 | 29 | 0.3256  | -0.1000         | -0.3045      | 0.1045       |
| Scarlet.glia              | -1.0000 | 29 | 0.3256  | -0.0667         | -0.2030      | 0.0697       |
| Bouteloua.gracilis        | NaN     | 29 | NaN     | 0.0000          | NaN          | NaN          |
| Pinus.edulis.S            | NaN     | 29 | NaN     | 0.0000          | NaN          | NaN          |
| Stipa.A                   | NaN     | 29 | NaN     | 0.0000          | NaN          | NaN          |
| Stipa.B                   | NaN     | 29 | NaN     | 0.0000          | NaN          | NaN          |
| Stipa.très.grand          | NaN     | 29 | NaN     | 0.0000          | NaN          | NaN          |
| Ephedra                   | NaN     | 29 | NaN     | 0.0000          | NaN          | NaN          |
| Grande.grass.corymbe      | NaN     | 29 | NaN     | 0.0000          | NaN          | NaN          |
| Boraginacée.rosette.grise | NaN     | 29 | NaN     | 0.0000          | NaN          | NaN          |
| Grass.à.noëud             | NaN     | 29 | NaN     | 0.0000          | NaN          | NaN          |
| Brachypode                | NaN     | 29 | NaN     | 0.0000          | NaN          | NaN          |
| Carex                     | NaN     | 29 | NaN     | 0.0000          | NaN          | NaN          |
| Cactus                    | NaN     | 29 | NaN     | 0.0000          | NaN          | NaN          |
| Hordeum                   | NaN     | 29 | NaN     | 0.0000          | NaN          | NaN          |
| Chenopodiaceae            | NaN     | 29 | NaN     | 0.0000          | NaN          | NaN          |
| Ribes                     | NaN     | 29 | NaN     | 0.0000          | NaN          | NaN          |
| Aster.grise               | NaN     | 29 | NaN     | 0.0000          | NaN          | NaN          |
| Rosette.frisée            | NaN     | 29 | NaN     | 0.0000          | NaN          | NaN          |
| Chamaephyte.gris          | NaN     | 29 | NaN     | 0.0000          | NaN          | NaN          |
| Castilleja                | NaN     | 29 | NaN     | 0.0000          | NaN          | NaN          |
| Opuntia                   | NaN     | 29 | NaN     | 0.0000          | NaN          | NaN          |
| Rubiaceae                 | NaN     | 29 | NaN     | 0.0000          | NaN          | NaN          |
| Andropogon                | NaN     | 29 | NaN     | 0.0000          | NaN          | NaN          |
| Pinus.edulis.R            | 1.0000  | 29 | 0.3256  | 0.3333          | -0.3484      | 1.0151       |

## Multivariate Correlation of Plants and Saxicoles

There is no significant multivariate correlation between the veg and saxicole communities, regardless of whether the community data are relativized. This is likely a result of the two communities responded to different variables with low correlation (i.e. rocks = saxicoles and light = plants). This was true either without or with relativization by species max.

```
v.d <- vegdist(v.com.ds)
l.d <- vegdist(com.ds)
```

```
mantel(v.d ~ l.d)
```

```
##      mantelr      pval1      pval2      pval3      llim.2.5%      ulim.97.5%
## -0.002762319  0.513000000  0.488000000  0.914000000 -0.034504235  0.032707393
```

```
v.d <- vegdist(v.com.ds.rel)
l.d <- vegdist(com.ds.rel)
```

```
mantel(v.d ~ l.d)
```

```
##      mantelr      pval1      pval2      pval3      llim.2.5%      ulim.97.5%
##  0.02328021  0.21200000  0.78900000  0.44300000 -0.01176642  0.05838093
```

## Structural Equation Modeling

```
com.prepared <- cbind(id = 1.dat[, "Moth"], tree = 1.dat[, "Tree.pairs"], com)
v.com.prepared <- cbind(id = 1.dat[, "Moth"], tree = 1.dat[, "Tree.pairs"], v.com)

l.dist.euc <- distancePairedSamples(
  sequences = com.prepared,
  grouping.column = "id",
  time.column = "tree",
  exclude.columns = NULL,
  method = "euclidean",
  sum.distances = FALSE,
  parallel.execution = FALSE
)

l.dist.man <- distancePairedSamples(
  sequences = com.prepared,
  grouping.column = "id",
  time.column = "tree",
  exclude.columns = NULL,
  method = "manhattan",
  sum.distances = FALSE,
  parallel.execution = FALSE
)

v.dist.euc <- distancePairedSamples(
  sequences = v.com.prepared,
  grouping.column = "id",
  time.column = "tree",
  exclude.columns = NULL,
  method = "euclidean",
  sum.distances = FALSE,
  parallel.execution = FALSE
)

v.dist.man <- distancePairedSamples(
  sequences = v.com.prepared,
  grouping.column = "id",
  time.column = "tree",
  exclude.columns = NULL,
  method = "manhattan",
  sum.distances = FALSE,
  parallel.execution = FALSE
)

cor(l.dist.man[[1]], l.dist.euc[[1]])

## [1] 0.9422796
cor(v.dist.man[[1]], v.dist.euc[[1]])

## [1] 0.9612754

d.litter <- tapply(1.dat[, "Litter.."], 1.dat[, "Tree.pairs"], diff)
d.rock <- tapply((1.dat[, "Big.rock.."] + 1.dat[, "Small.rock.."]),
```

```

      l.dat[, "Tree.pairs"], diff)
d.light <- tapply(l.dat[, "Light...average"], l.dat[, "Tree.pairs"], diff)
d.com <- l.dist.man[[1]]
d.abun <- tapply(abun, l.dat[, "Tree.pairs"], diff)
d.rich <- tapply(rich, l.dat[, "Tree.pairs"], diff)
d.shan <- tapply(shan, l.dat[, "Tree.pairs"], diff)
d.isp <- apply(isp.com, 2, function(x, f) tapply(x, f, diff), f = l.dat[, "Tree.pairs"])
colnames(d.isp) <- paste("d", colnames(isp.com), sep = ".")

round(cor(cbind(d.litter, d.rock, d.light, d.abun, d.rich, d.shan, d.com)), 3)

##          d.litter d.rock d.light d.abun d.rich d.shan d.com
## d.litter    1.000 -0.998 -0.171 -0.530 -0.695 -0.651  0.154
## d.rock      -0.998  1.000  0.196  0.513  0.694  0.656 -0.140
## d.light     -0.171  0.196  1.000  0.108  0.268  0.290 -0.133
## d.abun      -0.530  0.513  0.108  1.000  0.649  0.353 -0.448
## d.rich      -0.695  0.694  0.268  0.649  1.000  0.888 -0.143
## d.shan      -0.651  0.656  0.290  0.353  0.888  1.000 -0.071
## d.com        0.154 -0.140 -0.133 -0.448 -0.143 -0.071  1.000

sem.dat <- data.frame(d.litter, d.rock, d.light, d.abun, d.rich, d.shan, d.com, d.isp)
sem.path <- matrix(c(0, 1, 1, 0,
                    1, 0, 0, 1,
                    0, 0, 0, 1,
                    0, 0, 0, 0), 4, 4, byrow = TRUE)
rownames(sem.path) <- colnames(sem.path) <- c("d.litter", "d.light", "d.rock", "d.com")

model.com <- psem(lm(d.rock ~ d.litter, sem.dat), lm(d.com ~ d.light + d.rock, sem.dat))
model.com1 <- psem(lm(d.rock ~ d.litter, sem.dat), lm(d.com ~ d.litter + d.light + d.rock, sem.dat))
model.abun <- psem(lm(d.rock ~ d.litter, sem.dat), lm(d.abun ~ d.light + d.rock, sem.dat))
model.rich <- psem(lm(d.rock ~ d.litter, sem.dat), lm(d.rich ~ d.light + d.rock, sem.dat))
model.shan <- psem(lm(d.rock ~ d.litter, sem.dat), lm(d.shan ~ d.light + d.rock, sem.dat))
model.Acacon <- psem(lm(d.rock ~ d.litter, sem.dat), lm(d.Acacon ~ d.light + d.rock, sem.dat))
model.Acaame <- psem(lm(d.rock ~ d.litter, sem.dat), lm(d.Acaame ~ d.light + d.rock, sem.dat))
model.Canros <- psem(lm(d.rock ~ d.litter, sem.dat), lm(d.Canros ~ d.light + d.rock, sem.dat))
model.Canros1 <- psem(lm(d.rock ~ d.litter, sem.dat), lm(d.Canros ~ d.light + d.rock, sem.dat))

d.litter <- tapply(l.dat[, "Litter.."], l.dat[, "Tree.pairs"], diff)
d.rock <- tapply((l.dat[, "Big.rock.."] + l.dat[, "Small.rock.."]),
                l.dat[, "Tree.pairs"], diff)
d.light <- tapply(l.dat[, "Light...average"], l.dat[, "Tree.pairs"], diff)

d.v.com <- v.dist.man[[1]]
d.v.abun <- tapply(v.abun, l.dat[, "Tree.pairs"], diff)
d.v.rich <- tapply(v.rich, l.dat[, "Tree.pairs"], diff)
d.v.shan <- tapply(v.shan, l.dat[, "Tree.pairs"], diff)
d.v.isp <- apply(v.isp.com, 2, function(x, f) tapply(x, f, diff), f = l.dat[, "Tree.pairs"])
colnames(d.v.isp) <- paste("d", colnames(v.isp.com), sep = ".")
v.sem.dat <- data.frame(d.litter, d.rock, d.light, d.v.abun, d.v.rich, d.v.shan, d.v.com, d.v.isp)

model.v.com <- psem(lm(d.rock ~ d.litter, v.sem.dat), lm(d.v.com ~ d.light + d.rock, v.sem.dat))
model.v.com1 <- psem(lm(d.rock ~ d.litter, v.sem.dat), lm(d.v.com ~ d.litter + d.light + d.rock, v.sem.dat))
model.v.abun <- psem(lm(d.rock ~ d.litter, v.sem.dat), lm(d.v.abun ~ d.light + d.rock, v.sem.dat))
model.v.rich <- psem(lm(d.rock ~ d.litter, v.sem.dat), lm(d.v.rich ~ d.light + d.rock, v.sem.dat))

```

```

model.v.shan <- psem(lm(d.rocks ~ d.litter, v.sem.dat), lm(d.v.shan ~ d.light + d.rocks, v.sem.dat))
model.v.Apache.plume <- psem(lm(d.rocks ~ d.litter, v.sem.dat),
                             lm(d.Apache.plume ~ d.light + d.rocks, v.sem.dat))
model.v.Asteraceae.ovales <- psem(lm(d.rocks ~ d.litter, v.sem.dat),
                                   lm(d.Asteraceae.ovales ~ d.light + d.rocks, v.sem.dat))

```

## Independent Test Method

Using indeendent tests for different effects along the hypothesized causal model that moth susceptibility affects tree traits (litter production), which affect the local environment (light, rocks), which in turn affect lichen, bryophyte and plant communities (abundance, richness, diversity, indicator species, composition).

moth-susceptibility -> tree traits -> local environment -> community

We can do this by parsing independent tests for each effect OR by using a structural equation model (SEM).

Testing for the effect of moth susceptibility:

```
t.test(d.litter)
```

```

##
## One Sample t-test
##
## data: d.litter
## t = 2.8665, df = 29, p-value = 0.00765
## alternative hypothesis: true mean is not equal to 0
## 95 percent confidence interval:
##  4.317792 25.822208
## sample estimates:
## mean of x
## 15.07

```

```
t.test(d.light)
```

```

##
## One Sample t-test
##
## data: d.light
## t = -9.2728, df = 29, p-value = 3.557e-10
## alternative hypothesis: true mean is not equal to 0
## 95 percent confidence interval:
## -18.47119 -11.79547
## sample estimates:
## mean of x
## -15.13333

```

```
t.test(d.rocks)
```

```

##
## One Sample t-test
##
## data: d.rocks
## t = -2.8178, df = 29, p-value = 0.008617
## alternative hypothesis: true mean is not equal to 0
## 95 percent confidence interval:
## -25.298305 -4.019028
## sample estimates:

```

```
## mean of x
## -14.65867
```

Effects of tree traits on local environment and environment correlations:

```
cor.test(d.light, d.litter)
```

```
##
## Pearson's product-moment correlation
##
## data: d.light and d.litter
## t = -0.92053, df = 28, p-value = 0.3652
## alternative hypothesis: true correlation is not equal to 0
## 95 percent confidence interval:
## -0.5007401 0.2013096
## sample estimates:
## cor
## -0.1713898
```

```
cor.test(d.rock, d.light)
```

```
##
## Pearson's product-moment correlation
##
## data: d.rock and d.light
## t = 1.0584, df = 28, p-value = 0.2989
## alternative hypothesis: true correlation is not equal to 0
## 95 percent confidence interval:
## -0.1766215 0.5196770
## sample estimates:
## cor
## 0.1961275
```

```
summary(lm(d.rock ~ d.litter))
```

```
##
## Call:
## lm(formula = d.rock ~ d.litter)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -2.4466 -0.7468 -0.3273  0.2442  6.9590
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept)  0.22870    0.34616   0.661   0.514
## d.litter     -0.98788    0.01079 -91.529 <2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 1.674 on 28 degrees of freedom
## Multiple R-squared:  0.9967, Adjusted R-squared:  0.9965
## F-statistic: 8378 on 1 and 28 DF, p-value: < 2.2e-16
```

Effects of local environment on lichen, and possible direct effects of tree traits:



```
summary(lm(d.abun ~ d.rocks))
```

```
##
## Call:
## lm(formula = d.abun ~ d.rocks)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -7.8587 -1.3596  0.5429  1.6415  5.8098
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept) -0.55053    0.67673  -0.814  0.42279
## d.rocks      0.06777    0.02140   3.166  0.00371 **
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 3.284 on 28 degrees of freedom
## Multiple R-squared:  0.2637, Adjusted R-squared:  0.2374
## F-statistic: 10.03 on 1 and 28 DF,  p-value: 0.003706
```

```
summary(lm(d.rich ~ d.rocks))
```

```
##
## Call:
## lm(formula = d.rich ~ d.rocks)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -5.7375 -2.3674 -0.1611  1.6950  7.5293
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept) -0.85626    0.70878  -1.208  0.237
## d.rocks      0.11441    0.02242   5.104 2.09e-05 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 3.44 on 28 degrees of freedom
## Multiple R-squared:  0.4819, Adjusted R-squared:  0.4634
## F-statistic: 26.05 on 1 and 28 DF,  p-value: 2.089e-05
```

```
summary(lm(d.shan ~ d.rocks))
```

```
##
## Call:
## lm(formula = d.shan ~ d.rocks)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -1.46785 -0.60402  0.04559  0.63369  1.38124
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept) -0.106623   0.154747  -0.689   0.496
```

```
## d.rocks      0.022537   0.004894   4.605 8.17e-05 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.751 on 28 degrees of freedom
## Multiple R-squared:  0.4309, Adjusted R-squared:  0.4106
## F-statistic: 21.2 on 1 and 28 DF,  p-value: 8.167e-05
```

```
summary(lm(d.Acacon ~ d.rocks, sem.dat))
```

```
##
## Call:
## lm(formula = d.Acacon ~ d.rocks, data = sem.dat)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -0.17556 -0.01439  0.01337  0.03252  0.09108
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept) -0.0238762  0.0126055  -1.894  0.06858 .
## d.rocks      0.0014183  0.0003987   3.557  0.00136 **
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.06117 on 28 degrees of freedom
## Multiple R-squared:  0.3113, Adjusted R-squared:  0.2867
## F-statistic: 12.66 on 1 and 28 DF,  p-value: 0.001357
```

```
summary(lm(d.Acaame ~ d.rocks, sem.dat))
```

```
##
## Call:
## lm(formula = d.Acaame ~ d.rocks, data = sem.dat)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -0.64206 -0.09675  0.03298  0.07873  0.56715
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept) -0.068167   0.042641  -1.599   0.121
## d.rocks      0.006310   0.001349   4.679 6.67e-05 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.2069 on 28 degrees of freedom
## Multiple R-squared:  0.4388, Adjusted R-squared:  0.4188
## F-statistic: 21.89 on 1 and 28 DF,  p-value: 6.669e-05
```

```
summary(lm(d.Canros ~ d.rocks, sem.dat))
```

```
##
## Call:
## lm(formula = d.Canros ~ d.rocks, data = sem.dat)
##
```

```
## Residuals:
##      Min       1Q   Median       3Q      Max
## -1.04560 -0.22148  0.06461  0.28602  0.81105
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept) -0.196087   0.096385  -2.034 0.051479 .
## d.rocks      0.012797   0.003048   4.198 0.000247 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.4678 on 28 degrees of freedom
## Multiple R-squared:  0.3863, Adjusted R-squared:  0.3643
## F-statistic: 17.62 on 1 and 28 DF,  p-value: 0.0002467
```

```
summary(lm(d.abun ~ d.light))
```

```
##
## Call:
## lm(formula = d.abun ~ d.light)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -8.3371 -2.7395  0.6687  1.5171  8.1163
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept) -0.85872    1.38331  -0.621   0.540
## d.light      0.04528    0.07905   0.573   0.571
##
## Residual standard error: 3.805 on 28 degrees of freedom
## Multiple R-squared:  0.01159, Adjusted R-squared: -0.02372
## F-statistic: 0.3282 on 1 and 28 DF,  p-value: 0.5713
```

```
summary(lm(d.rich ~ d.light))
```

```
##
## Call:
## lm(formula = d.rich ~ d.light)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -6.758 -3.199 -0.836  3.003 12.001
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept) -0.40551    1.67397  -0.242   0.810
## d.light      0.14061    0.09565   1.470   0.153
##
## Residual standard error: 4.605 on 28 degrees of freedom
## Multiple R-squared:  0.07164, Adjusted R-squared:  0.03848
## F-statistic: 2.161 on 1 and 28 DF,  p-value: 0.1527
```

```
summary(lm(d.shan ~ d.light))
```

```
##
```

```
## Call:
## lm(formula = d.shan ~ d.light)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -1.5927 -0.7784  0.1074  0.5385  2.1225
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept)  0.04306    0.34638   0.124   0.902
## d.light      0.03172    0.01979   1.603   0.120
##
## Residual standard error: 0.9528 on 28 degrees of freedom
## Multiple R-squared:  0.08402, Adjusted R-squared:  0.05131
## F-statistic: 2.568 on 1 and 28 DF, p-value: 0.1202
summary(lm(d.Acacon ~ d.light, sem.dat))

##
## Call:
## lm(formula = d.Acacon ~ d.light, data = sem.dat)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -0.21083 -0.02561  0.02198  0.04135  0.09381
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept)  0.007098    0.024294   0.292   0.7723
## d.light      0.003421    0.001388   2.464   0.0201 *
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.06682 on 28 degrees of freedom
## Multiple R-squared:  0.1782, Adjusted R-squared:  0.1489
## F-statistic: 6.072 on 1 and 28 DF, p-value: 0.02014
summary(lm(d.Acaame ~ d.light, sem.dat))

##
## Call:
## lm(formula = d.Acaame ~ d.light, data = sem.dat)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -0.85875 -0.06371  0.06088  0.15869  0.27225
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept)  0.03200    0.09117   0.351   0.7283
## d.light      0.01273    0.00521   2.444   0.0211 *
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.2508 on 28 degrees of freedom
```

```
## Multiple R-squared:  0.1758, Adjusted R-squared:  0.1463
## F-statistic: 5.972 on 1 and 28 DF,  p-value: 0.0211
summary(lm(d.Canros ~ d.light, sem.dat))

##
## Call:
## lm(formula = d.Canros ~ d.light, data = sem.dat)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -0.9699 -0.3253  0.1547  0.3191  1.2307
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept)  0.03300    0.19704   0.168   0.868
## d.light      0.02753    0.01126   2.445   0.021 *
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.542 on 28 degrees of freedom
## Multiple R-squared:  0.176, Adjusted R-squared:  0.1466
## F-statistic:  5.98 on 1 and 28 DF,  p-value: 0.02101
summary(lm(d.abun ~ d.litter))

##
## Call:
## lm(formula = d.abun ~ d.litter)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -7.380 -1.218  0.494  1.607  5.733
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept) -0.50153    0.67144  -0.747  0.46132
## d.litter     -0.06917    0.02094  -3.304  0.00261 **
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 3.246 on 28 degrees of freedom
## Multiple R-squared:  0.2805, Adjusted R-squared:  0.2548
## F-statistic: 10.92 on 1 and 28 DF,  p-value: 0.002612
summary(lm(d.rich ~ d.litter))

##
## Call:
## lm(formula = d.rich ~ d.litter)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -5.7618 -2.0890 -0.0954  1.7166  7.5545
##
## Coefficients:
```

```
##           Estimate Std. Error t value Pr(>|t|)
## (Intercept) -0.82616    0.71101  -1.162    0.255
## d.litter    -0.11328    0.02217  -5.110 2.05e-05 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 3.438 on 28 degrees of freedom
## Multiple R-squared:  0.4826, Adjusted R-squared:  0.4641
## F-statistic: 26.11 on 1 and 28 DF,  p-value: 2.053e-05
summary(lm(d.shan ~ d.litter))
```

```
##
## Call:
## lm(formula = d.shan ~ d.litter)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -1.47085 -0.59769  0.03512  0.59650  1.39944
##
## Coefficients:
##           Estimate Std. Error t value Pr(>|t|)
## (Intercept) -0.103513   0.156232  -0.663    0.513
## d.litter     -0.022128   0.004871  -4.543 9.68e-05 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.7554 on 28 degrees of freedom
## Multiple R-squared:  0.4243, Adjusted R-squared:  0.4037
## F-statistic: 20.64 on 1 and 28 DF,  p-value: 9.675e-05
summary(lm(d.Acacon ~ d.litter, sem.dat))
```

```
##
## Call:
## lm(formula = d.Acacon ~ d.litter, data = sem.dat)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -0.17743 -0.01528  0.01435  0.03220  0.09098
##
## Coefficients:
##           Estimate Std. Error t value Pr(>|t|)
## (Intercept) -0.0240028   0.0127820  -1.878  0.07085 .
## d.litter     -0.0013712   0.0003985  -3.441  0.00184 **
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.0618 on 28 degrees of freedom
## Multiple R-squared:  0.2971, Adjusted R-squared:  0.272
## F-statistic: 11.84 on 1 and 28 DF,  p-value: 0.001839
summary(lm(d.Acaame ~ d.litter, sem.dat))
```

```
##
## Call:
```

```
## lm(formula = d.Acaame ~ d.litter, data = sem.dat)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -0.64969 -0.10426  0.03407  0.08146  0.56925
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept) -0.067611   0.043169  -1.566   0.129
## d.litter     -0.006175   0.001346  -4.588 8.56e-05 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.2087 on 28 degrees of freedom
## Multiple R-squared:  0.4291, Adjusted R-squared:  0.4087
## F-statistic: 21.05 on 1 and 28 DF,  p-value: 8.558e-05
summary(lm(d.Canros ~ d.litter, sem.dat))
```

```
##
## Call:
## lm(formula = d.Canros ~ d.litter, data = sem.dat)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -1.06651 -0.21741  0.05103  0.27634  0.81235
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept) -0.193646   0.097001  -1.996 0.055705 .
## d.litter     -0.012609   0.003024  -4.169 0.000267 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.469 on 28 degrees of freedom
## Multiple R-squared:  0.383, Adjusted R-squared:  0.361
## F-statistic: 17.38 on 1 and 28 DF,  p-value: 0.0002666
```

SEM testing for this pathway, note that here community distance is the sum of squared differences for each tree pair (susceptible - resistant) for all species:

```
summary(model.abun, .progressBar = FALSE)
```

```
##
## Structural Equation Model of model.abun
##
## Call:
##      d.rocks ~ d.litter
##      d.abun ~ d.light + d.rocks
##
##      AIC      BIC
## 28.447 38.255
##
## ---
## Tests of directed separation:
##
```

```

##           Independ.Claim Test.Type DF Crit.Value P.Value
## d.abun ~ d.litter + ...      coef 26    -2.1260  0.0432 *
## d.rocks ~ d.light + ...      coef 27     2.5465  0.0169 *
##
## Global goodness-of-fit:
##
## Fisher's C = 14.447 with P-value = 0.006 and on 4 degrees of freedom
##
## ---
## Coefficients:
##
## Response Predictor Estimate Std.Error DF Crit.Value P.Value Std.Estimate
## d.rocks d.litter -0.9879  0.0108 28 -91.5294  0.0000 -0.9983 ***
## d.abun d.light  0.0030  0.0709 27  0.0428  0.9662  0.0072
## d.abun d.rocks  0.0676  0.0222 27  3.0408  0.0052  0.5121 **
##
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05
##
## ---
## Individual R-squared:
##
## Response method R.squared
## d.rocks none 1.00
## d.abun none 0.26
summary(model.rich, .progressBar = FALSE)

##
## Structural Equation Model of model.rich
##
## Call:
## d.rocks ~ d.litter
## d.rich ~ d.light + d.rocks
##
## AIC BIC
## 23.564 33.372
##
## ---
## Tests of directed separation:
##
##           Independ.Claim Test.Type DF Crit.Value P.Value
## d.rich ~ d.litter + ...      coef 26    -0.6906  0.4960
## d.rocks ~ d.light + ...      coef 27     2.5465  0.0169 *
##
## Global goodness-of-fit:
##
## Fisher's C = 9.564 with P-value = 0.048 and on 4 degrees of freedom
##
## ---
## Coefficients:
##
## Response Predictor Estimate Std.Error DF Crit.Value P.Value Std.Estimate
## d.rocks d.litter -0.9879  0.0108 28 -91.5294  0.0000 -0.9983 ***
## d.rich d.light  0.0718  0.0729 27  0.9854  0.3332  0.1368
## d.rich d.rocks  0.1100  0.0229 27  4.8086  0.0001  0.6674 ***

```



```
##
##   Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05
##
## ---
## Individual R-squared:
##
##   Response method R.squared
##   d.rocks    none        1.0
##   d.rich     none        0.5
summary(model.shan, .progressBar = FALSE)

##
## Structural Equation Model of model.shan
##
## Call:
##   d.rocks ~ d.litter
##   d.shan ~ d.light + d.rocks
##
##       AIC       BIC
##  22.182   31.99
##
## ---
## Tests of directed separation:
##
##           Independ.Claim Test.Type DF Crit.Value P.Value
##   d.shan ~ d.litter + ...      coef 26   -0.0130  0.9897
##   d.rocks ~ d.light + ...      coef 27    2.5465  0.0169 *
##
## Global goodness-of-fit:
##
##   Fisher's C = 8.182 with P-value = 0.085 and on 4 degrees of freedom
##
## ---
## Coefficients:
##
##   Response Predictor Estimate Std.Error DF Crit.Value P.Value Std.Estimate
##   d.rocks d.litter  -0.9879   0.0108  28   -91.5294  0.0000   -0.9983 ***
##   d.shan  d.light    0.0183   0.0158  27    1.1596  0.2563    0.1676
##   d.shan  d.rocks    0.0214   0.0050  27    4.3156  0.0002    0.6236 ***
##
##   Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05
##
## ---
## Individual R-squared:
##
##   Response method R.squared
##   d.rocks    none        1.00
##   d.shan     none        0.46
summary(model.com, .progressBar = FALSE)

##
## Structural Equation Model of model.com
##
```

```

## Call:
##   d.rocks ~ d.litter
##   d.com ~ d.light + d.rocks
##
##      AIC      BIC
## 27.066  36.874
##
## ---
## Tests of directed separation:
##
##      Independ.Claim Test.Type DF Crit.Value P.Value
##   d.com ~ d.litter + ...      coef 26      1.7840 0.0861
##   d.rocks ~ d.light + ...      coef 27      2.5465 0.0169 *
##
## Global goodness-of-fit:
##
##   Fisher's C = 13.066 with P-value = 0.011 and on 4 degrees of freedom
##
## ---
## Coefficients:
##
##   Response Predictor Estimate Std.Error DF Crit.Value P.Value Std.Estimate
##   d.rocks  d.litter  -0.9879    0.0108 28   -91.5294 0.0000    -0.9983 ***
##   d.com    d.light   -0.0350    0.0617 27    -0.5673 0.5752    -0.1096
##   d.com    d.rocks   -0.0119    0.0193 27    -0.6129 0.5450    -0.1184
##
##   Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05
##
## ---
## Individual R-squared:
##
##   Response method R.squared
##   d.rocks  none      1.00
##   d.com    none      0.03

```

```
summary(model.Acacon, .progressBar = FALSE)
```

```

##
## Structural Equation Model of model.Acacon
##
## Call:
##   d.rocks ~ d.litter
##   d.Acacon ~ d.light + d.rocks
##
##      AIC      BIC
## 23.133  32.941
##
## ---
## Tests of directed separation:
##
##      Independ.Claim Test.Type DF Crit.Value P.Value
##   d.Acacon ~ d.litter + ...      coef 26      0.5085 0.6154
##   d.rocks ~ d.light + ...      coef 27      2.5465 0.0169 *
##
## Global goodness-of-fit:

```

```

##
## Fisher's C = 9.133 with P-value = 0.058 and on 4 degrees of freedom
##
## ---
## Coefficients:
##
## Response Predictor Estimate Std.Error DF Crit.Value P.Value Std.Estimate
## d.rocks d.litter -0.9879 0.0108 28 -91.5294 0.0000 -0.9983 ***
## d.Acacon d.light 0.0026 0.0012 27 2.1628 0.0396 0.3252 *
## d.Acacon d.rocks 0.0013 0.0004 27 3.2863 0.0028 0.4941 **
##
## Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05
##
## ---
## Individual R-squared:
##
## Response method R.squared
## d.rocks none 1.00
## d.Acacon none 0.41

```

```
summary(model.Acaame, .progressBar = FALSE)
```

```

##
## Structural Equation Model of model.Acaame
##
## Call:
## d.rocks ~ d.litter
## d.Acaame ~ d.light + d.rocks
##
## AIC BIC
## 22.423 32.231
##
## ---
## Tests of directed separation:
##
## Independ.Claim Test.Type DF Crit.Value P.Value
## d.Acaame ~ d.litter + ... coef 26 -0.1558 0.8774
## d.rocks ~ d.light + ... coef 27 2.5465 0.0169 *
##
## Global goodness-of-fit:
##
## Fisher's C = 8.423 with P-value = 0.077 and on 4 degrees of freedom
##
## ---
## Coefficients:
##
## Response Predictor Estimate Std.Error DF Crit.Value P.Value Std.Estimate
## d.rocks d.litter -0.9879 0.0108 28 -91.5294 0.0000 -0.9983 ***
## d.Acaame d.light 0.0091 0.0041 27 2.2267 0.0345 0.3009 *
## d.Acaame d.rocks 0.0057 0.0013 27 4.4650 0.0001 0.6034 ***
##
## Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05
##
## ---
## Individual R-squared:

```

```
##
## Response method R.squared
## d.rocks none 1.00
## d.Acaame none 0.53

summary(model.Canros, .progressBar = FALSE)

##
## Structural Equation Model of model.Canros
##
## Call:
## d.rocks ~ d.litter
## d.Canros ~ d.light + d.rocks
##
## AIC BIC
## 23.898 33.706
##
## ---
## Tests of directed separation:
##
## Independ.Claim Test.Type DF Crit.Value P.Value
## d.Canros ~ d.litter + ... coef 26 -0.8201 0.4196
## d.rocks ~ d.light + ... coef 27 2.5465 0.0169 *
##
## Global goodness-of-fit:
##
## Fisher's C = 9.898 with P-value = 0.042 and on 4 degrees of freedom
##
## ---
## Coefficients:
##
## Response Predictor Estimate Std.Error DF Crit.Value P.Value Std.Estimate
## d.rocks d.litter -0.9879 0.0108 28 -91.5294 0.0000 -0.9983 ***
## d.Canros d.light 0.0203 0.0093 27 2.1836 0.0379 0.3095 *
## d.Canros d.rocks 0.0115 0.0029 27 3.9562 0.0005 0.5608 ***
##
## Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05
##
## ---
## Individual R-squared:
##
## Response method R.squared
## d.rocks none 1.00
## d.Canros none 0.48

summary(lm(d.v.abun ~ d.rocks))

##
## Call:
## lm(formula = d.v.abun ~ d.rocks)
##
## Residuals:
## Min 1Q Median 3Q Max
## -46.548 -9.167 -0.371 11.836 29.860
##
```

```
## Coefficients:
##           Estimate Std. Error t value Pr(>|t|)
## (Intercept) -23.61098    3.52322  -6.702 2.83e-07 ***
## d.rocks      -0.08716    0.11143  -0.782  0.441
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 17.1 on 28 degrees of freedom
## Multiple R-squared:  0.02138,    Adjusted R-squared:  -0.01357
## F-statistic: 0.6118 on 1 and 28 DF,  p-value: 0.4407
```

```
summary(lm(d.v.rich ~ d.rocks))
```

```
##
## Call:
## lm(formula = d.v.rich ~ d.rocks)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -1.6195 -0.7375  0.2342  0.3760  2.3148
##
## Coefficients:
##           Estimate Std. Error t value Pr(>|t|)
## (Intercept) -1.259773    0.199030  -6.330 7.57e-07 ***
## d.rocks       0.002744    0.006295   0.436  0.666
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.9659 on 28 degrees of freedom
## Multiple R-squared:  0.006742,    Adjusted R-squared:  -0.02873
## F-statistic: 0.1901 on 1 and 28 DF,  p-value: 0.6662
```

```
summary(lm(d.v.shan ~ d.rocks))
```

```
##
## Call:
## lm(formula = d.v.shan ~ d.rocks)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -0.63077 -0.28155  0.02544  0.29568  0.97384
##
## Coefficients:
##           Estimate Std. Error t value Pr(>|t|)
## (Intercept) -0.335709    0.078745  -4.263 0.000207 ***
## d.rocks      -0.002745    0.002491  -1.102 0.279691
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.3821 on 28 degrees of freedom
## Multiple R-squared:  0.04159,    Adjusted R-squared:  0.007366
## F-statistic: 1.215 on 1 and 28 DF,  p-value: 0.2797
```

```
summary(lm(d.Apache.plume ~ d.rocks, v.sem.dat))
```

```
##
```

```
## Call:
## lm(formula = d.Apache.plume ~ d.rocks, data = v.sem.dat)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -28.028  -4.455   4.278   6.677  14.799
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept) -12.13756    2.44690  -4.960 3.09e-05 ***
## d.rocks      -0.12763    0.07739  -1.649    0.11
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 11.87 on 28 degrees of freedom
## Multiple R-squared:  0.08854,    Adjusted R-squared:  0.05598
## F-statistic:  2.72 on 1 and 28 DF,  p-value: 0.1103
summary(lm(d.Asteraceae.ovales ~ d.rocks, v.sem.dat))
```

```
##
## Call:
## lm(formula = d.Asteraceae.ovales ~ d.rocks, data = v.sem.dat)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -31.976  -7.315   5.782   7.526  19.463
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept)  -7.44665    2.34354  -3.178  0.0036 **
## d.rocks       0.04684    0.07412   0.632  0.5325
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 11.37 on 28 degrees of freedom
## Multiple R-squared:  0.01406,    Adjusted R-squared: -0.02115
## F-statistic: 0.3994 on 1 and 28 DF,  p-value: 0.5325
summary(lm(d.v.abun ~ d.litter))
```

```
##
## Call:
## lm(formula = d.v.abun ~ d.litter)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -46.743  -8.907   0.019  11.943  30.269
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept) -23.44568    3.54674  -6.610 3.6e-07 ***
## d.litter     0.07381    0.11059   0.667    0.51
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
##
## Residual standard error: 17.15 on 28 degrees of freedom
## Multiple R-squared:  0.01566,    Adjusted R-squared:  -0.01949
## F-statistic: 0.4455 on 1 and 28 DF,  p-value: 0.5099
```

```
summary(lm(d.v.rich ~ d.litter))
```

```
##
## Call:
## lm(formula = d.v.rich ~ d.litter)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -1.6111 -0.7427  0.2214  0.3838  2.3153
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept) -1.253709   0.199585  -6.282 8.61e-07 ***
## d.litter     -0.003072   0.006223  -0.494   0.625
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.965 on 28 degrees of freedom
## Multiple R-squared:  0.008626,    Adjusted R-squared:  -0.02678
## F-statistic: 0.2436 on 1 and 28 DF,  p-value: 0.6254
```

```
summary(lm(d.v.shan ~ d.litter))
```

```
##
## Call:
## lm(formula = d.v.shan ~ d.litter)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -0.62023 -0.28853  0.04059  0.29668  0.97632
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept) -0.332721   0.079334  -4.194 0.000249 ***
## d.litter      0.002472   0.002474   0.999 0.326145
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.3836 on 28 degrees of freedom
## Multiple R-squared:  0.03444,    Adjusted R-squared:  -3.912e-05
## F-statistic: 0.9989 on 1 and 28 DF,  p-value: 0.3261
```

```
summary(lm(d.Apache.plume ~ d.litter, v.sem.dat))
```

```
##
## Call:
## lm(formula = d.Apache.plume ~ d.litter, data = v.sem.dat)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -28.098  -4.465   4.364   6.975  14.577
```

```
##
## Coefficients:
##             Estimate Std. Error t value Pr(>|t|)
## (Intercept) -12.05623    2.46985  -4.881 3.84e-05 ***
## d.litter      0.11875    0.07701   1.542  0.134
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 11.94 on 28 degrees of freedom
## Multiple R-squared:  0.07828,    Adjusted R-squared:  0.04536
## F-statistic: 2.378 on 1 and 28 DF,  p-value: 0.1343
summary(lm(d.Asteraceae.ovales ~ d.litter, v.sem.dat))
```

```
##
## Call:
## lm(formula = d.Asteraceae.ovales ~ d.litter, data = v.sem.dat)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -32.006  -7.296   5.653   7.482  19.553
##
## Coefficients:
##             Estimate Std. Error t value Pr(>|t|)
## (Intercept) -7.36833    2.34896  -3.137  0.00399 **
## d.litter     -0.05076    0.07324  -0.693  0.49395
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 11.36 on 28 degrees of freedom
## Multiple R-squared:  0.01687,    Adjusted R-squared: -0.01824
## F-statistic: 0.4804 on 1 and 28 DF,  p-value: 0.494
```

```
summary(lm(d.v.abun ~ d.light))
```

```
##
## Call:
## lm(formula = d.v.abun ~ d.light)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -47.204  -7.755   1.085  11.993  31.908
##
## Coefficients:
##             Estimate Std. Error t value Pr(>|t|)
## (Intercept) -23.8611    6.2747  -3.803 0.000711 ***
## d.light      -0.1010    0.3585  -0.282 0.780349
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 17.26 on 28 degrees of freedom
## Multiple R-squared:  0.002823,    Adjusted R-squared: -0.03279
## F-statistic: 0.07928 on 1 and 28 DF,  p-value: 0.7803
```

```
summary(lm(d.v.rich ~ d.light))
```



```
##
## Call:
## lm(formula = d.v.rich ~ d.light)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -1.7203 -0.7086  0.2372  0.4718  2.3085
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept) -1.10636    0.34979  -3.163  0.00374 **
## d.light      0.01280    0.01999   0.640  0.52727
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.9622 on 28 degrees of freedom
## Multiple R-squared:  0.01443,    Adjusted R-squared:  -0.02077
## F-statistic: 0.4098 on 1 and 28 DF,  p-value: 0.5273
```

```
summary(lm(d.v.shan ~ d.light))
```

```
##
## Call:
## lm(formula = d.v.shan ~ d.light)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -0.5917 -0.3570  0.1214  0.2817  0.9857
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept) -0.362101    0.141162  -2.565   0.016 *
## d.light      -0.004403    0.008066  -0.546   0.589
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.3883 on 28 degrees of freedom
## Multiple R-squared:  0.01053,    Adjusted R-squared:  -0.02481
## F-statistic: 0.298 on 1 and 28 DF,  p-value: 0.5895
```

```
summary(lm(d.Apache.plume ~ d.light, v.sem.dat))
```

```
##
## Call:
## lm(formula = d.Apache.plume ~ d.light, data = v.sem.dat)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -33.062  -4.319   4.807   9.297  16.737
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept) -14.6411    4.4197  -3.313  0.00256 **
## d.light      -0.2891    0.2525  -1.145  0.26208
## ---
```

```

## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 12.16 on 28 degrees of freedom
## Multiple R-squared:  0.0447, Adjusted R-squared:  0.01058
## F-statistic:  1.31 on 1 and 28 DF,  p-value: 0.2621
summary(lm(d.Asteraceae.ovals ~ d.light, v.sem.dat))

##
## Call:
## lm(formula = d.Asteraceae.ovals ~ d.light, data = v.sem.dat)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -31.874  -6.867   6.133   8.134  18.131
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept) -8.1407349  4.1640687  -1.955   0.0606 .
## d.light      -0.0004891  0.2379432  -0.002   0.9984
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 11.45 on 28 degrees of freedom
## Multiple R-squared:  1.509e-07, Adjusted R-squared:  -0.03571
## F-statistic: 4.225e-06 on 1 and 28 DF,  p-value: 0.9984
summary(model.v.com, .progressBar = FALSE)

##
## Structural Equation Model of model.v.com
##
## Call:
##      d.rocks ~ d.litter
##      d.v.com ~ d.light + d.rocks
##
##      AIC      BIC
## 28.300  38.108
##
## ---
## Tests of directed separation:
##
##              Independ.Claim Test.Type DF Crit.Value P.Value
## d.v.com ~ d.litter + ...      coef 26      2.0909 0.0465 *
## d.rocks ~ d.light + ...      coef 27      2.5465 0.0169 *
##
## Global goodness-of-fit:
##
## Fisher's C = 14.3 with P-value = 0.006 and on 4 degrees of freedom
##
## ---
## Coefficients:
##
##      Response Predictor Estimate Std.Error DF Crit.Value P.Value Std.Estimate
##      d.rocks d.litter -0.9879    0.0108 28    -91.5294 0.0000    -0.9983 ***

```

```

##      d.v.com   d.light   0.0177   0.3475 27      0.0508 0.9598      0.0099
##      d.v.com   d.rocks   0.0595   0.1090 27      0.5453 0.5900      0.1064
##
##   Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05
##
## ---
## Individual R-squared:
##
##   Response method R.squared
##   d.rocks      none        1.00
##   d.v.com      none        0.01
summary(model.v.abun, .progressBar = FALSE)

##
## Structural Equation Model of model.v.abun
##
## Call:
##   d.rocks ~ d.litter
##   d.v.abun ~ d.light + d.rocks
##
##      AIC      BIC
## 28.663  38.471
##
## ---
## Tests of directed separation:
##
##               Independ.Claim Test.Type DF Crit.Value P.Value
## d.v.abun ~ d.litter + ...      coef 26    -2.1770 0.0387 *
## d.rocks ~ d.light + ...      coef 27     2.5465 0.0169 *
##
## Global goodness-of-fit:
##
##   Fisher's C = 14.663 with P-value = 0.005 and on 4 degrees of freedom
##
## ---
## Coefficients:
##
##   Response Predictor Estimate Std.Error DF Crit.Value P.Value Std.Estimate
##   d.rocks d.litter  -0.9879    0.0108 28   -91.5294 0.0000   -0.9983 ***
##   d.v.abun d.light  -0.0483    0.3688 27    -0.1310 0.8967   -0.0254
##   d.v.abun d.rocks  -0.0842    0.1157 27    -0.7277 0.4731   -0.1412
##
##   Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05
##
## ---
## Individual R-squared:
##
##   Response method R.squared
##   d.rocks      none        1.00
##   d.v.abun     none        0.02
summary(model.v.rich, .progressBar = FALSE)

##

```

```
## Structural Equation Model of model.v.rich
##
## Call:
##   d.rocks ~ d.litter
##   d.v.rich ~ d.light + d.rocks
##
##       AIC       BIC
## 25.623   35.431
##
## ---
## Tests of directed separation:
##
##               Independ.Claim Test.Type DF Crit.Value P.Value
## d.v.rich ~ d.litter + ...      coef 26    -1.3873  0.1771
## d.rocks ~ d.light + ...      coef 27     2.5465  0.0169 *
##
## Global goodness-of-fit:
##
## Fisher's C = 11.623 with P-value = 0.02 and on 4 degrees of freedom
##
## ---
## Coefficients:
##
##   Response Predictor Estimate Std.Error DF Crit.Value P.Value Std.Estimate
## d.rocks d.litter -0.9879    0.0108 28   -91.5294  0.0000   -0.9983 ***
## d.v.rich d.light  0.0115    0.0207 27     0.5561  0.5827    0.1082
## d.v.rich d.rocks  0.0020    0.0065 27     0.3131  0.7566    0.0609
##
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05
##
## ---
## Individual R-squared:
##
##   Response method R.squared
## d.rocks none 1.00
## d.v.rich none 0.02
```

```
summary(model.v.shan, .progressBar = FALSE)
```

```
##
## Structural Equation Model of model.v.shan
##
## Call:
##   d.rocks ~ d.litter
##   d.v.shan ~ d.light + d.rocks
##
##       AIC       BIC
## 26.895   36.703
##
## ---
## Tests of directed separation:
##
##               Independ.Claim Test.Type DF Crit.Value P.Value
## d.v.shan ~ d.litter + ...      coef 26    -1.7395  0.0938
## d.rocks ~ d.light + ...      coef 27     2.5465  0.0169 *
```

```

##
## Global goodness-of-fit:
##
## Fisher's C = 12.895 with P-value = 0.012 and on 4 degrees of freedom
##
## ---
## Coefficients:
##
## Response Predictor Estimate Std.Error DF Crit.Value P.Value Std.Estimate
## d.rocks d.litter -0.9879 0.0108 28 -91.5294 0.0000 -0.9983 ***
## d.v.shan d.light -0.0028 0.0082 27 -0.3397 0.7367 -0.0651
## d.v.shan d.rocks -0.0026 0.0026 27 -0.9971 0.3276 -0.1912
##
## Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05
##
## ---
## Individual R-squared:
##
## Response method R.squared
## d.rocks none 1.00
## d.v.shan none 0.05
summary(model.v.Apache.plume, .progressBar = FALSE)

##
## Structural Equation Model of model.v.Apache.plume
##
## Call:
## d.rocks ~ d.litter
## d.Apache.plume ~ d.light + d.rocks
##
## AIC BIC
## 25.830 35.638
##
## ---
## Tests of directed separation:
##
## Independ.Claim Test.Type DF Crit.Value P.Value
## d.Apache.plume ~ d.litter + ... coef 26 -1.4474 0.1597
## d.rocks ~ d.light + ... coef 27 2.5465 0.0169 *
##
## Global goodness-of-fit:
##
## Fisher's C = 11.83 with P-value = 0.019 and on 4 degrees of freedom
##
## ---
## Coefficients:
##
## Response Predictor Estimate Std.Error DF Crit.Value P.Value Std.Estimate
## d.rocks d.litter -0.9879 0.0108 28 -91.5294 0.0000 -0.9983
## d.Apache.plume d.light -0.2176 0.2527 27 -0.8611 0.3968 -0.1592
## d.Apache.plume d.rocks -0.1142 0.0793 27 -1.4408 0.1611 -0.2663
##
## ***
##

```

```
##
##
##   Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05
##
## ---
## Individual R-squared:
##
##           Response method R.squared
##           d.rocks      none      1.00
##   d.Apache.plume     none      0.11
```

```
summary(model.v.Asteraceae.ovales, .progressBar = FALSE)
```

```
##
## Structural Equation Model of model.v.Asteraceae.ovales
##
## Call:
##   d.rocks ~ d.litter
##   d.Asteraceae.ovales ~ d.light + d.rocks
##
##           AIC           BIC
##   24.690      34.498
##
## ---
## Tests of directed separation:
##
##                               Independ.Claim Test.Type DF Crit.Value P.Value
##   d.Asteraceae.ovales ~ d.litter + ...      coef 26    -1.0976  0.2824
##                               d.rocks ~ d.light + ...      coef 27     2.5465  0.0169 *
```

| Global goodness-of-fit:  |  |  |  |  |  |  |  |
|--|--|--|--|--|--|--|--|
| Fisher's C = 10.69 with P-value = 0.03 and on 4 degrees of freedom |  |  |  |  |  |  |  |

```
##
## ---
## Coefficients:
##
##           Response Predictor Estimate Std.Error DF Crit.Value P.Value
##           d.rocks d.litter  -0.9879    0.0108 28   -91.5294  0.0000
##   d.Asteraceae.ovales d.light  -0.0310    0.2453 27    -0.1262  0.9005
##   d.Asteraceae.ovales d.rocks   0.0488    0.0770 27     0.6335  0.5317
## Std.Estimate
##   -0.9983 ***
##   -0.0246
##    0.1234
##
##   Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05
##
## ---
## Individual R-squared:
##
##           Response method R.squared
##           d.rocks      none      1.00
##   d.Asteraceae.ovales     none      0.01
```

## Analyses for Revisions

Tree -> Moth -> Trait -> Loc env -> Community (A, R, D, Comp)

Pair S/R Crown Litter Lichen Rocks Plants Light

### Lichen and plant community responses are not correlated

```
“{r mantel-l-v}
```

```
mantel(l.com.dif.d ~ v.com.dif.d)
```

```
## Both lichen and vegetation respond to moth susceptibility
```

```
```r
```

```
set.seed(12345)
```

```
xtable::xtable(adonis2(com.ds ~ Moth,
                        strata = l.dat[, "Tree.pairs"],
                        data = l.dat,
                        perm = 9999)
)
```

% latex table generated in R 4.0.4 by xtable 1.8-4 package % Tue Apr 20 17:11:44 2021

|          | Df | SumOfSqs | R2   | F    | Pr(>F) |
|----------|----|----------|------|------|--------|
| Moth     | 1  | 0.83     | 0.04 | 2.35 | 0.0305 |
| Residual | 58 | 20.54    | 0.96 |      |        |
| Total    | 59 | 21.37    | 1.00 |      |        |

```
set.seed(12345)
```

```
xtable::xtable(adonis2(v.com.ds ~ Moth,
                        strata = l.dat[, "Tree.pairs"],
                        data = l.dat,
                        perm = 9999)
)
```

% latex table generated in R 4.0.4 by xtable 1.8-4 package % Tue Apr 20 17:11:45 2021

|          | Df | SumOfSqs | R2   | F     | Pr(>F) |
|----------|----|----------|------|-------|--------|
| Moth     | 1  | 5.17     | 0.31 | 25.83 | 0.0001 |
| Residual | 58 | 11.62    | 0.69 |       |        |
| Total    | 59 | 16.79    | 1.00 |       |        |

```
tab.ttest.ard <- do.call(rbind,
                        lapply(
                          apply(data.frame(l.ard.dif, v.ard.dif), 2,
                                t.test),
                          unlist))[, c(1, 2, 6, 3)]
tab.lab <- rownames(tab.ttest.ard)
tab.ttest.ard <- apply(tab.ttest.ard, 2, as.numeric)
rownames(tab.ttest.ard) <- tab.lab
xtable::xtable(tab.ttest.ard, digits = 5)
```

% latex table generated in R 4.0.4 by xtable 1.8-4 package % Fri Apr 23 16:31:20 2021

|     | statistic.t | parameter.df | estimate.mean of x | p.value |
|-----|-------------|--------------|--------------------|---------|
| l.A | -2.24873    | 29.00000     | -1.54400           | 0.03230 |
| l.R | -2.95490    | 29.00000     | -2.53333           | 0.00615 |
| l.D | -2.44677    | 29.00000     | -0.43698           | 0.02071 |
| p.A | -7.13460    | 29.00000     | -22.43333          | 0.00000 |
| p.R | -7.47696    | 29.00000     | -1.30000           | 0.00000 |
| p.D | -4.21918    | 29.00000     | -0.29546           | 0.00022 |

## Moth impacts tree traits and the local environment

```
tab.ttest.envtra <- do.call(rbind,
  lapply(
    apply(data.frame(tra.dif, env.dif), 2,
      t.test),
    unlist))[, c(1, 2, 6, 3)]
tab.lab <- rownames(tab.ttest.envtra)
tab.ttest.envtra <- apply(tab.ttest.envtra, 2, as.numeric)
rownames(tab.ttest.envtra) <- tab.lab
xtable::xtable(tab.ttest.envtra, digits = 5)
```

% latex table generated in R 4.0.4 by xtable 1.8-4 package % Fri Apr 23 16:31:20 2021

|              | statistic.t | parameter.df | estimate.mean of x | p.value |
|--------------|-------------|--------------|--------------------|---------|
| trunk.radius | -3.59977    | 29.00000     | -3.13667           | 0.00117 |
| crown.radius | -4.61833    | 29.00000     | -58.48667          | 0.00007 |
| litter       | 2.86654     | 29.00000     | 15.07000           | 0.00765 |
| rocks        | -2.81780    | 29.00000     | -14.65867          | 0.00862 |
| rock.lg      | -2.46174    | 29.00000     | -9.68367           | 0.02001 |
| rock.sm      | -2.07917    | 29.00000     | -4.97500           | 0.04655 |
| light        | -9.27275    | 29.00000     | -15.13333          | 0.00000 |

## Tree environment correlate with community

```
set.seed(12345)
xtable::xtable(adonis2(com.ds ~ Big.rocks.. + Small.rocks.. + Light...average,
  strata = 1.dat[, "Tree.pairs"],
  by = "margin",
  data = data.frame(env, traits),
  perm = 9999, rank = TRUE)
)
```

```
## % latex table generated in R 4.0.4 by xtable 1.8-4 package
## % Wed Apr 21 12:26:26 2021
## \begin{table}[ht]
## \centering
## \begin{tabular}{lrrrrr}
## \hline
## & Df & SumOfSqs & R2 & F & Pr(>$F) \\
## \hline
## Big.rocks.. & 1 & 1.79 & 0.08 & 5.47 & 0.0004 \\
## Small.rocks.. & 1 & 0.27 & 0.01 & 0.81 & 0.5720 \\
## Light...average & 1 & 0.39 & 0.02 & 1.20 & 0.2649 \\
## Residual & 56 & 18.31 & 0.86 & & \end{tabular}
```



```

## Total & 59 & 21.37 & 1.00 & & \\
## \hline
## \end{tabular}
## \end{table}

set.seed(12345)
xtable::xtable(adonis2(v.com.ds ~ Light...average + Big.rock.. + Small.rock..,
                      strata = l.dat[, "Tree.pairs"],
                      by = "margin",
                      data = data.frame(env, traits),
                      perm = 9999)

)

## % latex table generated in R 4.0.4 by xtable 1.8-4 package
## % Wed Apr 21 12:26:30 2021
## \begin{table}[ht]
## \centering
## \begin{tabular}{lrrrrr}
## \hline
## & Df & SumOfSqs & R2 & F & Pr(>F) \\
## \hline
## Light...average & 1 & 2.93 & 0.17 & 13.00 & 0.0001 \\
## Big.rock.. & 1 & 0.10 & 0.01 & 0.44 & 0.7243 \\
## Small.rock.. & 1 & 0.73 & 0.04 & 3.26 & 0.0290 \\
## Residual & 56 & 12.61 & 0.75 & & \\
## Total & 59 & 16.79 & 1.00 & & \\
## \hline
## \end{tabular}
## \end{table}

summary(lm(l.A ~ rock.lg * rock.sm * light,
           data = data.frame(l.ard.dif, tra.dif, env.dif)))

##
## Call:
## lm(formula = l.A ~ rock.lg * rock.sm * light, data = data.frame(l.ard.dif,
##   tra.dif, env.dif))
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -7.5443 -0.9009  0.3873  1.2621  4.7576
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept)    1.2906171   1.9919281    0.648  0.5237
## rock.lg         0.2672626   0.1144530    2.335  0.0291 *
## rock.sm        -0.2489435   0.2305602   -1.080  0.2920
## light          0.0964938   0.1233636    0.782  0.4424
## rock.lg:rock.sm -0.0098077   0.0131545   -0.746  0.4638
## rock.lg:light    0.0108967   0.0067177    1.622  0.1190
## rock.sm:light    -0.0130569   0.0118033   -1.106  0.2806
## rock.lg:rock.sm:light -0.0002544  0.0005513   -0.461  0.6490
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 3.337 on 22 degrees of freedom

```

```
## Multiple R-squared:  0.4027, Adjusted R-squared:  0.2127
## F-statistic: 2.119 on 7 and 22 DF,  p-value: 0.08438

summary(lm(l.R ~ rock.lg * rock.sm * light,
           data = data.frame(l.ard.dif, tra.dif, env.dif)))

##
## Call:
## lm(formula = l.R ~ rock.lg * rock.sm * light, data = data.frame(l.ard.dif,
##   tra.dif, env.dif))
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -5.4034 -1.7571  0.5585   2.0862   3.9423
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept)    2.8682448   1.8246866   1.572  0.1302
## rock.lg         0.3576352   0.1048436   3.411  0.0025 **
## rock.sm         0.0782553   0.2112024   0.371  0.7145
## light          0.2596367   0.1130061   2.298  0.0315 *
## rock.lg:rock.sm  0.0060809   0.0120501   0.505  0.6188
## rock.lg:light    0.0114837   0.0061537   1.866  0.0754 .
## rock.sm:light    0.0050780   0.0108123   0.470  0.6432
## rock.lg:rock.sm:light 0.0003271  0.0005050   0.648  0.5238
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 3.057 on 22 degrees of freedom
## Multiple R-squared:  0.6785, Adjusted R-squared:  0.5762
## F-statistic: 6.634 on 7 and 22 DF,  p-value: 0.0002762

summary(lm(l.D ~ rock.lg * rock.sm * light,
           data = data.frame(l.ard.dif, tra.dif, env.dif)))

##
## Call:
## lm(formula = l.D ~ rock.lg * rock.sm * light, data = data.frame(l.ard.dif,
##   tra.dif, env.dif))
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -1.3539 -0.1798  0.1183   0.3590   0.9120
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept)    7.064e-01  3.914e-01   1.805  0.0848 .
## rock.lg         5.437e-02  2.249e-02   2.418  0.0243 *
## rock.sm         5.766e-02  4.530e-02   1.273  0.2163
## light          6.085e-02  2.424e-02   2.511  0.0199 *
## rock.lg:rock.sm  2.179e-03  2.585e-03   0.843  0.4082
## rock.lg:light    1.247e-03  1.320e-03   0.945  0.3552
## rock.sm:light    3.242e-03  2.319e-03   1.398  0.1761
## rock.lg:rock.sm:light 8.461e-05  1.083e-04   0.781  0.4431
## ---
```

```
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.6557 on 22 degrees of freedom
## Multiple R-squared:  0.6592, Adjusted R-squared:  0.5508
## F-statistic: 6.079 on 7 and 22 DF,  p-value: 0.0004929
summary(lm(l.A ~ light *rock.lg * rock.sm,
           data = data.frame(l.ard.dif, tra.dif, env.dif)))

##
## Call:
## lm(formula = l.A ~ light * rock.lg * rock.sm, data = data.frame(l.ard.dif,
##   tra.dif, env.dif))
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -7.5443 -0.9009  0.3873  1.2621  4.7576
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept)      1.2906171   1.9919281    0.648  0.5237
## light            0.0964938   0.1233636    0.782  0.4424
## rock.lg          0.2672626   0.1144530    2.335  0.0291 *
## rock.sm         -0.2489435   0.2305602   -1.080  0.2920
## light:rock.lg     0.0108967   0.0067177    1.622  0.1190
## light:rock.sm    -0.0130569   0.0118033   -1.106  0.2806
## rock.lg:rock.sm   -0.0098077   0.0131545   -0.746  0.4638
## light:rock.lg:rock.sm -0.0002544  0.0005513   -0.461  0.6490
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 3.337 on 22 degrees of freedom
## Multiple R-squared:  0.4027, Adjusted R-squared:  0.2127
## F-statistic: 2.119 on 7 and 22 DF,  p-value: 0.08438
summary(lm(l.R ~ light *rock.lg * rock.sm,
           data = data.frame(l.ard.dif, tra.dif, env.dif)))

##
## Call:
## lm(formula = l.R ~ light * rock.lg * rock.sm, data = data.frame(l.ard.dif,
##   tra.dif, env.dif))
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -5.4034 -1.7571  0.5585  2.0862  3.9423
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept)      2.8682448   1.8246866    1.572  0.1302
## light            0.2596367   0.1130061    2.298  0.0315 *
## rock.lg          0.3576352   0.1048436    3.411  0.0025 **
## rock.sm          0.0782553   0.2112024    0.371  0.7145
## light:rock.lg     0.0114837   0.0061537    1.866  0.0754 .
## light:rock.sm     0.0050780   0.0108123    0.470  0.6432
```

```
## rock.lg:rock.sm      0.0060809  0.0120501  0.505  0.6188
## light:rock.lg:rock.sm 0.0003271  0.0005050  0.648  0.5238
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 3.057 on 22 degrees of freedom
## Multiple R-squared:  0.6785, Adjusted R-squared:  0.5762
## F-statistic: 6.634 on 7 and 22 DF,  p-value: 0.0002762
summary(lm(l.D ~ light * rock.lg * rock.sm,
           data = data.frame(l.ard.dif, tra.dif, env.dif)))

##
## Call:
## lm(formula = l.D ~ light * rock.lg * rock.sm, data = data.frame(l.ard.dif,
##   tra.dif, env.dif))
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -1.3539 -0.1798  0.1183  0.3590  0.9120
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept)    7.064e-01  3.914e-01   1.805  0.0848 .
## light          6.085e-02  2.424e-02   2.511  0.0199 *
## rock.lg        5.437e-02  2.249e-02   2.418  0.0243 *
## rock.sm        5.766e-02  4.530e-02   1.273  0.2163
## light:rock.lg   1.247e-03  1.320e-03   0.945  0.3552
## light:rock.sm   3.242e-03  2.319e-03   1.398  0.1761
## rock.lg:rock.sm 2.179e-03  2.585e-03   0.843  0.4082
## light:rock.lg:rock.sm 8.461e-05 1.083e-04   0.781  0.4431
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.6557 on 22 degrees of freedom
## Multiple R-squared:  0.6592, Adjusted R-squared:  0.5508
## F-statistic: 6.079 on 7 and 22 DF,  p-value: 0.0004929
summary(lm(l.A ~ rock.lg + rock.sm + light,
           data = data.frame(l.ard.dif, tra.dif, env.dif)))

##
## Call:
## lm(formula = l.A ~ rock.lg + rock.sm + light, data = data.frame(l.ard.dif,
##   tra.dif, env.dif))
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -7.7485 -0.6511  0.6642  1.3935  5.4237
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept) -0.427328  1.224495  -0.349  0.72991
## rock.lg      0.088123  0.030432   2.896  0.00757 **
## rock.sm      0.022591  0.050663   0.446  0.65935
```

```
## light          0.009973  0.071228  0.140  0.88972
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 3.346 on 26 degrees of freedom
## Multiple R-squared:  0.2904, Adjusted R-squared:  0.2085
## F-statistic: 3.547 on 3 and 26 DF,  p-value: 0.02821
summary(lm(l.R ~ rock.lg + rock.sm + light,
           data = data.frame(l.ard.dif, tra.dif, env.dif)))

##
## Call:
## lm(formula = l.R ~ rock.lg + rock.sm + light, data = data.frame(l.ard.dif,
##   tra.dif, env.dif))
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -5.6550 -1.9714  0.6468  2.0461  6.0752
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept)  0.371141   1.130676   0.328   0.745
## rock.lg      0.162543   0.028100   5.784 4.3e-06 ***
## rock.sm     -0.005166   0.046781  -0.110   0.913
## light       0.089614   0.065770   1.363   0.185
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 3.089 on 26 degrees of freedom
## Multiple R-squared:  0.6119, Adjusted R-squared:  0.5672
## F-statistic: 13.67 on 3 and 26 DF,  p-value: 1.515e-05
summary(lm(l.D ~ rock.lg + rock.sm + light,
           data = data.frame(l.ard.dif, tra.dif, env.dif)))

##
## Call:
## lm(formula = l.D ~ rock.lg + rock.sm + light, data = data.frame(l.ard.dif,
##   tra.dif, env.dif))
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -1.20164 -0.37452  0.01855  0.38633  1.20307
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept)  0.1937003  0.2527542   0.766   0.450
## rock.lg      0.0315016  0.0062816   5.015 3.23e-05 ***
## rock.sm     -0.0007058  0.0104575  -0.067   0.947
## light       0.0217497  0.0147024   1.479   0.151
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.6906 on 26 degrees of freedom
```

```
## Multiple R-squared:  0.5531, Adjusted R-squared:  0.5016
## F-statistic: 10.73 on 3 and 26 DF,  p-value: 9.066e-05

summary(lm(l.A ~ light +rock.lg + rock.sm,
           data = data.frame(l.ard.dif, tra.dif, env.dif)))

##
## Call:
## lm(formula = l.A ~ light + rock.lg + rock.sm, data = data.frame(l.ard.dif,
##      tra.dif, env.dif))
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -7.7485 -0.6511  0.6642  1.3935  5.4237
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept) -0.427328   1.224495  -0.349   0.72991
## light        0.009973   0.071228   0.140   0.88972
## rock.lg      0.088123   0.030432   2.896   0.00757 **
## rock.sm      0.022591   0.050663   0.446   0.65935
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 3.346 on 26 degrees of freedom
## Multiple R-squared:  0.2904, Adjusted R-squared:  0.2085
## F-statistic: 3.547 on 3 and 26 DF,  p-value: 0.02821

summary(lm(l.R ~ light +rock.lg + rock.sm,
           data = data.frame(l.ard.dif, tra.dif, env.dif)))

##
## Call:
## lm(formula = l.R ~ light + rock.lg + rock.sm, data = data.frame(l.ard.dif,
##      tra.dif, env.dif))
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -5.6550 -1.9714  0.6468  2.0461  6.0752
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept)  0.371141   1.130676   0.328   0.745
## light        0.089614   0.065770   1.363   0.185
## rock.lg      0.162543   0.028100   5.784 4.3e-06 ***
## rock.sm     -0.005166   0.046781  -0.110   0.913
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 3.089 on 26 degrees of freedom
## Multiple R-squared:  0.6119, Adjusted R-squared:  0.5672
## F-statistic: 13.67 on 3 and 26 DF,  p-value: 1.515e-05

summary(lm(l.D ~ light +rock.lg + rock.sm,
           data = data.frame(l.ard.dif, tra.dif, env.dif)))
```

```
##
## Call:
## lm(formula = l.D ~ light + rock.lg + rock.sm, data = data.frame(l.ard.dif,
##   tra.dif, env.dif))
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -1.20164 -0.37452  0.01855  0.38633  1.20307
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept)  0.1937003  0.2527542   0.766   0.450
## light        0.0217497  0.0147024   1.479   0.151
## rock.lg      0.0315016  0.0062816   5.015 3.23e-05 ***
## rock.sm     -0.0007058  0.0104575  -0.067   0.947
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.6906 on 26 degrees of freedom
## Multiple R-squared:  0.5531, Adjusted R-squared:  0.5016
## F-statistic: 10.73 on 3 and 26 DF,  p-value: 9.066e-05
summary(lm(p.A ~ rock.lg * rock.sm * light,
  data = data.frame(v.ard.dif, tra.dif, env.dif)))
```

```
##
## Call:
## lm(formula = p.A ~ rock.lg * rock.sm * light, data = data.frame(v.ard.dif,
##   tra.dif, env.dif))
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -45.808  -8.565   2.356  11.435  25.518
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept)    -24.997498  10.598639  -2.359   0.0276 *
## rock.lg        -0.322706   0.608981  -0.530   0.6015
## rock.sm        -0.574845   1.226763  -0.469   0.6440
## light         -0.068351   0.656392  -0.104   0.9180
## rock.lg:rock.sm -0.027964   0.069993  -0.400   0.6934
## rock.lg:light   -0.026183   0.035744  -0.733   0.4716
## rock.sm:light    0.006300   0.062803   0.100   0.9210
## rock.lg:rock.sm:light -0.001141  0.002933  -0.389   0.7011
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 17.76 on 22 degrees of freedom
## Multiple R-squared:  0.1937, Adjusted R-squared: -0.06288
## F-statistic: 0.7549 on 7 and 22 DF,  p-value: 0.6297
summary(lm(p.R ~ rock.lg * rock.sm * light,
  data = data.frame(v.ard.dif, tra.dif, env.dif)))
```

```
##
```

```
## Call:
## lm(formula = p.R ~ rock.lg * rock.sm * light, data = data.frame(v.ard.dif,
##   tra.dif, env.dif))
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -1.15006 -0.67011 -0.00113  0.40891  2.13338
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept)    -1.121e+00  5.309e-01  -2.111   0.0463 *
## rock.lg         1.329e-02  3.050e-02   0.436   0.6674
## rock.sm        -3.598e-03  6.145e-02  -0.059   0.9538
## light          1.453e-02  3.288e-02   0.442   0.6629
## rock.lg:rock.sm  1.782e-03  3.506e-03   0.508   0.6163
## rock.lg:light   -4.340e-04  1.790e-03  -0.242   0.8107
## rock.sm:light    1.363e-03  3.146e-03   0.433   0.6690
## rock.lg:rock.sm:light 5.302e-05  1.469e-04   0.361   0.7217
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.8894 on 22 degrees of freedom
## Multiple R-squared:  0.3383, Adjusted R-squared:  0.1278
## F-statistic: 1.607 on 7 and 22 DF,  p-value: 0.1857
summary(lm(p.D ~ rock.lg * rock.sm * light,
  data = data.frame(v.ard.dif, tra.dif, env.dif)))
```

```
##
## Call:
## lm(formula = p.D ~ rock.lg * rock.sm * light, data = data.frame(v.ard.dif,
##   tra.dif, env.dif))
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -0.61818 -0.27861 -0.01608  0.24591  0.88670
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept)    -4.975e-01  2.268e-01  -2.194   0.0391 *
## rock.lg        -9.983e-03  1.303e-02  -0.766   0.4518
## rock.sm        -1.668e-02  2.625e-02  -0.635   0.5317
## light          -1.037e-02  1.405e-02  -0.738   0.4680
## rock.lg:rock.sm -3.217e-04  1.498e-03  -0.215   0.8319
## rock.lg:light   -7.732e-04  7.648e-04  -1.011   0.3230
## rock.sm:light   -2.122e-04  1.344e-03  -0.158   0.8759
## rock.lg:rock.sm:light -2.246e-05  6.277e-05  -0.358   0.7239
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.3799 on 22 degrees of freedom
## Multiple R-squared:  0.2557, Adjusted R-squared:  0.01892
## F-statistic: 1.08 on 7 and 22 DF,  p-value: 0.4088
```



```
summary(lm(p.A ~ light *rock.lg * rock.sm,
           data = data.frame(v.ard.dif, tra.dif, env.dif)))
```

```
##
## Call:
## lm(formula = p.A ~ light * rock.lg * rock.sm, data = data.frame(v.ard.dif,
##   tra.dif, env.dif))
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -45.808  -8.565   2.356  11.435  25.518
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept)    -24.997498   10.598639  -2.359   0.0276 *
## light           -0.068351    0.656392  -0.104   0.9180
## rock.lg         -0.322706    0.608981  -0.530   0.6015
## rock.sm         -0.574845    1.226763  -0.469   0.6440
## light:rock.lg   -0.026183    0.035744  -0.733   0.4716
## light:rock.sm    0.006300    0.062803   0.100   0.9210
## rock.lg:rock.sm -0.027964    0.069993  -0.400   0.6934
## light:rock.lg:rock.sm -0.001141   0.002933  -0.389   0.7011
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 17.76 on 22 degrees of freedom
## Multiple R-squared:  0.1937, Adjusted R-squared:  -0.06288
## F-statistic: 0.7549 on 7 and 22 DF,  p-value: 0.6297
```

```
summary(lm(p.R ~ light *rock.lg * rock.sm,
           data = data.frame(v.ard.dif, tra.dif, env.dif)))
```

```
##
## Call:
## lm(formula = p.R ~ light * rock.lg * rock.sm, data = data.frame(v.ard.dif,
##   tra.dif, env.dif))
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -1.15006 -0.67011 -0.00113  0.40891  2.13338
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept)    -1.121e+00   5.309e-01  -2.111   0.0463 *
## light           1.453e-02   3.288e-02   0.442   0.6629
## rock.lg         1.329e-02   3.050e-02   0.436   0.6674
## rock.sm        -3.598e-03   6.145e-02  -0.059   0.9538
## light:rock.lg   -4.340e-04   1.790e-03  -0.242   0.8107
## light:rock.sm    1.363e-03   3.146e-03   0.433   0.6690
## rock.lg:rock.sm  1.782e-03   3.506e-03   0.508   0.6163
## light:rock.lg:rock.sm 5.302e-05   1.469e-04   0.361   0.7217
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
```

```
## Residual standard error: 0.8894 on 22 degrees of freedom
## Multiple R-squared:  0.3383, Adjusted R-squared:  0.1278
## F-statistic: 1.607 on 7 and 22 DF,  p-value: 0.1857

summary(lm(p.D ~ light *rock.lg * rock.sm,
           data = data.frame(v.ard.dif, tra.dif, env.dif)))

##
## Call:
## lm(formula = p.D ~ light * rock.lg * rock.sm, data = data.frame(v.ard.dif,
##      tra.dif, env.dif))
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -0.61818 -0.27861 -0.01608  0.24591  0.88670
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept)   -4.975e-01  2.268e-01  -2.194   0.0391 *
## light         -1.037e-02  1.405e-02  -0.738   0.4680
## rock.lg       -9.983e-03  1.303e-02  -0.766   0.4518
## rock.sm       -1.668e-02  2.625e-02  -0.635   0.5317
## light:rock.lg  -7.732e-04  7.648e-04  -1.011   0.3230
## light:rock.sm  -2.122e-04  1.344e-03  -0.158   0.8759
## rock.lg:rock.sm -3.217e-04  1.498e-03  -0.215   0.8319
## light:rock.lg:rock.sm -2.246e-05  6.277e-05  -0.358   0.7239
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.3799 on 22 degrees of freedom
## Multiple R-squared:  0.2557, Adjusted R-squared:  0.01892
## F-statistic:  1.08 on 7 and 22 DF,  p-value: 0.4088

summary(lm(p.A ~ rock.lg + rock.sm + light,
           data = data.frame(v.ard.dif, tra.dif, env.dif)))

##
## Call:
## lm(formula = p.A ~ rock.lg + rock.sm + light, data = data.frame(v.ard.dif,
##      tra.dif, env.dif))
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -45.955  -8.621   2.115  12.151  28.829
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept) -23.55502     6.14481  -3.833 0.000721 ***
## rock.lg       0.11754     0.15271   0.770 0.448432
## rock.sm      -0.53383     0.25424  -2.100 0.045607 *
## light         0.02616     0.35744   0.073 0.942215
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 16.79 on 26 degrees of freedom
```

```
## Multiple R-squared:  0.1479, Adjusted R-squared:  0.04957
## F-statistic: 1.504 on 3 and 26 DF,  p-value: 0.2368

summary(lm(p.R ~ rock.lg + rock.sm + light,
           data = data.frame(v.ard.dif, tra.dif, env.dif)))

##
## Call:
## lm(formula = p.R ~ rock.lg + rock.sm + light, data = data.frame(v.ard.dif,
##      tra.dif, env.dif))
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -1.09085 -0.72885  0.07251  0.43267  2.04097
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept) -1.027067   0.302605  -3.394  0.00222 **
## rock.lg       0.019656   0.007521   2.614  0.01470 *
## rock.sm      -0.036574   0.012520  -2.921  0.00712 **
## light         0.017481   0.017602   0.993  0.32981
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.8268 on 26 degrees of freedom
## Multiple R-squared:  0.3242, Adjusted R-squared:  0.2462
## F-statistic: 4.157 on 3 and 26 DF,  p-value: 0.01565

summary(lm(p.D ~ rock.lg + rock.sm + light,
           data = data.frame(v.ard.dif, tra.dif, env.dif)))

##
## Call:
## lm(formula = p.D ~ rock.lg + rock.sm + light, data = data.frame(v.ard.dif,
##      tra.dif, env.dif))
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -0.48929 -0.33019 -0.02457  0.29568  0.88860
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept) -0.3546159  0.1309685  -2.708  0.0118 *
## rock.lg       0.0027760  0.0032549   0.853  0.4015
## rock.sm      -0.0142947  0.0054187  -2.638  0.0139 *
## light        -0.0009857  0.0076183  -0.129  0.8980
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.3579 on 26 degrees of freedom
## Multiple R-squared:  0.2196, Adjusted R-squared:  0.1296
## F-statistic: 2.439 on 3 and 26 DF,  p-value: 0.08707

summary(lm(p.A ~ light + rock.lg + rock.sm,
           data = data.frame(v.ard.dif, tra.dif, env.dif)))
```

```
##
## Call:
## lm(formula = p.A ~ light + rock.lg + rock.sm, data = data.frame(v.ard.dif,
##   tra.dif, env.dif))
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -45.955  -8.621   2.115  12.151  28.829
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept) -23.55502     6.14481  -3.833 0.000721 ***
## light         0.02616     0.35744   0.073 0.942215
## rock.lg       0.11754     0.15271   0.770 0.448432
## rock.sm      -0.53383     0.25424  -2.100 0.045607 *
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 16.79 on 26 degrees of freedom
## Multiple R-squared:  0.1479, Adjusted R-squared:  0.04957
## F-statistic: 1.504 on 3 and 26 DF,  p-value: 0.2368
summary(lm(p.R ~ light +rock.lg + rock.sm,
  data = data.frame(v.ard.dif, tra.dif, env.dif)))
```

```
##
## Call:
## lm(formula = p.R ~ light + rock.lg + rock.sm, data = data.frame(v.ard.dif,
##   tra.dif, env.dif))
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -1.09085 -0.72885  0.07251  0.43267  2.04097
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept) -1.027067   0.302605  -3.394  0.00222 **
## light         0.017481   0.017602   0.993  0.32981
## rock.lg       0.019656   0.007521   2.614  0.01470 *
## rock.sm      -0.036574   0.012520  -2.921  0.00712 **
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.8268 on 26 degrees of freedom
## Multiple R-squared:  0.3242, Adjusted R-squared:  0.2462
## F-statistic: 4.157 on 3 and 26 DF,  p-value: 0.01565
summary(lm(p.D ~ light +rock.lg + rock.sm,
  data = data.frame(v.ard.dif, tra.dif, env.dif)))
```

```
##
## Call:
## lm(formula = p.D ~ light + rock.lg + rock.sm, data = data.frame(v.ard.dif,
##   tra.dif, env.dif))
##
```

```
## Residuals:
##      Min       1Q   Median       3Q      Max
## -0.48929 -0.33019 -0.02457  0.29568  0.88860
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept) -0.3546159  0.1309685  -2.708  0.0118 *
## light       -0.0009857  0.0076183  -0.129  0.8980
## rock.lg      0.0027760  0.0032549   0.853  0.4015
## rock.sm     -0.0142947  0.0054187  -2.638  0.0139 *
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.3579 on 26 degrees of freedom
## Multiple R-squared:  0.2196, Adjusted R-squared:  0.1296
## F-statistic: 2.439 on 3 and 26 DF,  p-value: 0.08707
```

## Structural Equation Models

```
l.com.dif <- split(com, l.dat[, "Tree.pairs"])
l.com.dif <- lapply(l.com.dif, function(x) x[2, ] - x[1, ])
l.com.dif <- do.call(rbind, l.com.dif)

v.com.dif <- split(v.com, l.dat[, "Tree.pairs"])
v.com.dif <- lapply(v.com.dif, function(x) x[2, ] - x[1, ])
v.com.dif <- do.call(rbind, v.com.dif)

l.com.dif.d <- dist(l.com.dif)
v.com.dif.d <- dist(v.com.dif)

l.com.dif.nms <- nmds(l.com.dif.d, 1, 2)
l.com.dif.ord <- nmds.min(l.com.dif.nms, 2)

## Minimum stress for given dimensionality: 0.07460277
## r^2 for minimum stress configuration: 0.9809944

l.com.dif.vec <- envfit(l.com.dif.ord,
                      data.frame(env.dif, tra.dif)[, c("rock.lg",
   "rock.sm",
   "light",
   "litter")])

v.com.dif.nms <- nmds(v.com.dif.d, 2, 3)
v.com.dif.ord <- nmds.min(v.com.dif.nms, 3)

## Minimum stress for given dimensionality: 0.03324742
## r^2 for minimum stress configuration: 0.9927886

v.com.dif.vec <- envfit(v.com.dif.ord,
                      data.frame(env.dif, tra.dif)[, c("rock.lg",
   "rock.sm",
   "light",
   "litter")])

colnames(l.com.dif.ord) <- paste0("l.", colnames(l.com.dif.ord))
```

```

colnames(v.com.dif.ord) <- paste0("p.", colnames(v.com.dif.ord))

l.com.dif.ord.proc <- procrustes(env.dif[, "rock.lg"], l.com.dif.ord)$Yrot

## Warning in procrustes(env.dif[, "rock.lg"], l.com.dif.ord): X has fewer axes than Y: X adjusted to c
v.com.dif.ord.proc <- procrustes(env.dif[, "rock.sm"], v.com.dif.ord)$Yrot

## Warning in procrustes(env.dif[, "rock.sm"], v.com.dif.ord): X has fewer axes than Y: X adjusted to c
colnames(l.com.dif.ord.proc) <- paste0("rot.", colnames(l.com.dif.ord))
colnames(v.com.dif.ord.proc) <- paste0("rot.", colnames(v.com.dif.ord))

l.com.dif.vec.rot <- envfit(l.com.dif.ord.proc,
                           data.frame(env.dif[, -1], litter = tra.dif[, "litter"]))
v.com.dif.vec.rot <- envfit(v.com.dif.ord.proc,
                           data.frame(env.dif[, -1], litter = tra.dif[, "litter"]))

sem.dat <- data.frame(tra.dif, env.dif, l.ard.dif, v.ard.dif, l.com.dif.ord, v.com.dif.ord, l.com.dif.ord)
colnames(sem.dat)[colnames(sem.dat) == "crown.radius"] <- "crown"
colnames(sem.dat)[colnames(sem.dat) == "trunk.radius"] <- "trunk"

tab.ttest.ldat <- do.call(rbind,
                         lapply(
                           apply(l.dat[, -1:-3], 2,
                                t.test),
                           unlist))[, c(1, 2, 6, 3)]
tab.lab <- rownames(tab.ttest.ldat)
tab.ttest.ldat <- apply(tab.ttest.ldat, 2, as.numeric)
rownames(tab.ttest.ldat) <- tab.lab
xtable::xtable(tab.ttest.ldat, digits = 5)

% latex table generated in R 4.0.4 by xtable 1.8-4 package % Fri Apr 23 16:31:21 2021
xtable::xtable(na.omit(tab.ttest.ldat[tab.ttest.ldat[, "p.value"] <= 0.05,]))

% latex table generated in R 4.0.4 by xtable 1.8-4 package % Fri Apr 23 16:31:21 2021
tab.ttest.vdat <- do.call(rbind,
                         lapply(
                           apply(v.dat[, -1:-8], 2,
                                t.test),
                           unlist))[, c(1, 2, 6, 3)]
tab.lab <- rownames(tab.ttest.vdat)
tab.ttest.vdat <- apply(tab.ttest.vdat, 2, as.numeric)
rownames(tab.ttest.vdat) <- tab.lab
xtable::xtable(tab.ttest.vdat, digits = 5)

% latex table generated in R 4.0.4 by xtable 1.8-4 package % Fri Apr 23 16:31:21 2021
xtable::xtable(na.omit(tab.ttest.vdat[tab.ttest.vdat[, "p.value"] <= 0.05,]))

% latex table generated in R 4.0.4 by xtable 1.8-4 package % Fri Apr 23 16:31:21 2021
lav.l.all <- 'light ~ crown
litter ~ crown
rock.lg ~ litter
l.A ~ light + rock.lg
l.R ~ light + rock.lg'

```

|                 | statistic.t | parameter.df | estimate.mean of x | p.value |
|-----------------|-------------|--------------|--------------------|---------|
| Litter..        | 30.56225    | 59.00000     | 79.80633           | 0.00000 |
| Big.rocks..     | 7.69468     | 59.00000     | 14.90117           | 0.00000 |
| Small.rocks..   | 3.84706     | 59.00000     | 4.79783            | 0.00030 |
| Shrubs..        | 2.61579     | 59.00000     | 0.40567            | 0.01129 |
| Grass..         | 1.00000     | 59.00000     | 0.02467            | 0.32139 |
| Branches..      | 1.00000     | 59.00000     | 0.07100            | 0.32139 |
| Light...N       | 12.09160    | 59.00000     | 17.67833           | 0.00000 |
| Light...S       | 12.00919    | 59.00000     | 17.80833           | 0.00000 |
| Light...average | 13.30890    | 59.00000     | 17.74333           | 0.00000 |
| Acacon          | 3.91476     | 59.00000     | 0.02833            | 0.00024 |
| Acaame          | 4.79957     | 59.00000     | 0.14000            | 0.00001 |
| Acaobp          | 1.12174     | 59.00000     | 0.14933            | 0.26652 |
| Sterile.sp      | 1.00000     | 59.00000     | 0.00100            | 0.32139 |
| Brown.cr        |             | 59.00000     | 0.00000            |         |
| Lobalp          | 1.98868     | 59.00000     | 0.00233            | 0.05138 |
| Canros          | 5.70908     | 59.00000     | 0.32017            | 0.00000 |
| Calare          | 2.04690     | 59.00000     | 0.01967            | 0.04513 |
| Phydub          | 3.55666     | 59.00000     | 0.09633            | 0.00075 |
| Rhichr          | 3.82975     | 59.00000     | 0.29150            | 0.00031 |
| Xanlin          | 3.63277     | 59.00000     | 0.62233            | 0.00059 |
| Xanpli          | 4.25869     | 59.00000     | 0.21150            | 0.00007 |
| Xanele          | 2.54509     | 59.00000     | 0.03867            | 0.01356 |
| GrBr.cr         | 1.00000     | 59.00000     | 0.00067            | 0.32139 |
| Gray.cr         | 1.69236     | 59.00000     | 0.00250            | 0.09585 |
| Synrur          | 1.67611     | 59.00000     | 0.04933            | 0.09901 |
| Cerpur.Bryarg   | 1.23020     | 59.00000     | 0.00867            | 0.22350 |

```

1.D ~ light + rock.lg
1.X1 ~ light + rock.lg
1.X2 ~ light + rock.lg
1.A ~~ 1.R
1.A ~~ 1.D
1.R ~~ 1.D
1.A ~~ 1.X1
1.R ~~ 1.X1
'
lav.v.all <- 'light ~ crown
litter ~ crown
rock.sm ~ litter
p.A ~ light + rock.sm
p.R ~ light + rock.sm + litter
p.D ~ light + rock.sm
p.X1 ~ light + rock.sm
p.X2 ~ light + rock.sm
p.X3 ~ light + rock.sm
p.A ~~ p.X2
p.A ~~ p.R
p.A ~~ p.D
p.R ~~ p.D
p.A ~~ p.X1
p.R ~~ p.X1
'
```

|                 | statistic.t | parameter.df | estimate.mean of x | p.value |
|-----------------|-------------|--------------|--------------------|---------|
| Litter..        | 30.56       | 59.00        | 79.81              | 0.00    |
| Big.rocks..     | 7.69        | 59.00        | 14.90              | 0.00    |
| Small.rocks..   | 3.85        | 59.00        | 4.80               | 0.00    |
| Shrubs..        | 2.62        | 59.00        | 0.41               | 0.01    |
| Light...N       | 12.09       | 59.00        | 17.68              | 0.00    |
| Light...S       | 12.01       | 59.00        | 17.81              | 0.00    |
| Light...average | 13.31       | 59.00        | 17.74              | 0.00    |
| Acacon          | 3.91        | 59.00        | 0.03               | 0.00    |
| Acaame          | 4.80        | 59.00        | 0.14               | 0.00    |
| Canros          | 5.71        | 59.00        | 0.32               | 0.00    |
| Calare          | 2.05        | 59.00        | 0.02               | 0.05    |
| Phydub          | 3.56        | 59.00        | 0.10               | 0.00    |
| Rhichr          | 3.83        | 59.00        | 0.29               | 0.00    |
| Xanlin          | 3.63        | 59.00        | 0.62               | 0.00    |
| Xanpli          | 4.26        | 59.00        | 0.21               | 0.00    |
| Xanele          | 2.55        | 59.00        | 0.04               | 0.01    |

```

lav.l.rot.nolight <- 'litter ~ crown
                      rock.lg ~ litter
                      l.A ~ rock.lg
                      l.R ~ rock.lg
                      l.D ~ rock.lg
                      rot.l.X1 ~ rock.lg
                      rot.l.X2 ~ rock.lg
                      l.A ~~ l.R
                      l.A ~~ l.D
                      l.R ~~ l.D
                      l.A ~~ rot.l.X1
                      l.R ~~ rot.l.X1
                      '

lav.v.rot.nolight <- 'litter ~ crown
                      rock.sm ~ litter
                      p.A ~ rock.sm
                      p.R ~ rock.sm
                      p.D ~ rock.sm
                      rot.p.X1 ~ rock.sm
                      rot.p.X2 ~ rock.sm
                      rot.p.X3 ~ rock.sm
                      p.A ~~ rot.p.X2
                      p.A ~~ p.R
                      p.A ~~ p.D
                      p.R ~~ p.D
                      p.A ~~ rot.p.X1
                      p.R ~~ rot.p.X1
                      '

lav.l.rot.all <- 'light ~ crown
                  litter ~ crown
                  light ~ trunk
                  litter ~ trunk
                  rock.lg ~ litter
                  l.A ~ light + rock.lg
                  l.R ~ light + rock.lg

```



|                           | statistic.t | parameter.df | estimate.mean of x | p.value |
|---------------------------|-------------|--------------|--------------------|---------|
| Apache.plume              | 4.64843     | 59.00000     | 6.53333            | 0.00002 |
| Juniperus.monosperma      | 1.00000     | 59.00000     | 0.08333            | 0.32139 |
| Rhus.trilobata            | 1.80478     | 59.00000     | 1.58333            | 0.07621 |
| Asteraceae.ovales         | 4.64433     | 59.00000     | 6.23333            | 0.00002 |
| Bouteloua.gracilis        |             | 59.00000     | 0.00000            |         |
| Pinus.edulis.R            | 1.00000     | 59.00000     | 0.16667            | 0.32139 |
| Pinus.edulis.S            |             | 59.00000     | 0.00000            |         |
| Stipa.A                   |             | 59.00000     | 0.00000            |         |
| Stipa.B                   |             | 59.00000     | 0.00000            |         |
| Stipa.très.grand          |             | 59.00000     | 0.00000            |         |
| Ephedra                   |             | 59.00000     | 0.00000            |         |
| Rabbit.brush              | 1.00000     | 59.00000     | 0.33333            | 0.32139 |
| Grande.grass.corymbe      |             | 59.00000     | 0.00000            |         |
| Boraginacée.rosette.grise |             | 59.00000     | 0.00000            |         |
| Avena                     | 1.76218     | 59.00000     | 0.10000            | 0.08322 |
| Grass.à.nœud              |             | 59.00000     | 0.00000            |         |
| Brachypode                |             | 59.00000     | 0.00000            |         |
| Carex                     |             | 59.00000     | 0.00000            |         |
| Cactus                    |             | 59.00000     | 0.00000            |         |
| Hordeum                   |             | 59.00000     | 0.00000            |         |
| Chenopodiaceae            |             | 59.00000     | 0.00000            |         |
| Ribes                     |             | 59.00000     | 0.00000            |         |
| Aster.grise               |             | 59.00000     | 0.00000            |         |
| Rosette.frisée            |             | 59.00000     | 0.00000            |         |
| Chamaephyte.gris          |             | 59.00000     | 0.00000            |         |
| Castilleja                |             | 59.00000     | 0.00000            |         |
| Opuntia                   |             | 59.00000     | 0.00000            |         |
| Rubiaceae                 |             | 59.00000     | 0.00000            |         |
| Plante.grise.allongée     | 1.00000     | 59.00000     | 0.05000            | 0.32139 |
| Scarlet.glia              | 1.00000     | 59.00000     | 0.03333            | 0.32139 |
| Andropogon                |             | 59.00000     | 0.00000            |         |

|                   | statistic.t | parameter.df | estimate.mean of x | p.value |
|-------------------|-------------|--------------|--------------------|---------|
| Apache.plume      | 4.65        | 59.00        | 6.53               | 0.00    |
| Asteraceae.ovales | 4.64        | 59.00        | 6.23               | 0.00    |

```

1.D ~ light + rock.lg
rot.1.X1 ~ light + rock.lg
rot.1.X2 ~ light + rock.lg
1.A ~~ 1.R
1.A ~~ 1.D
1.R ~~ 1.D
1.A ~~ rot.1.X1
1.R ~~ rot.1.X1
'
lav.v.rot.all <- 'light ~ crown
litter ~ crown
light ~ trunk
litter ~ trunk
rock.sm ~ litter
p.A ~ light + rock.sm
p.R ~ light + rock.sm

```

```

        p.D ~ light + rock.sm
        rot.p.X1 ~ light + rock.sm
        rot.p.X2 ~ light + rock.sm
        rot.p.X3 ~ light + rock.sm
        p.A ~~ rot.p.X2
        p.A ~~ p.R
        p.A ~~ p.D
        p.R ~~ p.D
        p.A ~~ rot.p.X1
        p.R ~~ rot.p.X1
    ,

std <- function(x){(x - mean(x)) / sd(x)}

set.seed(12345)
fit.l.all.raw <- lavaan::sem(lav.l.all, data = sem.dat)
set.seed(12345)
fit.v.all.raw <- lavaan::sem(lav.v.all, data = sem.dat)

## Warning in lav_data_full(data = data, group = group, cluster = cluster, : lavaan
## WARNING: some observed variances are (at least) a factor 1000 times larger than
## others; use varTable(fit) to investigate

set.seed(12345)
fit.l.all <- lavaan::sem(lav.l.all, data = apply(sem.dat, 2, std))
set.seed(12345)
fit.v.all <- lavaan::sem(lav.v.all, data = apply(sem.dat, 2, std))
set.seed(12345)
fit.l.rot.all <- lavaan::sem(lav.l.rot.all, data = apply(sem.dat, 2, std))
set.seed(12345)
fit.v.rot.all <- lavaan::sem(lav.v.rot.all, data = apply(sem.dat, 2, std))
set.seed(12345)
fit.l.rot.nolight <- lavaan::sem(lav.l.rot.nolight, data = apply(sem.dat, 2, std))
set.seed(12345)
fit.v.rot.nolight <- lavaan::sem(lav.v.rot.nolight, data = apply(sem.dat, 2, std))

summary(fit.l.all.raw, rsquare = TRUE)

## lavaan 0.6-8 ended normally after 121 iterations
##
##      Estimator                      ML
##      Optimization method          NLMINB
##      Number of model parameters    31
##
##      Number of observations        30
##
## Model Test User Model:
##
##      Test statistic                18.541
##      Degrees of freedom             13
##      P-value (Chi-square)           0.138
##
## Parameter Estimates:

```

```

##
## Standard errors
## Information
## Information saturated (h1) model
## Standard
## Expected
## Structured
##
## Regressions:
## Estimate Std.Err z-value P(>|z|)
## light ~
## crown -0.005 0.024 -0.204 0.839
## litter ~
## crown 0.216 0.065 3.341 0.001
## rock.lg ~
## litter -0.675 0.059 -11.495 0.000
## 1.A ~
## light 0.016 0.065 0.239 0.811
## rock.lg 0.092 0.027 3.417 0.001
## 1.R ~
## light 0.088 0.060 1.478 0.139
## rock.lg 0.162 0.025 6.518 0.000
## 1.D ~
## light 0.022 0.013 1.615 0.106
## rock.lg 0.031 0.006 5.661 0.000
## 1.X1 ~
## light 0.029 0.040 0.709 0.479
## rock.lg 0.037 0.017 2.244 0.025
## 1.X2 ~
## light 0.025 0.034 0.736 0.462
## rock.lg -0.024 0.014 -1.697 0.090
##
## Covariances:
## Estimate Std.Err z-value P(>|z|)
## .1.A ~~
## .1.R 4.023 1.799 2.236 0.025
## .1.D -0.127 0.368 -0.346 0.729
## .1.R ~~
## .1.D 1.363 0.420 3.250 0.001
## .1.A ~~
## .1.X1 4.221 1.347 3.132 0.002
## .1.R ~~
## .1.X1 2.448 1.111 2.204 0.028
## .1.A ~~
## .1.X2 -3.251 1.113 -2.919 0.004
## .1.R ~~
## .1.X2 -0.466 0.871 -0.534 0.593
## .1.D ~~
## .1.X1 0.048 0.227 0.213 0.832
## .1.X2 0.196 0.197 0.994 0.320
## .1.X1 ~~
## .1.X2 0.297 0.586 0.507 0.612
##
## Variances:
## Estimate Std.Err z-value P(>|z|)
## .light 77.135 19.916 3.873 0.000
## .litter 584.196 150.839 3.873 0.000

```

```
##      .rock.lg      83.027    21.438    3.873    0.000
##      .l.A         9.776     2.524    3.873    0.000
##      .l.R         8.276     2.137    3.873    0.000
##      .l.D         0.413     0.107    3.873    0.000
##      .l.X1        3.750     0.968    3.873    0.000
##      .l.X2        2.724     0.703    3.873    0.000
```

```
##
```

```
## R-Square:
```

```
##           Estimate
##      light      0.001
##      litter     0.271
##      rock.lg    0.815
##      l.A        0.282
##      l.R        0.600
##      l.D        0.538
##      l.X1       0.157
##      l.X2       0.101
```

```
summary(fit.v.all.raw, rsquare = TRUE)
```

```
## lavaan 0.6-8 ended normally after 235 iterations
```

```
##
```

```
##      Estimator                      ML
##      Optimization method          NLMINB
##      Number of model parameters    40
##
##      Number of observations        30
##
```

```
## Model Test User Model:
```

```
##
```

```
##      Test statistic                12.147
##      Degrees of freedom              14
##      P-value (Chi-square)           0.595
##
```

```
## Parameter Estimates:
```

```
##
```

```
##      Standard errors                Standard
##      Information                    Expected
##      Information saturated (h1) model  Structured
##
```

```
## Regressions:
```

```
##           Estimate Std.Err z-value P(>|z|)
##      light ~
##      crown      -0.005    0.024   -0.204    0.839
##      litter ~
##      crown       0.216    0.065    3.341    0.001
##      rock.sm ~
##      litter     -0.312    0.060   -5.169    0.000
##      p.A ~
##      light       0.047    0.328    0.143    0.887
##      rock.sm    -0.477    0.224   -2.128    0.033
##      p.R ~
##      light       0.020    0.016    1.217    0.224
##      rock.sm    -0.046    0.012   -3.835    0.000
##      litter     -0.013    0.003   -4.027    0.000
```

```

## p.D ~
##   light      -0.000    0.007   -0.071    0.944
##   rock.sm    -0.013    0.005   -2.704    0.007
## p.X1 ~
##   light      0.118    0.200    0.589    0.556
##   rock.sm     0.093    0.136    0.684    0.494
## p.X2 ~
##   light     -0.018    0.209   -0.086    0.931
##   rock.sm     0.164    0.142    1.151    0.250
## p.X3 ~
##   light      0.191    0.248    0.771    0.441
##   rock.sm     0.356    0.169    2.108    0.035
##
## Covariances:
##               Estimate Std.Err z-value P(>|z|)
## .p.A ~~
## .p.X2      -89.124   33.272   -2.679    0.007
## .p.R        5.236    2.439    2.147    0.032
## .p.D        1.732    1.025    1.690    0.091
## .p.R ~~
## .p.D        0.229    0.064    3.602    0.000
## .p.A ~~
## .p.X1     -85.041   31.772   -2.677    0.007
## .p.R ~~
## .p.X1      -1.262    1.383   -0.913    0.361
## .p.A ~~
## .p.X3     -58.230   35.996   -1.618    0.106
## .p.R ~~
## .p.X2      -3.100    1.536   -2.019    0.044
## .p.X3        0.231    1.692    0.137    0.891
## .p.D ~~
## .p.X1      -0.109    0.593   -0.184    0.854
## .p.X2      -1.337    0.666   -2.007    0.045
## .p.X3        0.241    0.736    0.328    0.743
## .p.X1 ~~
## .p.X2       8.347   17.700    0.472    0.637
## .p.X3     -12.723   21.025   -0.605    0.545
## .p.X2 ~~
## .p.X3     -28.403   22.483   -1.263    0.206
##
## Variances:
##               Estimate Std.Err z-value P(>|z|)
## .light       77.135   19.916    3.873    0.000
## .litter     584.195  150.839    3.873    0.000
## .rock.sm     87.816   22.674    3.873    0.000
## .p.A       249.877   64.518    3.873    0.000
## .p.R         0.605    0.156    3.873    0.000
## .p.D         0.114    0.029    3.873    0.000
## .p.X1       92.255   23.820    3.873    0.000
## .p.X2      101.118   26.109    3.873    0.000
## .p.X3      141.992   36.662    3.873    0.000
##
## R-Square:
##               Estimate

```

```
##      light          0.001
##      litter         0.271
##      rock.sm        0.471
##      p.A            0.131
##      p.R            0.265
##      p.D            0.196
##      p.X1           0.027
##      p.X2           0.042
##      p.X3           0.145
```

```
summary(fit.l.all, rsquare = TRUE)
```

```
## lavaan 0.6-8 ended normally after 58 iterations
```

```
##
##      Estimator                      ML
##      Optimization method          NLMINB
##      Number of model parameters    31
##
##      Number of observations        30
##
## Model Test User Model:
##
##      Test statistic                18.541
##      Degrees of freedom             13
##      P-value (Chi-square)           0.138
##
```

```
## Parameter Estimates:
```

```
##
##      Standard errors                Standard
##      Information                    Expected
##      Information saturated (h1) model Structured
##
```

```
## Regressions:
```

```
##      Estimate Std.Err z-value P(>|z|)
##      light ~
##      crown      -0.037   0.182   -0.204   0.839
##      litter ~
##      crown       0.521   0.156    3.341   0.001
##      rock.lg ~
##      litter     -0.903   0.079  -11.495   0.000
##      1.A ~
##      light       0.037   0.154    0.239   0.811
##      rock.lg     0.528   0.154    3.417   0.001
##      1.R ~
##      light       0.168   0.114    1.478   0.139
##      rock.lg     0.742   0.114    6.518   0.000
##      1.D ~
##      light       0.197   0.122    1.615   0.106
##      rock.lg     0.691   0.122    5.661   0.000
##      1.X1 ~
##      light       0.118   0.167    0.709   0.479
##      rock.lg     0.374   0.167    2.244   0.025
##      1.X2 ~
##      light       0.128   0.174    0.736   0.462
##      rock.lg    -0.295   0.174   -1.697   0.090
```

```
##
## Covariances:
##           Estimate Std.Err z-value P(>|z|)
##   .l.A ~~
##   .l.R           0.228   0.102   2.236   0.025
##   .l.D          -0.035   0.100  -0.346   0.729
##   .l.R ~~
##   .l.D           0.297   0.091   3.250   0.001
##   .l.A ~~
##   .l.X1           0.520   0.166   3.132   0.002
##   .l.R ~~
##   .l.X1           0.242   0.110   2.204   0.028
##   .l.A ~~
##   .l.X2          -0.490   0.168  -2.919   0.004
##   .l.R ~~
##   .l.X2          -0.056   0.105  -0.534   0.593
##   .l.D ~~
##   .l.X1           0.023   0.108   0.213   0.832
##   .l.X2           0.114   0.114   0.994   0.320
##   .l.X1 ~~
##   .l.X2           0.078   0.154   0.507   0.612
##
## Variances:
##           Estimate Std.Err z-value P(>|z|)
##   .light          0.965   0.249   3.873   0.000
##   .litter          0.705   0.182   3.873   0.000
##   .rock.lg         0.179   0.046   3.873   0.000
##   .l.A             0.691   0.178   3.873   0.000
##   .l.R             0.375   0.097   3.873   0.000
##   .l.D             0.432   0.112   3.873   0.000
##   .l.X1            0.806   0.208   3.873   0.000
##   .l.X2            0.876   0.226   3.873   0.000
##
## R-Square:
##           Estimate
##   light          0.001
##   litter          0.271
##   rock.lg         0.815
##   l.A             0.282
##   l.R             0.600
##   l.D             0.538
##   l.X1            0.157
##   l.X2            0.101
```

```
summary(fit.v.all, rsquare = TRUE)
```

```
## lavaan 0.6-8 ended normally after 52 iterations
```

```
##
##   Estimator                      ML
##   Optimization method          NLMINB
##   Number of model parameters    40
##
##   Number of observations        30
##
## Model Test User Model:
```

```

##
## Test statistic 12.147
## Degrees of freedom 14
## P-value (Chi-square) 0.595
##
## Parameter Estimates:
##
## Standard errors Standard
## Information Expected
## Information saturated (h1) model Structured
##
## Regressions:
## Estimate Std.Err z-value P(>|z|)
## light ~
## crown -0.037 0.182 -0.204 0.839
## litter ~
## crown 0.521 0.156 3.341 0.001
## rock.sm ~
## litter -0.686 0.133 -5.169 0.000
## p.A ~
## light 0.024 0.170 0.143 0.887
## rock.sm -0.363 0.170 -2.128 0.033
## p.R ~
## light 0.184 0.152 1.217 0.224
## rock.sm -0.634 0.165 -3.835 0.000
## litter -0.386 0.096 -4.027 0.000
## p.D ~
## light -0.012 0.164 -0.071 0.944
## rock.sm -0.442 0.164 -2.704 0.007
## p.X1 ~
## light 0.106 0.180 0.589 0.556
## rock.sm 0.123 0.180 0.684 0.494
## p.X2 ~
## light -0.015 0.179 -0.086 0.931
## rock.sm 0.206 0.179 1.151 0.250
## p.X3 ~
## light 0.129 0.167 0.771 0.441
## rock.sm 0.353 0.167 2.108 0.035
##
## Covariances:
## Estimate Std.Err z-value P(>|z|)
## .p.A ~~
## .p.X2 -0.495 0.185 -2.679 0.007
## .p.R 0.319 0.149 2.147 0.032
## .p.D 0.262 0.155 1.690 0.091
## .p.R ~~
## .p.D 0.628 0.174 3.602 0.000
## .p.A ~~
## .p.X1 -0.497 0.186 -2.677 0.007
## .p.R ~~
## .p.X1 -0.134 0.146 -0.913 0.361
## .p.A ~~
## .p.X3 -0.256 0.158 -1.618 0.106
## .p.R ~~

```



```

##      .p.X2      -0.312    0.154   -2.019    0.044
##      .p.X3      0.018    0.134    0.137    0.891
##      .p.D ~~~~
##      .p.X1      -0.029    0.156   -0.184    0.854
##      .p.X2      -0.334    0.166   -2.007    0.045
##      .p.X3      0.048    0.145    0.328    0.743
##      .p.X1 ~~~~
##      .p.X2      0.080    0.171    0.472    0.637
##      .p.X3      -0.097    0.160   -0.605    0.545
##      .p.X2 ~~~~
##      .p.X3      -0.206    0.163   -1.263    0.206
##
## Variances:
##      Estimate Std.Err z-value P(>|z|)
##      .light    0.965   0.249   3.873   0.000
##      .litter    0.705   0.182   3.873   0.000
##      .rock.sm   0.511   0.132   3.873   0.000
##      .p.A       0.842   0.218   3.873   0.000
##      .p.R       0.667   0.172   3.873   0.000
##      .p.D       0.775   0.200   3.873   0.000
##      .p.X1      0.936   0.242   3.873   0.000
##      .p.X2      0.927   0.239   3.873   0.000
##      .p.X3      0.812   0.210   3.873   0.000
##
## R-Square:
##      Estimate
##      light      0.001
##      litter     0.271
##      rock.sm    0.471
##      p.A        0.131
##      p.R        0.265
##      p.D        0.196
##      p.X1       0.027
##      p.X2       0.042
##      p.X3       0.145

```

```
summary(fit.l.rot.all, rsquare = TRUE)
```

```

## lavaan 0.6-8 ended normally after 58 iterations
##
##      Estimator                      ML
##      Optimization method          NLMINB
##      Number of model parameters    33
##
##      Number of observations        30
##
## Model Test User Model:
##
##      Test statistic                26.681
##      Degrees of freedom             19
##      P-value (Chi-square)          0.112
##
## Parameter Estimates:
##
##      Standard errors                Standard

```

```

##      Information                               Expected
##      Information saturated (h1) model          Structured
##
## Regressions:
##      Estimate Std.Err z-value P(>|z|)
##      light ~
##      crown      -0.052   0.202   -0.256   0.798
##      litter ~
##      crown       0.594   0.170    3.506   0.000
##      light ~
##      trunk       0.034   0.202    0.169   0.866
##      litter ~
##      trunk      -0.172   0.170   -1.016   0.309
##      rock.lg ~
##      litter     -0.903   0.079  -11.495   0.000
##      l.A ~
##      light       0.037   0.154    0.239   0.811
##      rock.lg     0.528   0.154    3.417   0.001
##      l.R ~
##      light       0.168   0.114    1.478   0.139
##      rock.lg     0.742   0.114    6.518   0.000
##      l.D ~
##      light       0.197   0.122    1.615   0.106
##      rock.lg     0.691   0.122    5.661   0.000
##      rot.l.X1 ~
##      light       0.051   0.161    0.320   0.749
##      rock.lg     0.462   0.161    2.873   0.004
##      rot.l.X2 ~
##      light       0.174   0.180    0.966   0.334
##      rock.lg    -0.023   0.180   -0.130   0.897
##
## Covariances:
##      Estimate Std.Err z-value P(>|z|)
##      .l.A ~~
##      .l.R         0.228   0.102    2.236   0.025
##      .l.D        -0.035   0.100   -0.346   0.729
##      .l.R ~~
##      .l.D         0.297   0.091    3.250   0.001
##      .l.A ~~
##      .rot.l.X1     0.677   0.181    3.751   0.000
##      .l.R ~~
##      .rot.l.X1     0.241   0.106    2.266   0.023
##      .l.A ~~
##      .rot.l.X2    -0.098   0.148   -0.662   0.508
##      .l.R ~~
##      .rot.l.X2     0.095   0.110    0.866   0.386
##      .l.D ~~
##      .rot.l.X1    -0.028   0.104   -0.269   0.788
##      .rot.l.X2     0.106   0.118    0.904   0.366
##      .rot.l.X1 ~~
##      .rot.l.X2     0.154   0.156    0.987   0.324
##
## Variances:
##      Estimate Std.Err z-value P(>|z|)

```

```
##      .light      0.964    0.249    3.873    0.000
##      .litter      0.681    0.176    3.873    0.000
##      .rock.lg      0.179    0.046    3.873    0.000
##      .l.A      0.691    0.178    3.873    0.000
##      .l.R      0.375    0.097    3.873    0.000
##      .l.D      0.432    0.112    3.873    0.000
##      .rot.l.X1      0.751    0.194    3.873    0.000
##      .rot.l.X2      0.938    0.242    3.873    0.000
```

```
##
## R-Square:
##           Estimate
##      light      0.002
##      litter      0.295
##      rock.lg      0.815
##      l.A      0.282
##      l.R      0.601
##      l.D      0.539
##      rot.l.X1      0.219
##      rot.l.X2      0.031
```

```
summary(fit.v.rot.all, rsquare = TRUE)
```

```
## lavaan 0.6-8 ended normally after 48 iterations
```

```
##
##      Estimator                      ML
##      Optimization method          NLMINB
##      Number of model parameters          41
##
##      Number of observations          30
##
## Model Test User Model:
##
##      Test statistic          30.762
##      Degrees of freedom          22
##      P-value (Chi-square)          0.101
##
```

```
## Parameter Estimates:
##
##      Standard errors          Standard
##      Information          Expected
##      Information saturated (h1) model          Structured
##
```

```
## Regressions:
##           Estimate Std.Err z-value P(>|z|)
##      light ~
##      crown      -0.052    0.202   -0.256    0.798
##      litter ~
##      crown      0.594    0.170    3.506    0.000
##      light ~
##      trunk      0.034    0.202    0.169    0.866
##      litter ~
##      trunk     -0.172    0.170   -1.016    0.309
##      rock.sm ~
##      litter     -0.686    0.133   -5.169    0.000
##      p.A ~
```

```

##      light          0.024    0.170    0.143    0.887
##      rock.sm       -0.363    0.170   -2.127    0.033
## p.R ~
##      light          0.197    0.169    1.165    0.244
##      rock.sm       -0.372    0.169   -2.202    0.028
## p.D ~
##      light         -0.012    0.164   -0.071    0.944
##      rock.sm       -0.442    0.164   -2.704    0.007
## rot.p.X1 ~
##      light          0.142    0.160    0.888    0.375
##      rock.sm          0.433    0.160    2.711    0.007
## rot.p.X2 ~
##      light          0.063    0.182    0.344    0.731
##      rock.sm       -0.013    0.182   -0.071    0.944
## rot.p.X3 ~
##      light          0.070    0.182    0.387    0.699
##      rock.sm       -0.014    0.182   -0.080    0.937
##
## Covariances:
##              Estimate Std.Err z-value P(>|z|)
## .p.A ~~
##   .rot.p.X2      -0.344    0.176   -1.953    0.051
##   .p.R           0.363    0.166    2.187    0.029
##   .p.D           0.262    0.155    1.690    0.091
## .p.R ~~
##   .p.D           0.672    0.191    3.524    0.000
## .p.A ~~
##   .rot.p.X1      -0.511    0.172   -2.973    0.003
## .p.R ~~
##   .rot.p.X1      -0.115    0.144   -0.799    0.425
## .p.A ~~
##   .rot.p.X3       0.300    0.173    1.731    0.083
## .p.R ~~
##   .rot.p.X2      -0.134    0.165   -0.814    0.416
##   .rot.p.X3       0.311    0.172    1.807    0.071
## .p.D ~~
##   .rot.p.X1      -0.068    0.139   -0.486    0.627
##   .rot.p.X2      -0.008    0.158   -0.048    0.962
##   .rot.p.X3       0.300    0.167    1.798    0.072
## .rot.p.X1 ~~
##   .rot.p.X2      -0.107    0.155   -0.687    0.492
##   .rot.p.X3       0.215    0.159    1.350    0.177
## .rot.p.X2 ~~
##   .rot.p.X3      -0.181    0.179   -1.011    0.312
##
## Variances:
##              Estimate Std.Err z-value P(>|z|)
## .light          0.964    0.249    3.873    0.000
## .litter          0.681    0.176    3.873    0.000
## .rock.sm         0.511    0.132    3.873    0.000
## .p.A             0.842    0.218    3.873    0.000
## .p.R             0.825    0.213    3.873    0.000
## .p.D             0.775    0.200    3.873    0.000
## .rot.p.X1        0.741    0.191    3.873    0.000

```

```
##      .rot.p.X2          0.963    0.249    3.873    0.000
##      .rot.p.X3          0.962    0.248    3.873    0.000
##
## R-Square:
##              Estimate
##      light          0.002
##      litter          0.295
##      rock.sm         0.471
##      p.A             0.131
##      p.R             0.170
##      p.D             0.196
##      rot.p.X1        0.215
##      rot.p.X2        0.004
##      rot.p.X3        0.005
```

```
summary(fit.l.rot.nolight, rsquare = TRUE)
```

```
## lavaan 0.6-8 ended normally after 54 iterations
##
##      Estimator                      ML
##      Optimization method          NLMINB
##      Number of model parameters    24
##
##      Number of observations        30
##
## Model Test User Model:
##
##      Test statistic                17.024
##      Degrees of freedom             11
##      P-value (Chi-square)           0.107
##
## Parameter Estimates:
##
##      Standard errors                Standard
##      Information                    Expected
##      Information saturated (h1) model Structured
##
## Regressions:
##              Estimate  Std.Err  z-value  P(>|z|)
##      litter ~
##      crown          0.521    0.156    3.341    0.001
##      rock.lg ~
##      litter        -0.903    0.079   -11.495    0.000
##      l.A ~
##      rock.lg        0.533    0.155    3.446    0.001
##      l.R ~
##      rock.lg        0.764    0.118    6.489    0.000
##      l.D ~
##      rock.lg        0.718    0.127    5.643    0.000
##      rot.l.X1 ~
##      rock.lg        0.469    0.161    2.911    0.004
##      rot.l.X2 ~
##      rock.lg        0.000    0.183    0.000    1.000
##
## Covariances:
```

```

##               Estimate Std.Err z-value P(>|z|)
## .l.A ~~
## .l.R           0.234    0.105    2.218    0.027
## .l.D          -0.028    0.104   -0.266    0.790
## .l.R ~~
## .l.D           0.328    0.099    3.303    0.001
## .l.A ~~
## .rot.l.X1       0.679    0.181    3.751    0.000
## .l.R ~~
## .rot.l.X1       0.250    0.110    2.261    0.024
## .l.A ~~
## .rot.l.X2      -0.092    0.150   -0.612    0.541
## .l.R ~~
## .rot.l.X2       0.123    0.116    1.058    0.290
## .l.D ~~
## .rot.l.X1      -0.018    0.109   -0.169    0.866
## .rot.l.X2       0.139    0.126    1.107    0.268
## .rot.l.X1 ~~
## .rot.l.X2       0.162    0.159    1.023    0.306
##
## Variances:
##               Estimate Std.Err z-value P(>|z|)
## .litter         0.705    0.182    3.873    0.000
## .rock.lg         0.179    0.046    3.873    0.000
## .l.A             0.692    0.179    3.873    0.000
## .l.R             0.402    0.104    3.873    0.000
## .l.D             0.469    0.121    3.873    0.000
## .rot.l.X1        0.754    0.195    3.873    0.000
## .rot.l.X2        0.967    0.250    3.873    0.000
##
## R-Square:
##               Estimate
## .litter         0.271
## .rock.lg         0.815
## .l.A             0.284
## .l.R             0.584
## .l.D             0.515
## .rot.l.X1        0.220
## .rot.l.X2        0.000

```

```
summary(fit.v.rot.nolight, rsquare = TRUE)
```

```

## lavaan 0.6-8 ended normally after 41 iterations
##
## Estimator                      ML
## Optimization method            NLMINB
## Number of model parameters      31
##
## Number of observations          30
##
## Model Test User Model:
##
## Test statistic                  20.525
## Degrees of freedom              13
## P-value (Chi-square)            0.083

```

```

##
## Parameter Estimates:
##
## Standard errors          Standard
## Information              Expected
## Information saturated (h1) model  Structured
##
## Regressions:
##      Estimate  Std.Err  z-value  P(>|z|)
## litter ~
##   crown      0.521    0.156    3.341    0.001
## rock.sm ~
##   litter     -0.686    0.133   -5.169    0.000
## p.A ~
##   rock.sm    -0.358    0.170   -2.098    0.036
## p.R ~
##   rock.sm    -0.331    0.172   -1.921    0.055
## p.D ~
##   rock.sm    -0.445    0.164   -2.719    0.007
## rot.p.X1 ~
##   rock.sm     0.463    0.162    2.859    0.004
## rot.p.X2 ~
##   rock.sm    -0.000    0.183   -0.000    1.000
## rot.p.X3 ~
##   rock.sm     0.000    0.183    0.000    1.000
##
## Covariances:
##      Estimate  Std.Err  z-value  P(>|z|)
## .p.A ~~
##   .rot.p.X2    -0.342    0.176   -1.942    0.052
## .p.R
##   .p.D         0.367    0.169    2.169    0.030
##   .p.D         0.262    0.155    1.688    0.091
## .p.R ~~
##   .p.D         0.670    0.193    3.474    0.001
## .p.A ~~
##   .rot.p.X1    -0.508    0.173   -2.933    0.003
## .p.R ~~
##   .rot.p.X1    -0.089    0.149   -0.602    0.547
## .p.A ~~
##   .rot.p.X3     0.301    0.174    1.735    0.083
## .p.R ~~
##   .rot.p.X2    -0.123    0.168   -0.730    0.466
##   .rot.p.X3     0.324    0.177    1.834    0.067
## .p.D ~~
##   .rot.p.X1    -0.069    0.141   -0.491    0.623
##   .rot.p.X2    -0.008    0.158   -0.052    0.958
##   .rot.p.X3     0.299    0.167    1.790    0.074
## .rot.p.X1 ~~
##   .rot.p.X2    -0.099    0.157   -0.626    0.532
##   .rot.p.X3     0.224    0.162    1.385    0.166
## .rot.p.X2 ~~
##   .rot.p.X3    -0.177    0.179   -0.985    0.325
##
## Variances:

```

```
##               Estimate Std.Err z-value P(>|z|)
## .litter        0.705    0.182   3.873  0.000
## .rock.sm       0.511    0.132   3.873  0.000
## .p.A           0.843    0.218   3.873  0.000
## .p.R           0.861    0.222   3.873  0.000
## .p.D           0.776    0.200   3.873  0.000
## .rot.p.X1      0.760    0.196   3.873  0.000
## .rot.p.X2      0.967    0.250   3.873  0.000
## .rot.p.X3      0.967    0.250   3.873  0.000
##
## R-Square:
##               Estimate
## litter         0.271
## rock.sm        0.471
## p.A            0.128
## p.R            0.110
## p.D            0.198
## rot.p.X1       0.214
## rot.p.X2       0.000
## rot.p.X3       0.000
```

## SEM Variable R-Squares

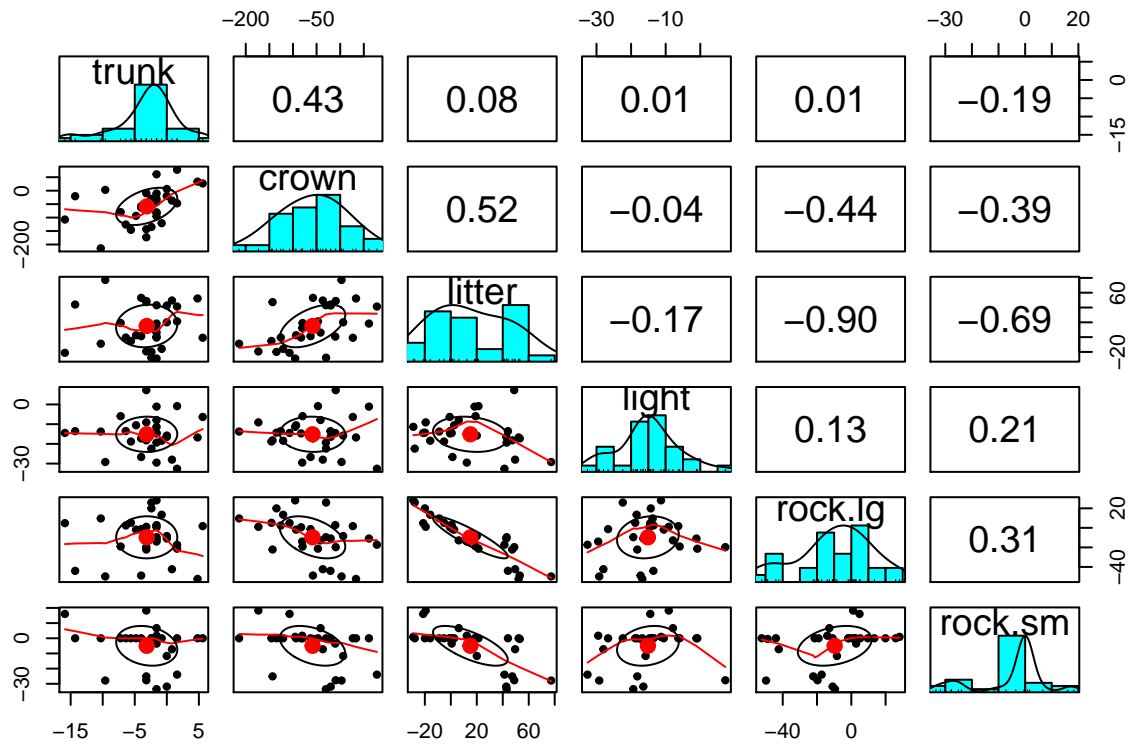
```
get_R2 <- function(x){
  out <- capture.output(summary(x, rsquare = TRUE))
  out <- out[grepl("R-Square:",out):length(out)]
  out <- out[!(grepl("R-Square:", out)) & !(grepl("Estimate", out))]
  out <- out[out != ""]
  out <- strsplit(out, " ")
  out <- lapply(out, function(x) x[x != ""])
  out <- do.call(rbind, out)
  out.names <- out[, 1]
  out <- as.numeric(out[, 2])
  names(out) <- out.names
  return(out)
}

r2.l.rot.all <- get_R2(fit.l.rot.all)
r2.v.rot.all <- get_R2(fit.v.rot.all)
```

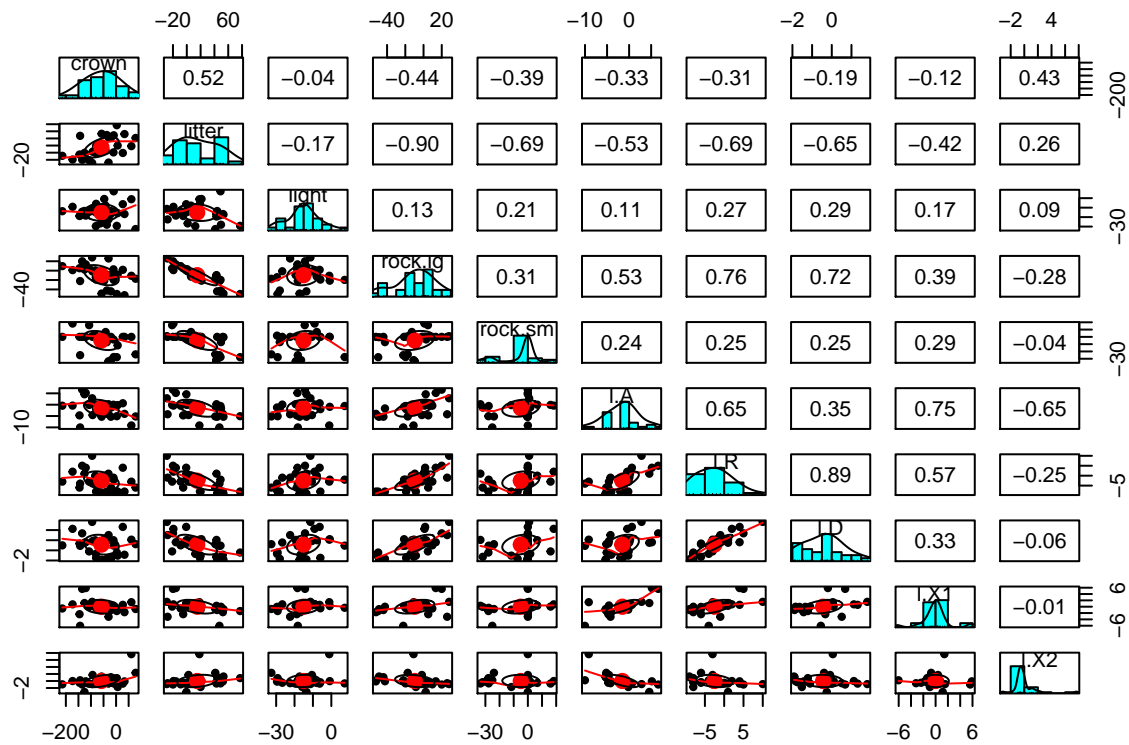
## SEM variable inter-correlations plot

```
pairs.panels(sem.dat[, c("trunk", "crown", "litter", "light", "rock.lg", "rock.sm")])
```

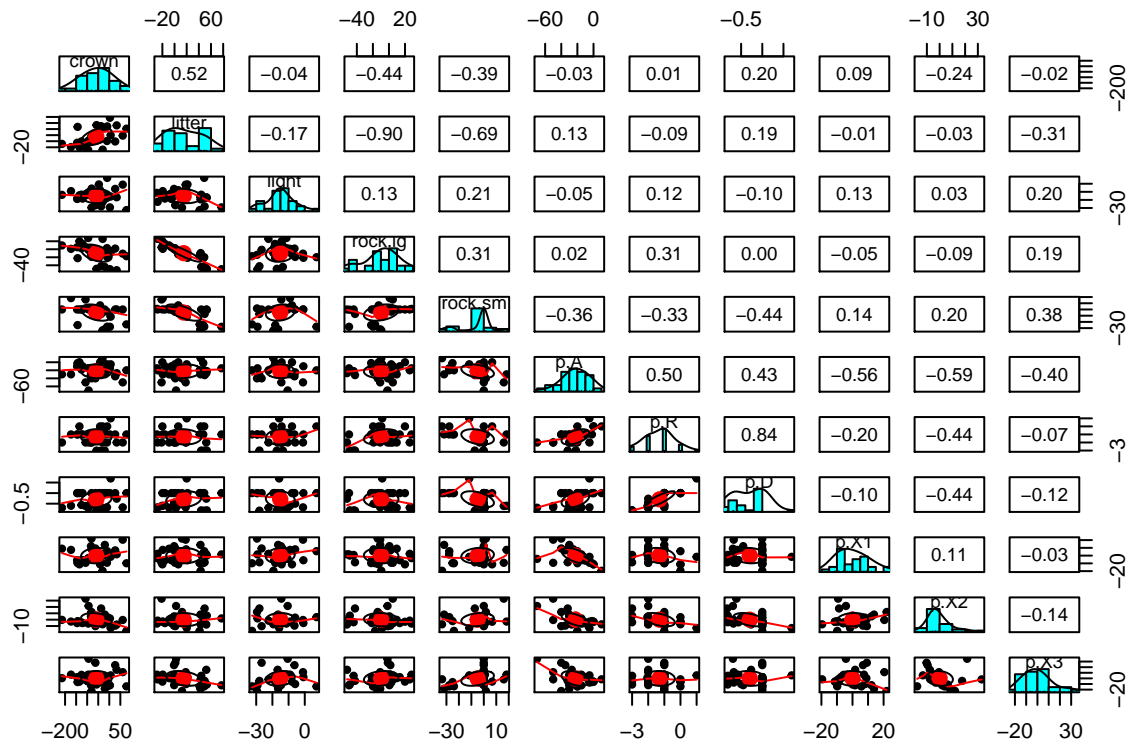




```
pairs.panels(sem.dat[, c("crown", "litter", "light", "rock.lg", "rock.sm",
                        "l.A", "l.R", "l.D", "l.X1", "l.X2")])
```



```
pairs.panels(sem.dat[, c("crown", "litter", "light", "rock.lg", "rock.sm",
                        "p.A", "p.R", "p.D", "p.X1", "p.X2", "p.X3")])
```



## SEM Skew-Kurtosis Check

```
skc.sem <- skew_kurtosis(sem.dat)
skc.sem.flags <- skc.sem[(abs(skc.sem[, "skew_2se"]) > 1 |
                          abs(skc.sem[, "kurt_2se"]) > 1), ]
kable(skc.sem.flags)
```

|          | skew      | skew_2se  | kurt     | kurt_2se  |
|----------|-----------|-----------|----------|-----------|
| LX1      | 0.3854049 | 0.4514075 | 2.683946 | 1.6115042 |
| LX2      | 2.6079952 | 3.0546283 | 9.344848 | 5.6108660 |
| p.X2     | 1.2498696 | 1.4639165 | 1.705619 | 1.0240934 |
| rot.LX2  | 1.9574132 | 2.2926307 | 5.705369 | 3.4256372 |
| rot.p.X1 | 1.1461696 | 1.3424572 | 1.444625 | 0.8673866 |

## SEM Modification Indices

```
xtable::xtable(modindices(fit.l.rot.all))
```

% latex table generated in R 4.0.4 by xtable 1.8-4 package % Fri Apr 23 16:31:27 2021

```
xtable::xtable(modindices(fit.v.rot.all))
```

% latex table generated in R 4.0.4 by xtable 1.8-4 package % Fri Apr 23 16:31:27 2021

## SEM Parameter Estimates

```
xtable::xtable(table_results(fit.l.all))
```

% latex table generated in R 4.0.4 by xtable 1.8-4 package % Fri Apr 23 16:31:28 2021

```
xtable::xtable(table_results(fit.v.all))
```

% latex table generated in R 4.0.4 by xtable 1.8-4 package % Fri Apr 23 16:31:28 2021

```
xtable::xtable(table_results(fit.l.rot.all))
```

% latex table generated in R 4.0.4 by xtable 1.8-4 package % Fri Apr 23 16:31:28 2021

```
xtable::xtable(table_results(fit.v.rot.all))
```

% latex table generated in R 4.0.4 by xtable 1.8-4 package % Fri Apr 23 16:31:28 2021

## SEM Model Fit Measures

```
sem.fm.l.all <- fitMeasures(fit.l.all)
sem.fm.v.all <- fitMeasures(fit.v.all)
sem.fm.l.rot.all <- fitMeasures(fit.l.rot.all)
sem.fm.v.rot.all <- fitMeasures(fit.v.rot.all)

sem.fm.tab.all <- rbind(sem.fm.l.all[c("chisq", "df", "pvalue")],
                        sem.fm.v.all[c("chisq", "df", "pvalue")])
rownames(sem.fm.tab.all) <- c("Lichens", "Plants")
colnames(sem.fm.tab.all) <- c("$\\chi^2$", "\\textit{df}", "\\textit{p}-value")
sem.fm.tab.rot.all <- rbind(sem.fm.l.rot.all[c("chisq", "df", "pvalue")],
                           sem.fm.v.rot.all[c("chisq", "df", "pvalue")])
rownames(sem.fm.tab.rot.all) <- c("Lichens", "Plants")
colnames(sem.fm.tab.rot.all) <- c("$\\chi^2$", "\\textit{df}", "\\textit{p}-value")

print(xtable::xtable(sem.fm.tab.all, digits = 3),
      sanitize.text.function = function(x) {x})
```

% latex table generated in R 4.0.4 by xtable 1.8-4 package % Fri Apr 23 16:31:28 2021

```
print(xtable::xtable(sem.fm.tab.rot.all, digits = 3),
      sanitize.text.function = function(x) {x})
```

% latex table generated in R 4.0.4 by xtable 1.8-4 package % Fri Apr 23 16:31:29 2021

## Ordination Plots

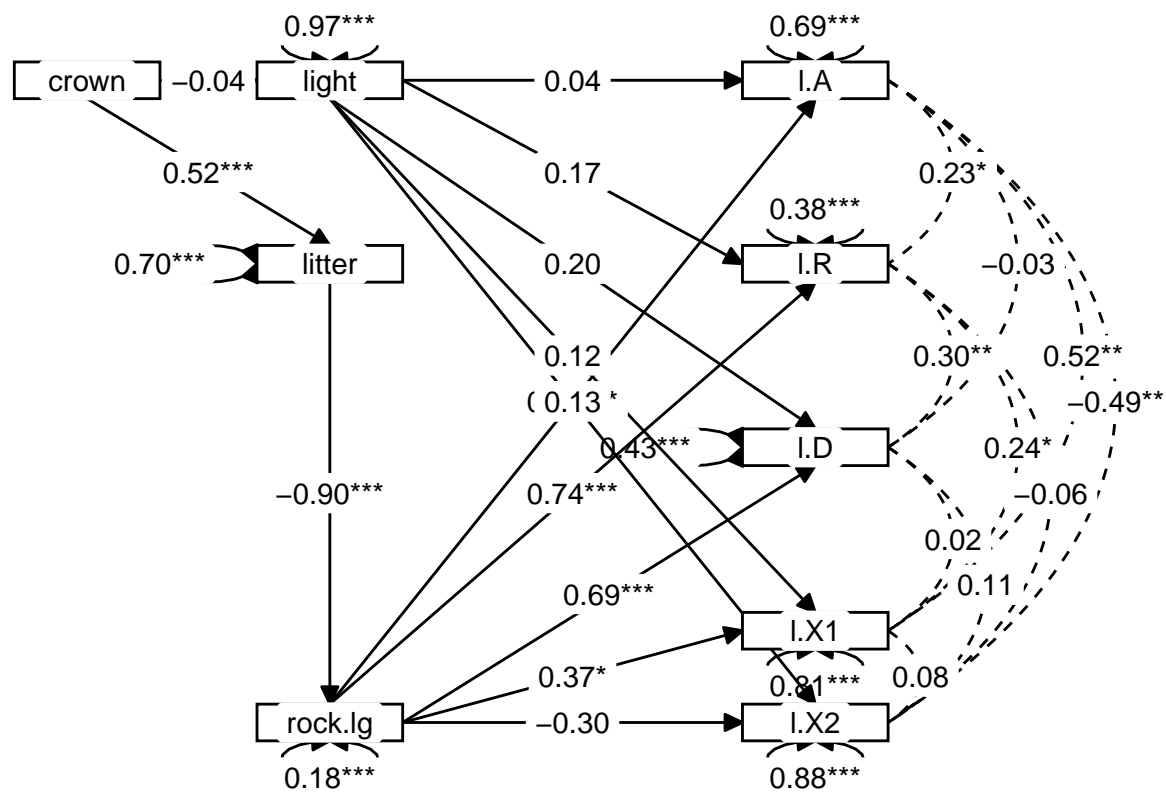
```
par(mfrow = c(1,2))
plot(l.com.dif.ord[, 1:2], xlab = "Axis 1", ylab = "Axis 2", pch = 19)
plot(l.com.dif.vec, add = TRUE)
plot(v.com.dif.ord[, 1:2], xlab = "Axis 1", ylab = "Axis 2", pch = 19)
plot(v.com.dif.vec, add = TRUE)
```



```

      "",      "litter", "",      "l.R",
      "",      "",      "",      "",
      "",      "",      "",      "l.D",
      "",      "",      "",      "",
      "",      "",      "",      "l.X1",
      "",      "rock.lg", "", "l.X2",
      rows = 8)
tg.l.all <- prepare_graph(fit.l.all, layout = lay)
plot(tg.l.all)

```



```

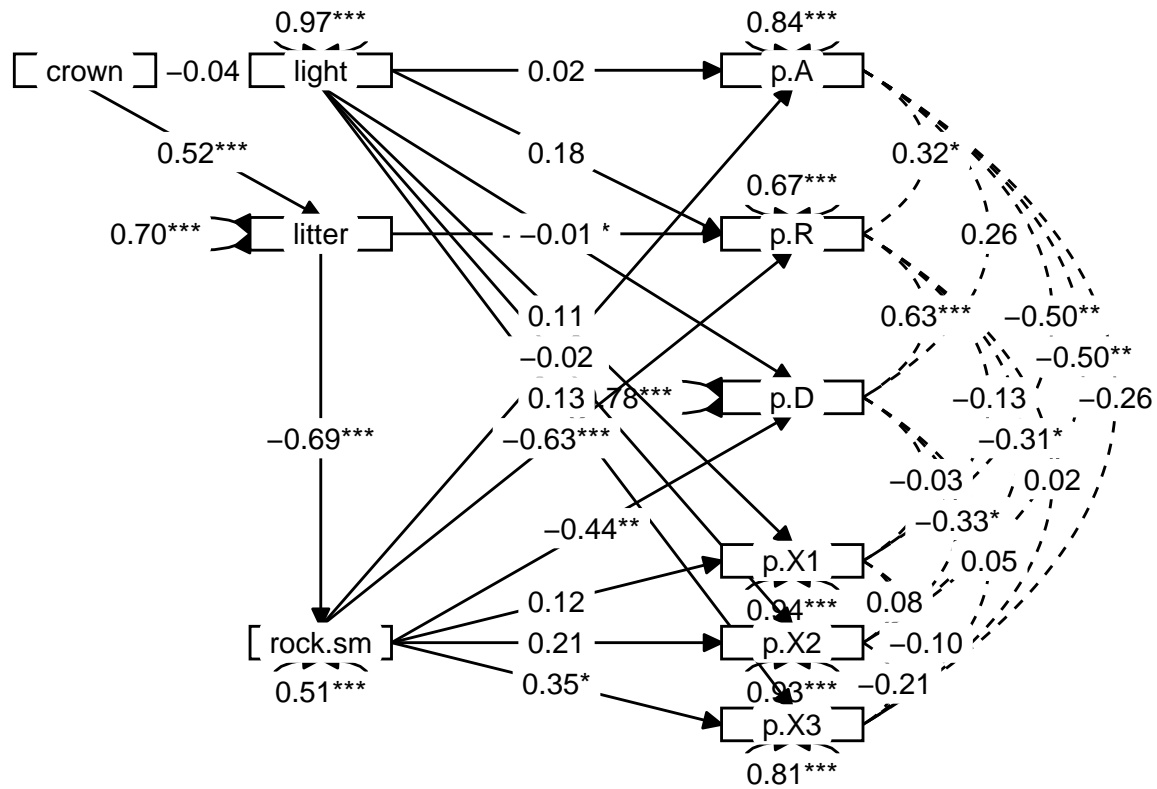
lay <- get_layout("crown", "light", "",      "p.A",
      "",      "",      "",      "",
      "",      "litter", "",      "p.R",
      "",      "",      "",      "",
      "",      "",      "",      "p.D",
      "",      "",      "",      "",
      "",      "",      "",      "p.X1",
      "",      "rock.sm", "", "p.X2",
      "",      "",      "",      "p.X3",
      rows = 9)

```

```

tg.v.all <- prepare_graph(fit.v.all, layout = lay)
plot(tg.v.all)

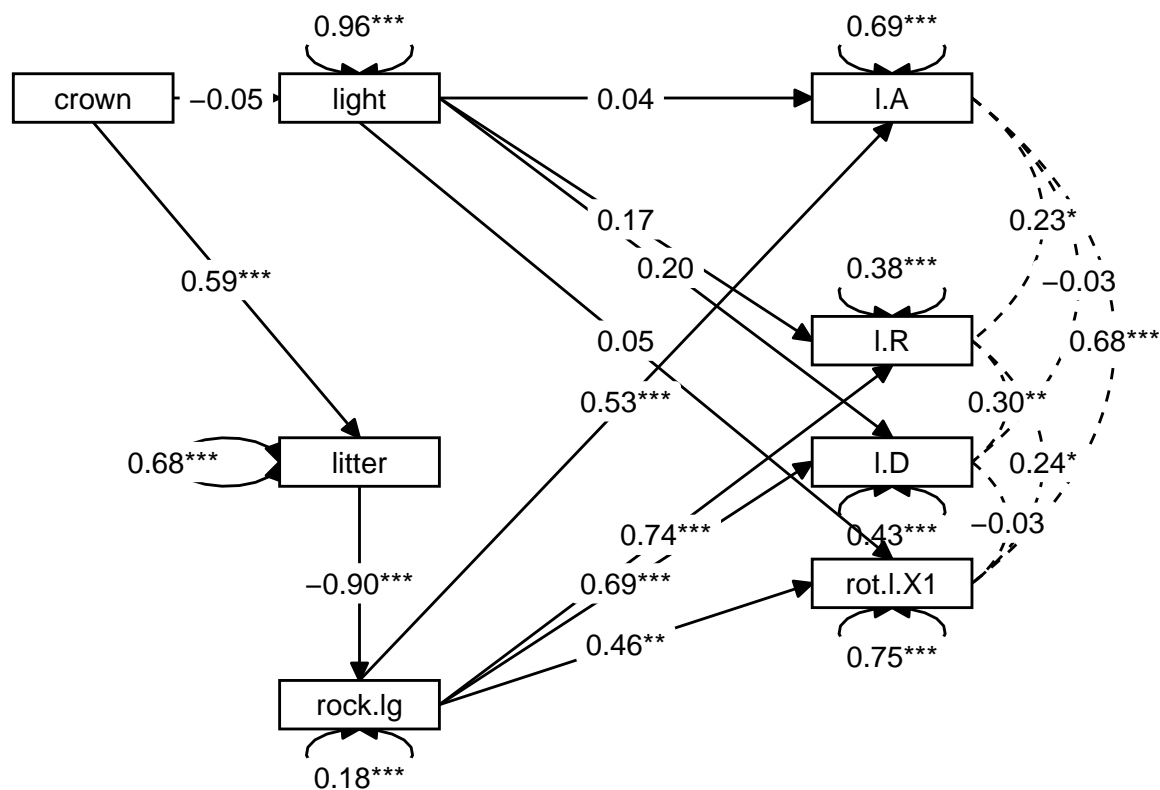
```



```
lay <- get_layout("crown", "light", "", "l.A",
  "", "", "", "", "l.R",
  "", "litter", "", "l.D",
  "", "", "", "rot.l.X1",
  "", "rock.lg", "", "",
  rows = 6)

tg.l.rot.all <- prepare_graph(fit.l.rot.all, layout = lay)

## Some edges involve nodes not in layout. These were dropped.
plot(tg.l.rot.all)
```

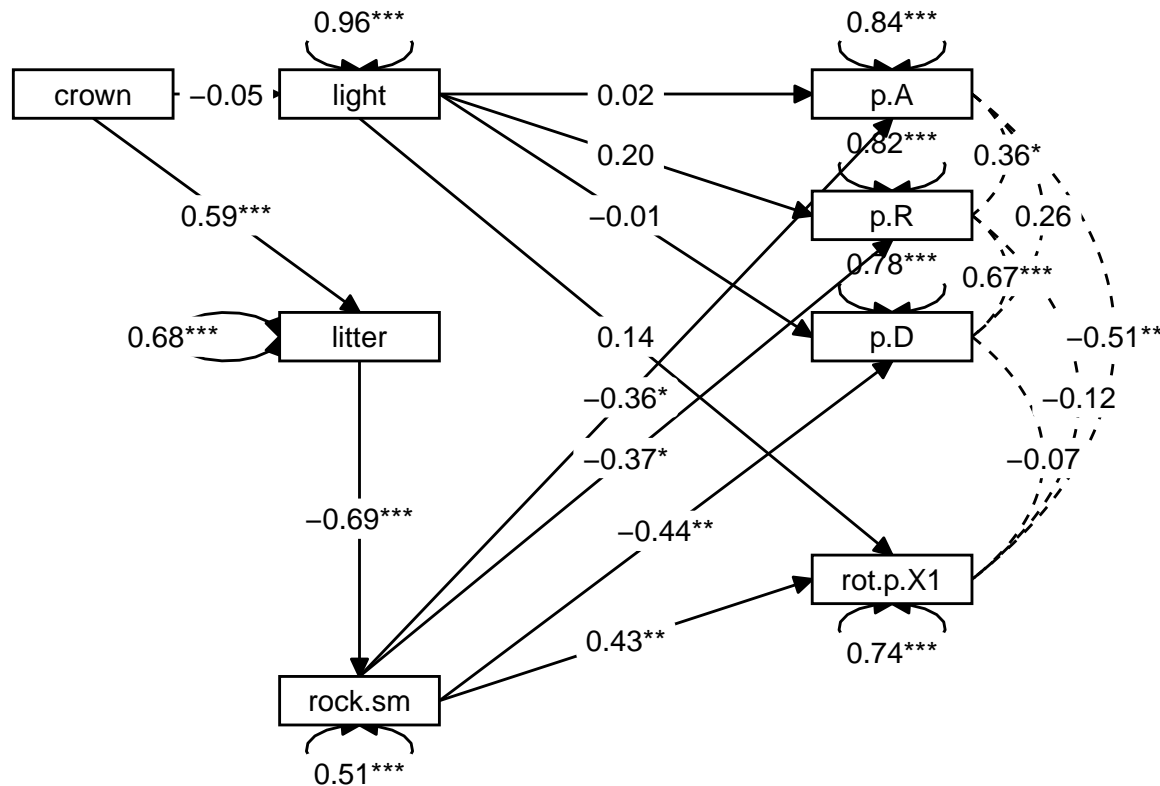


```
lay <- get_layout("crown", "light", "", "p.A",
  "", "", "", "p.R",
  "", "litter", "", "p.D",
  "", "", "", "",
  "", "", "", "rot.p.X1",
  "", "rock.sm", "", "",
  rows = 6)
```

```
tg.v.rot.all <- prepare_graph(fit.v.rot.all, layout = lay)
```

```
## Some edges involve nodes not in layout. These were dropped.
```

```
plot(tg.v.rot.all)
```



## Causal Pathway of Moth Susceptibility Effects on Communities

- Moth susceptibility indirectly influences plants and lichen
  1. Crown effect of moth increases litter effects but does not affect light differences
  2. Differences in litter between moth susceptible and resistant trees decreases the differences of both large and small rocks
  3. Differences in large rocks increases lichen community differences (abundance, richness, diversity, composition) and the difference in small rocks decreases the plant community differences (abundance richness, diversity and composition) between susceptible and resistant trees
- Both SEMs fit the data lichen ( $df = 19$ ,  $X^2 = 26.6808212$ ,  $p$ -value = 0.1123101) nor the plant ( $df = 22$ ,  $X^2 = 30.7624162$ ,  $p$ -value = 0.1010805) models showing significant differences from their observed covariance matrices based on  $X^2$  Goodness of Fit tests.
- Ultimately, moth induced changes explained significant amounts of community variation in differences in lichen abundance ( $R^2 = 0.282$ ), richness ( $R^2 = 0.601$ ) and diversity ( $R^2 = 0.539$ ), as well as in plant community differences in abundance ( $R^2 = 0.131$ ), richness ( $R^2 = 0.131$ ) and diversity ( $R^2 = 0.196$ ). Whole community differences between moth susceptible and resistant trees were also significantly explained by crown size differences for both lichens ( $R^2 = 0.219$ ) and plants ( $R^2 = 0.215$ ).
- See SEM path diagrams
- The effects can be interpreted as so:
  - As crown differences increase, litter differences increase
  - As litter differences increase, large rock differences decrease
  - As litter differences increase, small rock differences decrease
  - As large rock differences increase, lichen differences increase
  - As small rock differences increase, plant differences decrease

```
write.csv(file = "results/sem_results_lichen.csv",
          table_results(fit.l.rot.all)[, c("label", "est_sig", "se", "pval")],
          row.names = FALSE)
write.csv(file = "results/sem_results_plant.csv",
```



```
table_results(fit.v.rot.all)[, c("label", "est_sig", "se", "pval")],
row.names = FALSE)
```

| label                  | est_sig  | se   | pval | confint        |
|------------------------|----------|------|------|----------------|
| light.ON.crown         | -0.05    | 0.20 | 0.80 | [-0.45, 0.34]  |
| litter.ON.crown        | 0.59***  | 0.17 | 0.00 | [0.26, 0.93]   |
| light.ON.trunk         | 0.03     | 0.20 | 0.87 | [-0.36, 0.43]  |
| litter.ON.trunk        | -0.17    | 0.17 | 0.31 | [-0.50, 0.16]  |
| rock.lg.ON.litter      | -0.90*** | 0.08 | 0.00 | [-1.06, -0.75] |
| l.A.ON.light           | 0.04     | 0.15 | 0.81 | [-0.27, 0.34]  |
| l.A.ON.rock.lg         | 0.53***  | 0.15 | 0.00 | [0.22, 0.83]   |
| l.R.ON.light           | 0.17     | 0.11 | 0.14 | [-0.05, 0.39]  |
| l.R.ON.rock.lg         | 0.74***  | 0.11 | 0.00 | [0.52, 0.96]   |
| l.D.ON.light           | 0.20     | 0.12 | 0.11 | [-0.04, 0.44]  |
| l.D.ON.rock.lg         | 0.69***  | 0.12 | 0.00 | [0.45, 0.93]   |
| rot.l.X1.ON.light      | 0.05     | 0.16 | 0.75 | [-0.26, 0.37]  |
| rot.l.X1.ON.rock.lg    | 0.46**   | 0.16 | 0.00 | [0.15, 0.78]   |
| rot.l.X2.ON.light      | 0.17     | 0.18 | 0.33 | [-0.18, 0.53]  |
| rot.l.X2.ON.rock.lg    | -0.02    | 0.18 | 0.90 | [-0.38, 0.33]  |
| l.A.WITH.l.R           | 0.23*    | 0.10 | 0.03 | [0.03, 0.43]   |
| l.A.WITH.l.D           | -0.03    | 0.10 | 0.73 | [-0.23, 0.16]  |
| l.R.WITH.l.D           | 0.30**   | 0.09 | 0.00 | [0.12, 0.48]   |
| l.A.WITH.rot.l.X1      | 0.68***  | 0.18 | 0.00 | [0.32, 1.03]   |
| l.R.WITH.rot.l.X1      | 0.24*    | 0.11 | 0.02 | [0.03, 0.45]   |
| Variances.light        | 0.96***  | 0.25 | 0.00 | [0.48, 1.45]   |
| Variances.litter       | 0.68***  | 0.18 | 0.00 | [0.34, 1.03]   |
| Variances.rock.lg      | 0.18***  | 0.05 | 0.00 | [0.09, 0.27]   |
| Variances.l.A          | 0.69***  | 0.18 | 0.00 | [0.34, 1.04]   |
| Variances.l.R          | 0.38***  | 0.10 | 0.00 | [0.19, 0.57]   |
| Variances.l.D          | 0.43***  | 0.11 | 0.00 | [0.21, 0.65]   |
| Variances.rot.l.X1     | 0.75***  | 0.19 | 0.00 | [0.37, 1.13]   |
| Variances.rot.l.X2     | 0.94***  | 0.24 | 0.00 | [0.46, 1.41]   |
| l.A.WITH.rot.l.X2      | -0.10    | 0.15 | 0.51 | [-0.39, 0.19]  |
| l.R.WITH.rot.l.X2      | 0.10     | 0.11 | 0.39 | [-0.12, 0.31]  |
| l.D.WITH.rot.l.X1      | -0.03    | 0.10 | 0.79 | [-0.23, 0.18]  |
| l.D.WITH.rot.l.X2      | 0.11     | 0.12 | 0.37 | [-0.12, 0.34]  |
| rot.l.X1.WITH.rot.l.X2 | 0.15     | 0.16 | 0.32 | [-0.15, 0.46]  |
| Variances.crown        | 0.97     | 0.00 | NA   | [0.97, 0.97]   |
| crown.WITH.trunk       | 0.41     | 0.00 | NA   | [0.41, 0.41]   |
| Variances.trunk        | 0.97     | 0.00 | NA   | [0.97, 0.97]   |

| label             | est_sig  | se   | pval | confint        |
|-------------------|----------|------|------|----------------|
| light.ON.crown    | -0.05    | 0.20 | 0.80 | [-0.45, 0.34]  |
| litter.ON.crown   | 0.59***  | 0.17 | 0.00 | [0.26, 0.93]   |
| light.ON.trunk    | 0.03     | 0.20 | 0.87 | [-0.36, 0.43]  |
| litter.ON.trunk   | -0.17    | 0.17 | 0.31 | [-0.50, 0.16]  |
| rock.sm.ON.litter | -0.69*** | 0.13 | 0.00 | [-0.95, -0.43] |
| p.A.ON.light      | 0.02     | 0.17 | 0.89 | [-0.31, 0.36]  |
| p.A.ON.rock.sm    | -0.36*   | 0.17 | 0.03 | [-0.70, -0.03] |
| p.R.ON.light      | 0.20     | 0.17 | 0.24 | [-0.13, 0.53]  |
| p.R.ON.rock.sm    | -0.37*   | 0.17 | 0.03 | [-0.70, -0.04] |

| label                  | est_sig | se   | pval | confint        |
|------------------------|---------|------|------|----------------|
| p.D.ON.light           | -0.01   | 0.16 | 0.94 | [-0.33, 0.31]  |
| p.D.ON.rock.sm         | -0.44** | 0.16 | 0.01 | [-0.76, -0.12] |
| rot.p.X1.ON.light      | 0.14    | 0.16 | 0.37 | [-0.17, 0.46]  |
| rot.p.X1.ON.rock.sm    | 0.43**  | 0.16 | 0.01 | [0.12, 0.75]   |
| rot.p.X2.ON.light      | 0.06    | 0.18 | 0.73 | [-0.29, 0.42]  |
| rot.p.X2.ON.rock.sm    | -0.01   | 0.18 | 0.94 | [-0.37, 0.34]  |
| rot.p.X3.ON.light      | 0.07    | 0.18 | 0.70 | [-0.29, 0.43]  |
| rot.p.X3.ON.rock.sm    | -0.01   | 0.18 | 0.94 | [-0.37, 0.34]  |
| p.A.WITH.rot.p.X2      | -0.34   | 0.18 | 0.05 | [-0.69, 0.00]  |
| p.A.WITH.p.R           | 0.36*   | 0.17 | 0.03 | [0.04, 0.69]   |
| p.A.WITH.p.D           | 0.26    | 0.16 | 0.09 | [-0.04, 0.57]  |
| p.R.WITH.p.D           | 0.67*** | 0.19 | 0.00 | [0.30, 1.05]   |
| p.A.WITH.rot.p.X1      | -0.51** | 0.17 | 0.00 | [-0.85, -0.17] |
| p.R.WITH.rot.p.X1      | -0.12   | 0.14 | 0.42 | [-0.40, 0.17]  |
| Variances.light        | 0.96*** | 0.25 | 0.00 | [0.48, 1.45]   |
| Variances.litter       | 0.68*** | 0.18 | 0.00 | [0.34, 1.03]   |
| Variances.rock.sm      | 0.51*** | 0.13 | 0.00 | [0.25, 0.77]   |
| Variances.p.A          | 0.84*** | 0.22 | 0.00 | [0.42, 1.27]   |
| Variances.p.R          | 0.82*** | 0.21 | 0.00 | [0.41, 1.24]   |
| Variances.p.D          | 0.78*** | 0.20 | 0.00 | [0.38, 1.17]   |
| Variances.rot.p.X1     | 0.74*** | 0.19 | 0.00 | [0.37, 1.12]   |
| Variances.rot.p.X2     | 0.96*** | 0.25 | 0.00 | [0.48, 1.45]   |
| Variances.rot.p.X3     | 0.96*** | 0.25 | 0.00 | [0.48, 1.45]   |
| p.A.WITH.rot.p.X3      | 0.30    | 0.17 | 0.08 | [-0.04, 0.64]  |
| p.R.WITH.rot.p.X2      | -0.13   | 0.16 | 0.42 | [-0.46, 0.19]  |
| p.R.WITH.rot.p.X3      | 0.31    | 0.17 | 0.07 | [-0.03, 0.65]  |
| p.D.WITH.rot.p.X1      | -0.07   | 0.14 | 0.63 | [-0.34, 0.20]  |
| p.D.WITH.rot.p.X2      | -0.01   | 0.16 | 0.96 | [-0.32, 0.30]  |
| p.D.WITH.rot.p.X3      | 0.30    | 0.17 | 0.07 | [-0.03, 0.63]  |
| rot.p.X1.WITH.rot.p.X2 | -0.11   | 0.16 | 0.49 | [-0.41, 0.20]  |
| rot.p.X1.WITH.rot.p.X3 | 0.21    | 0.16 | 0.18 | [-0.10, 0.53]  |
| rot.p.X2.WITH.rot.p.X3 | -0.18   | 0.18 | 0.31 | [-0.53, 0.17]  |
| Variances.crown        | 0.97    | 0.00 | NA   | [0.97, 0.97]   |
| crown.WITH.trunk       | 0.41    | 0.00 | NA   | [0.41, 0.41]   |
| Variances.trunk        | 0.97    | 0.00 | NA   | [0.97, 0.97]   |

|     | lhs      | op | rhs      | mi     | epc   | sepc.lv | sepc.all | sepc.nox |
|-----|----------|----|----------|--------|-------|---------|----------|----------|
| 34  | crown    | ~~ | crown    | 0.00   | 0.00  | 0.00    | 0.00     | 0.00     |
| 35  | crown    | ~~ | trunk    | 0.00   | -0.00 | -0.00   |          | -0.00    |
| 36  | trunk    | ~~ | trunk    | 0.00   | 0.00  | 0.00    | 0.00     | 0.00     |
| 37  | light    | ~~ | litter   | 0.93   | -0.14 | -0.14   | -0.18    | -0.18    |
| 38  | light    | ~~ | rock.lg  | 0.08   | -0.02 | -0.02   | -0.05    | -0.05    |
| 39  | light    | ~~ | l.A      | 3.81   | 1.06  | 1.06    | 1.30     | 1.30     |
| 40  | light    | ~~ | l.R      | 0.61   | -0.90 | -0.90   | -1.49    | -1.49    |
| 41  | light    | ~~ | l.D      | 0.01   | -0.12 | -0.12   | -0.18    | -0.18    |
| 42  | light    | ~~ | rot.l.X1 | 4.26   | -1.18 | -1.18   | -1.39    | -1.39    |
| 43  | light    | ~~ | rot.l.X2 | 6.42   | 4.61  | 4.61    | 4.85     | 4.85     |
| 44  | litter   | ~~ | rock.lg  | 0.02   | -0.02 | -0.02   | -0.05    | -0.05    |
| 45  | litter   | ~~ | l.A      | 2.49   | -0.05 | -0.05   | -0.07    | -0.07    |
| 46  | litter   | ~~ | l.R      | 2.41   | 0.10  | 0.10    | 0.20     | 0.20     |
| 47  | litter   | ~~ | l.D      | 1.29   | -0.09 | -0.09   | -0.16    | -0.16    |
| 48  | litter   | ~~ | rot.l.X1 | 1.88   | 0.04  | 0.04    | 0.06     | 0.06     |
| 49  | litter   | ~~ | rot.l.X2 | 4.51   | -0.21 | -0.21   | -0.27    | -0.27    |
| 50  | rock.lg  | ~~ | l.A      | 0.54   | 0.01  | 0.01    | 0.02     | 0.02     |
| 51  | rock.lg  | ~~ | l.R      | 0.62   | 0.02  | 0.02    | 0.07     | 0.07     |
| 52  | rock.lg  | ~~ | l.D      | 0.53   | -0.02 | -0.02   | -0.07    | -0.07    |
| 53  | rock.lg  | ~~ | rot.l.X1 | 1.06   | -0.01 | -0.01   | -0.03    | -0.03    |
| 54  | rock.lg  | ~~ | rot.l.X2 | 0.42   | 0.02  | 0.02    | 0.06     | 0.06     |
| 55  | light    | ~  | litter   | 0.93   | -0.21 | -0.21   | -0.21    | -0.21    |
| 56  | light    | ~  | rock.lg  | 0.49   | 0.15  | 0.15    | 0.15     | 0.15     |
| 57  | light    | ~  | l.A      | 0.36   | 0.24  | 0.24    | 0.24     | 0.24     |
| 58  | light    | ~  | l.R      | 0.42   | 0.18  | 0.18    | 0.18     | 0.18     |
| 59  | light    | ~  | l.D      | 0.45   | 0.20  | 0.20    | 0.20     | 0.20     |
| 60  | light    | ~  | rot.l.X1 | 0.35   | 0.27  | 0.27    | 0.27     | 0.27     |
| 61  | light    | ~  | rot.l.X2 | 0.93   | 3.73  | 3.73    | 3.74     | 3.74     |
| 62  | litter   | ~  | light    | 0.93   | -0.15 | -0.15   | -0.15    | -0.15    |
| 63  | litter   | ~  | rock.lg  | 0.02   | -0.09 | -0.09   | -0.09    | -0.09    |
| 64  | litter   | ~  | l.A      | 0.05   | 0.06  | 0.06    | 0.06     | 0.06     |
| 65  | litter   | ~  | l.R      | 0.00   | 0.01  | 0.01    | 0.01     | 0.01     |
| 66  | litter   | ~  | l.D      | 0.42   | -0.20 | -0.20   | -0.19    | -0.19    |
| 67  | litter   | ~  | rot.l.X1 | 0.01   | -0.02 | -0.02   | -0.02    | -0.02    |
| 68  | litter   | ~  | rot.l.X2 | 3.62   | -0.44 | -0.44   | -0.44    | -0.44    |
| 69  | rock.lg  | ~  | light    | 0.07   | -0.02 | -0.02   | -0.02    | -0.02    |
| 70  | rock.lg  | ~  | l.A      | 0.52   | -0.07 | -0.07   | -0.07    | -0.07    |
| 71  | rock.lg  | ~  | l.R      | 0.00   | -0.00 | -0.00   | -0.00    | -0.00    |
| 72  | rock.lg  | ~  | l.D      | 0.00   | 0.00  | 0.00    | 0.00     | 0.00     |
| 73  | rock.lg  | ~  | rot.l.X1 | 0.93   | -0.09 | -0.09   | -0.09    | -0.09    |
| 74  | rock.lg  | ~  | rot.l.X2 | 0.11   | -0.03 | -0.03   | -0.03    | -0.03    |
| 75  | rock.lg  | ~  | crown    | 0.23   | 0.04  | 0.04    | 0.04     | 0.04     |
| 76  | rock.lg  | ~  | trunk    | 1.07   | 0.08  | 0.08    | 0.08     | 0.08     |
| 77  | l.A      | ~  | litter   | 0.54   | 0.04  | 0.04    | 0.04     | 0.04     |
| 82  | l.A      | ~  | crown    | 6.63   | 0.07  | 0.07    | 0.07     | 0.07     |
| 83  | l.A      | ~  | trunk    | 0.98   | 0.02  | 0.02    | 0.02     | 0.02     |
| 84  | l.R      | ~  | litter   | 0.62   | 0.09  | 0.09    | 0.10     | 0.10     |
| 89  | l.R      | ~  | crown    | 1.36   | -0.07 | -0.07   | -0.07    | -0.07    |
| 90  | l.R      | ~  | trunk    | 0.34   | -0.03 | -0.03   | -0.03    | -0.03    |
| 91  | l.D      | ~  | litter   | 0.53   | -0.11 | -0.11   | -0.11    | -0.11    |
| 96  | l.D      | ~  | crown    | 1.25   | 0.08  | 0.08    | 0.08     | 0.08     |
| 97  | l.D      | ~  | trunk    | 2.60   | 0.10  | 0.10    | 0.10     | 0.10     |
| 98  | rot.l.X1 | ~  | litter   | 1.06   | -0.06 | -0.06   | -0.06    | -0.06    |
| 103 | rot.l.X1 | ~  | crown    | 6.42   | -0.07 | -0.07   | -0.07    | -0.07    |
| 104 | rot.l.X1 | ~  | trunk    | 0.63   | -0.02 | -0.02   | -0.02    | -0.02    |
| 105 | rot.l.X2 | ~  | litter   | 0.4291 | 0.12  | 0.12    | 0.12     | 0.12     |
| 110 | rot.l.X2 | ~  | crown    | 9.20   | 0.28  | 0.28    | 0.28     | 0.28     |
| 111 | rot.l.X2 | ~  | trunk    | 0.76   | 0.07  | 0.07    | 0.07     | 0.07     |
| 112 | crown    | ~  | light    | 0.00   | 0.01  | 0.01    | 0.01     | 0.01     |

|     | lhs      | op | rhs      | mi   | epc   | sepc.lv | sepc.all | sepc.nox |
|-----|----------|----|----------|------|-------|---------|----------|----------|
| 42  | crown    | ~~ | crown    | 0.00 | -0.00 | 0.00    | 0.00     | 0.00     |
| 43  | crown    | ~~ | trunk    | 0.00 | 0.00  | 0.00    |          | 0.00     |
| 44  | trunk    | ~~ | trunk    | 0.00 | 0.00  | 0.00    | 0.00     | 0.00     |
| 45  | light    | ~~ | litter   | 0.93 | -0.14 | -0.14   | -0.18    | -0.18    |
| 46  | light    | ~~ | rock.sm  | 0.47 | 0.09  | 0.09    | 0.13     | 0.13     |
| 47  | light    | ~~ | p.A      | 2.22 | -2.13 | -2.13   | -2.37    | -2.37    |
| 48  | light    | ~~ | p.R      | 1.48 | -2.22 | -2.22   | -2.49    | -2.49    |
| 49  | light    | ~~ | p.D      | 0.40 | 1.16  | 1.16    | 1.34     | 1.34     |
| 50  | light    | ~~ | rot.p.X1 | 1.45 | -1.81 | -1.81   | -2.14    | -2.14    |
| 51  | light    | ~~ | rot.p.X2 | 0.77 | -2.35 | -2.35   | -2.44    | -2.44    |
| 52  | light    | ~~ | rot.p.X3 | 1.18 | 2.71  | 2.71    | 2.81     | 2.81     |
| 53  | litter   | ~~ | rock.sm  | 0.00 | -0.01 | -0.01   | -0.02    | -0.02    |
| 54  | litter   | ~~ | p.A      | 1.90 | 0.09  | 0.09    | 0.12     | 0.12     |
| 55  | litter   | ~~ | p.R      | 4.87 | -0.19 | -0.19   | -0.25    | -0.25    |
| 56  | litter   | ~~ | p.D      | 2.09 | 0.12  | 0.12    | 0.17     | 0.17     |
| 57  | litter   | ~~ | rot.p.X1 | 0.94 | 0.07  | 0.07    | 0.10     | 0.10     |
| 58  | litter   | ~~ | rot.p.X2 | 0.29 | 0.07  | 0.07    | 0.08     | 0.08     |
| 59  | litter   | ~~ | rot.p.X3 | 2.17 | -0.17 | -0.17   | -0.21    | -0.21    |
| 60  | rock.sm  | ~~ | p.A      | 0.00 | 0.00  | 0.00    | 0.01     | 0.01     |
| 61  | rock.sm  | ~~ | p.R      | 9.48 | -0.27 | -0.27   | -0.42    | -0.42    |
| 62  | rock.sm  | ~~ | p.D      | 4.53 | 0.19  | 0.19    | 0.30     | 0.30     |
| 63  | rock.sm  | ~~ | rot.p.X1 | 0.02 | -0.01 | -0.01   | -0.02    | -0.02    |
| 64  | rock.sm  | ~~ | rot.p.X2 | 0.02 | -0.02 | -0.02   | -0.03    | -0.03    |
| 65  | rock.sm  | ~~ | rot.p.X3 | 0.01 | -0.01 | -0.01   | -0.02    | -0.02    |
| 66  | light    | ~  | litter   | 0.93 | -0.21 | -0.21   | -0.21    | -0.21    |
| 67  | light    | ~  | rock.sm  | 1.29 | 0.22  | 0.22    | 0.22     | 0.22     |
| 68  | light    | ~  | p.A      | 1.76 | -0.71 | -0.71   | -0.71    | -0.71    |
| 69  | light    | ~  | p.R      | 1.82 | -0.71 | -0.71   | -0.72    | -0.72    |
| 70  | light    | ~  | p.D      | 1.55 | -0.55 | -0.55   | -0.55    | -0.55    |
| 71  | light    | ~  | rot.p.X1 | 1.40 | 0.53  | 0.53    | 0.53     | 0.53     |
| 72  | light    | ~  | rot.p.X2 | 0.06 | 0.94  | 0.94    | 0.94     | 0.94     |
| 73  | light    | ~  | rot.p.X3 | 0.54 | -2.85 | -2.85   | -2.85    | -2.85    |
| 74  | litter   | ~  | light    | 0.93 | -0.15 | -0.15   | -0.15    | -0.15    |
| 75  | litter   | ~  | rock.sm  | 0.00 | -0.02 | -0.02   | -0.02    | -0.02    |
| 76  | litter   | ~  | p.A      | 0.00 | -0.00 | -0.00   | -0.00    | -0.00    |
| 77  | litter   | ~  | p.R      | 3.55 | -0.36 | -0.36   | -0.37    | -0.37    |
| 78  | litter   | ~  | p.D      | 0.50 | -0.14 | -0.14   | -0.14    | -0.14    |
| 79  | litter   | ~  | rot.p.X1 | 0.28 | -0.11 | -0.11   | -0.11    | -0.11    |
| 80  | litter   | ~  | rot.p.X2 | 0.02 | 0.03  | 0.03    | 0.03     | 0.03     |
| 81  | litter   | ~  | rot.p.X3 | 1.84 | -0.25 | -0.25   | -0.25    | -0.25    |
| 82  | rock.sm  | ~  | light    | 0.44 | 0.09  | 0.09    | 0.09     | 0.09     |
| 83  | rock.sm  | ~  | p.A      | 0.85 | -0.19 | -0.19   | -0.19    | -0.19    |
| 84  | rock.sm  | ~  | p.R      | 5.06 | -0.45 | -0.45   | -0.46    | -0.46    |
| 85  | rock.sm  | ~  | p.D      | 1.04 | -0.22 | -0.22   | -0.22    | -0.22    |
| 86  | rock.sm  | ~  | rot.p.X1 | 0.07 | 0.06  | 0.06    | 0.06     | 0.06     |
| 87  | rock.sm  | ~  | rot.p.X2 | 0.53 | 0.14  | 0.14    | 0.14     | 0.14     |
| 88  | rock.sm  | ~  | rot.p.X3 | 0.63 | -0.15 | -0.15   | -0.15    | -0.15    |
| 89  | rock.sm  | ~  | crown    | 0.08 | -0.05 | -0.05   | -0.05    | -0.05    |
| 90  | rock.sm  | ~  | trunk    | 1.01 | -0.13 | -0.13   | -0.13    | -0.14    |
| 91  | p.A      | ~  | litter   | 0.00 | 0.01  | 0.01    | 0.01     | 0.01     |
| 97  | p.A      | ~  | crown    | 3.30 | -0.13 | -0.13   | -0.13    | -0.13    |
| 98  | p.A      | ~  | trunk    | 0.36 | -0.04 | -0.04   | -0.04    | -0.04    |
| 99  | p.R      | ~  | litter   | 9.48 | -0.36 | -0.36   | -0.36    | -0.36    |
| 105 | p.R      | ~  | crown    | 2.08 | -0.13 | -0.13   | -0.13    | -0.13    |
| 106 | p.R      | ~  | trunk    | 0.18 | -0.04 | -0.04   | -0.04    | -0.04    |
| 107 | p.D      | ~  | litter   | 4.53 | 0.25  | 0.25    | 0.25     | 0.25     |
| 113 | p.D      | ~  | crown    | 1.74 | 0.12  | 0.12    | 0.12     | 0.12     |
| 114 | p.D      | ~  | trunk    | 1.06 | 0.09  | 0.09    | 0.09     | 0.09     |
| 115 | rot.p.X1 | ~  | litter   | 0.02 | -0.01 | -0.01   | -0.01    | -0.01    |

|    | label             | est_sig  | se   | pval | confint        |
|----|-------------------|----------|------|------|----------------|
| 1  | light.ON.crown    | -0.04    | 0.18 | 0.84 | [-0.39, 0.32]  |
| 2  | litter.ON.crown   | 0.52***  | 0.16 | 0.00 | [0.22, 0.83]   |
| 3  | rock.lg.ON.litter | -0.90*** | 0.08 | 0.00 | [-1.06, -0.75] |
| 4  | l.A.ON.light      | 0.04     | 0.15 | 0.81 | [-0.27, 0.34]  |
| 5  | l.A.ON.rock.lg    | 0.53***  | 0.15 | 0.00 | [0.22, 0.83]   |
| 6  | l.R.ON.light      | 0.17     | 0.11 | 0.14 | [-0.05, 0.39]  |
| 7  | l.R.ON.rock.lg    | 0.74***  | 0.11 | 0.00 | [0.52, 0.96]   |
| 8  | l.D.ON.light      | 0.20     | 0.12 | 0.11 | [-0.04, 0.44]  |
| 9  | l.D.ON.rock.lg    | 0.69***  | 0.12 | 0.00 | [0.45, 0.93]   |
| 10 | l.X1.ON.light     | 0.12     | 0.17 | 0.48 | [-0.21, 0.45]  |
| 11 | l.X1.ON.rock.lg   | 0.37*    | 0.17 | 0.02 | [0.05, 0.70]   |
| 12 | l.X2.ON.light     | 0.13     | 0.17 | 0.46 | [-0.21, 0.47]  |
| 13 | l.X2.ON.rock.lg   | -0.30    | 0.17 | 0.09 | [-0.64, 0.05]  |
| 14 | l.A.WITH.l.R      | 0.23*    | 0.10 | 0.03 | [0.03, 0.43]   |
| 15 | l.A.WITH.l.D      | -0.03    | 0.10 | 0.73 | [-0.23, 0.16]  |
| 16 | l.R.WITH.l.D      | 0.30**   | 0.09 | 0.00 | [0.12, 0.48]   |
| 17 | l.A.WITH.l.X1     | 0.52**   | 0.17 | 0.00 | [0.19, 0.85]   |
| 18 | l.R.WITH.l.X1     | 0.24*    | 0.11 | 0.03 | [0.03, 0.46]   |
| 19 | Variances.light   | 0.97***  | 0.25 | 0.00 | [0.48, 1.45]   |
| 20 | Variances.litter  | 0.70***  | 0.18 | 0.00 | [0.35, 1.06]   |
| 21 | Variances.rock.lg | 0.18***  | 0.05 | 0.00 | [0.09, 0.27]   |
| 22 | Variances.l.A     | 0.69***  | 0.18 | 0.00 | [0.34, 1.04]   |
| 23 | Variances.l.R     | 0.38***  | 0.10 | 0.00 | [0.19, 0.57]   |
| 24 | Variances.l.D     | 0.43***  | 0.11 | 0.00 | [0.21, 0.65]   |
| 25 | Variances.l.X1    | 0.81***  | 0.21 | 0.00 | [0.40, 1.21]   |
| 26 | Variances.l.X2    | 0.88***  | 0.23 | 0.00 | [0.43, 1.32]   |
| 27 | l.A.WITH.l.X2     | -0.49**  | 0.17 | 0.00 | [-0.82, -0.16] |
| 28 | l.R.WITH.l.X2     | -0.06    | 0.11 | 0.59 | [-0.26, 0.15]  |
| 29 | l.D.WITH.l.X1     | 0.02     | 0.11 | 0.83 | [-0.19, 0.23]  |
| 30 | l.D.WITH.l.X2     | 0.11     | 0.11 | 0.32 | [-0.11, 0.34]  |
| 31 | l.X1.WITH.l.X2    | 0.08     | 0.15 | 0.61 | [-0.22, 0.38]  |
| 32 | Variances.crown   | 0.97     | 0.00 |      | [0.97, 0.97]   |

|    | label             | est_sig  | se   | pval | confint        |
|----|-------------------|----------|------|------|----------------|
| 1  | light.ON.crown    | -0.04    | 0.18 | 0.84 | [-0.39, 0.32]  |
| 2  | litter.ON.crown   | 0.52***  | 0.16 | 0.00 | [0.22, 0.83]   |
| 3  | rock.sm.ON.litter | -0.69*** | 0.13 | 0.00 | [-0.95, -0.43] |
| 4  | p.A.ON.light      | 0.02     | 0.17 | 0.89 | [-0.31, 0.36]  |
| 5  | p.A.ON.rock.sm    | -0.36*   | 0.17 | 0.03 | [-0.70, -0.03] |
| 6  | p.R.ON.light      | 0.18     | 0.15 | 0.22 | [-0.11, 0.48]  |
| 7  | p.R.ON.rock.sm    | -0.63*** | 0.17 | 0.00 | [-0.96, -0.31] |
| 8  | p.R.ON.litter     | -0.39*** | 0.10 | 0.00 | [-0.57, -0.20] |
| 9  | p.D.ON.light      | -0.01    | 0.16 | 0.94 | [-0.33, 0.31]  |
| 10 | p.D.ON.rock.sm    | -0.44**  | 0.16 | 0.01 | [-0.76, -0.12] |
| 11 | p.X1.ON.light     | 0.11     | 0.18 | 0.56 | [-0.25, 0.46]  |
| 12 | p.X1.ON.rock.sm   | 0.12     | 0.18 | 0.49 | [-0.23, 0.48]  |
| 13 | p.X2.ON.light     | -0.02    | 0.18 | 0.93 | [-0.37, 0.34]  |
| 14 | p.X2.ON.rock.sm   | 0.21     | 0.18 | 0.25 | [-0.14, 0.56]  |
| 15 | p.X3.ON.light     | 0.13     | 0.17 | 0.44 | [-0.20, 0.46]  |
| 16 | p.X3.ON.rock.sm   | 0.35*    | 0.17 | 0.03 | [0.02, 0.68]   |
| 17 | p.A.WITH.p.X2     | -0.50**  | 0.18 | 0.01 | [-0.86, -0.13] |
| 18 | p.A.WITH.p.R      | 0.32*    | 0.15 | 0.03 | [0.03, 0.61]   |
| 19 | p.A.WITH.p.D      | 0.26     | 0.16 | 0.09 | [-0.04, 0.57]  |
| 20 | p.R.WITH.p.D      | 0.63***  | 0.17 | 0.00 | [0.29, 0.97]   |
| 21 | p.A.WITH.p.X1     | -0.50**  | 0.19 | 0.01 | [-0.86, -0.13] |
| 22 | p.R.WITH.p.X1     | -0.13    | 0.15 | 0.36 | [-0.42, 0.15]  |
| 23 | Variances.light   | 0.97***  | 0.25 | 0.00 | [0.48, 1.45]   |
| 24 | Variances.litter  | 0.70***  | 0.18 | 0.00 | [0.35, 1.06]   |
| 25 | Variances.rock.sm | 0.51***  | 0.13 | 0.00 | [0.25, 0.77]   |
| 26 | Variances.p.A     | 0.84***  | 0.22 | 0.00 | [0.42, 1.27]   |
| 27 | Variances.p.R     | 0.67***  | 0.17 | 0.00 | [0.33, 1.00]   |
| 28 | Variances.p.D     | 0.78***  | 0.20 | 0.00 | [0.38, 1.17]   |
| 29 | Variances.p.X1    | 0.94***  | 0.24 | 0.00 | [0.46, 1.41]   |
| 30 | Variances.p.X2    | 0.93***  | 0.24 | 0.00 | [0.46, 1.40]   |
| 31 | Variances.p.X3    | 0.81***  | 0.21 | 0.00 | [0.40, 1.22]   |
| 32 | p.A.WITH.p.X3     | -0.26    | 0.16 | 0.11 | [-0.57, 0.05]  |
| 33 | p.R.WITH.p.X2     | -0.31*   | 0.15 | 0.04 | [-0.61, -0.01] |
| 34 | p.R.WITH.p.X3     | 0.02     | 0.13 | 0.89 | [-0.24, 0.28]  |
| 35 | p.D.WITH.p.X1     | -0.03    | 0.16 | 0.85 | [-0.33, 0.28]  |
| 36 | p.D.WITH.p.X2     | -0.33*   | 0.17 | 0.04 | [-0.66, -0.01] |
| 37 | p.D.WITH.p.X3     | 0.05     | 0.15 | 0.74 | [-0.24, 0.33]  |
| 38 | p.X1.WITH.p.X2    | 0.08     | 0.17 | 0.64 | [-0.25, 0.42]  |
| 39 | p.X1.WITH.p.X3    | -0.10    | 0.16 | 0.55 | [-0.41, 0.22]  |
| 40 | p.X2.WITH.p.X3    | -0.21    | 0.16 | 0.21 | [-0.52, 0.11]  |
| 41 | Variances.crown   | 0.97     | 0.00 |      | [0.97, 0.97]   |

|    | label                  | est_sig  | se   | pval | confint        |
|----|------------------------|----------|------|------|----------------|
| 1  | light.ON.crown         | -0.05    | 0.20 | 0.80 | [-0.45, 0.34]  |
| 2  | litter.ON.crown        | 0.59***  | 0.17 | 0.00 | [0.26, 0.93]   |
| 3  | light.ON.trunk         | 0.03     | 0.20 | 0.87 | [-0.36, 0.43]  |
| 4  | litter.ON.trunk        | -0.17    | 0.17 | 0.31 | [-0.50, 0.16]  |
| 5  | rock.lg.ON.litter      | -0.90*** | 0.08 | 0.00 | [-1.06, -0.75] |
| 6  | l.A.ON.light           | 0.04     | 0.15 | 0.81 | [-0.27, 0.34]  |
| 7  | l.A.ON.rock.lg         | 0.53***  | 0.15 | 0.00 | [0.22, 0.83]   |
| 8  | l.R.ON.light           | 0.17     | 0.11 | 0.14 | [-0.05, 0.39]  |
| 9  | l.R.ON.rock.lg         | 0.74***  | 0.11 | 0.00 | [0.52, 0.96]   |
| 10 | l.D.ON.light           | 0.20     | 0.12 | 0.11 | [-0.04, 0.44]  |
| 11 | l.D.ON.rock.lg         | 0.69***  | 0.12 | 0.00 | [0.45, 0.93]   |
| 12 | rot.l.X1.ON.light      | 0.05     | 0.16 | 0.75 | [-0.26, 0.37]  |
| 13 | rot.l.X1.ON.rock.lg    | 0.46**   | 0.16 | 0.00 | [0.15, 0.78]   |
| 14 | rot.l.X2.ON.light      | 0.17     | 0.18 | 0.33 | [-0.18, 0.53]  |
| 15 | rot.l.X2.ON.rock.lg    | -0.02    | 0.18 | 0.90 | [-0.38, 0.33]  |
| 16 | l.A.WITH.l.R           | 0.23*    | 0.10 | 0.03 | [0.03, 0.43]   |
| 17 | l.A.WITH.l.D           | -0.03    | 0.10 | 0.73 | [-0.23, 0.16]  |
| 18 | l.R.WITH.l.D           | 0.30**   | 0.09 | 0.00 | [0.12, 0.48]   |
| 19 | l.A.WITH.rot.l.X1      | 0.68***  | 0.18 | 0.00 | [0.32, 1.03]   |
| 20 | l.R.WITH.rot.l.X1      | 0.24*    | 0.11 | 0.02 | [0.03, 0.45]   |
| 21 | Variances.light        | 0.96***  | 0.25 | 0.00 | [0.48, 1.45]   |
| 22 | Variances.litter       | 0.68***  | 0.18 | 0.00 | [0.34, 1.03]   |
| 23 | Variances.rock.lg      | 0.18***  | 0.05 | 0.00 | [0.09, 0.27]   |
| 24 | Variances.l.A          | 0.69***  | 0.18 | 0.00 | [0.34, 1.04]   |
| 25 | Variances.l.R          | 0.38***  | 0.10 | 0.00 | [0.19, 0.57]   |
| 26 | Variances.l.D          | 0.43***  | 0.11 | 0.00 | [0.21, 0.65]   |
| 27 | Variances.rot.l.X1     | 0.75***  | 0.19 | 0.00 | [0.37, 1.13]   |
| 28 | Variances.rot.l.X2     | 0.94***  | 0.24 | 0.00 | [0.46, 1.41]   |
| 29 | l.A.WITH.rot.l.X2      | -0.10    | 0.15 | 0.51 | [-0.39, 0.19]  |
| 30 | l.R.WITH.rot.l.X2      | 0.10     | 0.11 | 0.39 | [-0.12, 0.31]  |
| 31 | l.D.WITH.rot.l.X1      | -0.03    | 0.10 | 0.79 | [-0.23, 0.18]  |
| 32 | l.D.WITH.rot.l.X2      | 0.11     | 0.12 | 0.37 | [-0.12, 0.34]  |
| 33 | rot.l.X1.WITH.rot.l.X2 | 0.15     | 0.16 | 0.32 | [-0.15, 0.46]  |
| 34 | Variances.crown        | 0.97     | 0.00 |      | [0.97, 0.97]   |
| 35 | crown.WITH.trunk       | 0.41     | 0.00 |      | [0.41, 0.41]   |
| 36 | Variances.trunk        | 0.97     | 0.00 |      | [0.97, 0.97]   |

|    | label                  | est_sig  | se   | pval | confint        |
|----|------------------------|----------|------|------|----------------|
| 1  | light.ON.crown         | -0.05    | 0.20 | 0.80 | [-0.45, 0.34]  |
| 2  | litter.ON.crown        | 0.59***  | 0.17 | 0.00 | [0.26, 0.93]   |
| 3  | light.ON.trunk         | 0.03     | 0.20 | 0.87 | [-0.36, 0.43]  |
| 4  | litter.ON.trunk        | -0.17    | 0.17 | 0.31 | [-0.50, 0.16]  |
| 5  | rock.sm.ON.litter      | -0.69*** | 0.13 | 0.00 | [-0.95, -0.43] |
| 6  | p.A.ON.light           | 0.02     | 0.17 | 0.89 | [-0.31, 0.36]  |
| 7  | p.A.ON.rock.sm         | -0.36*   | 0.17 | 0.03 | [-0.70, -0.03] |
| 8  | p.R.ON.light           | 0.20     | 0.17 | 0.24 | [-0.13, 0.53]  |
| 9  | p.R.ON.rock.sm         | -0.37*   | 0.17 | 0.03 | [-0.70, -0.04] |
| 10 | p.D.ON.light           | -0.01    | 0.16 | 0.94 | [-0.33, 0.31]  |
| 11 | p.D.ON.rock.sm         | -0.44**  | 0.16 | 0.01 | [-0.76, -0.12] |
| 12 | rot.p.X1.ON.light      | 0.14     | 0.16 | 0.37 | [-0.17, 0.46]  |
| 13 | rot.p.X1.ON.rock.sm    | 0.43**   | 0.16 | 0.01 | [0.12, 0.75]   |
| 14 | rot.p.X2.ON.light      | 0.06     | 0.18 | 0.73 | [-0.29, 0.42]  |
| 15 | rot.p.X2.ON.rock.sm    | -0.01    | 0.18 | 0.94 | [-0.37, 0.34]  |
| 16 | rot.p.X3.ON.light      | 0.07     | 0.18 | 0.70 | [-0.29, 0.43]  |
| 17 | rot.p.X3.ON.rock.sm    | -0.01    | 0.18 | 0.94 | [-0.37, 0.34]  |
| 18 | p.A.WITH.rot.p.X2      | -0.34    | 0.18 | 0.05 | [-0.69, 0.00]  |
| 19 | p.A.WITH.p.R           | 0.36*    | 0.17 | 0.03 | [0.04, 0.69]   |
| 20 | p.A.WITH.p.D           | 0.26     | 0.16 | 0.09 | [-0.04, 0.57]  |
| 21 | p.R.WITH.p.D           | 0.67***  | 0.19 | 0.00 | [0.30, 1.05]   |
| 22 | p.A.WITH.rot.p.X1      | -0.51**  | 0.17 | 0.00 | [-0.85, -0.17] |
| 23 | p.R.WITH.rot.p.X1      | -0.12    | 0.14 | 0.42 | [-0.40, 0.17]  |
| 24 | Variances.light        | 0.96***  | 0.25 | 0.00 | [0.48, 1.45]   |
| 25 | Variances.litter       | 0.68***  | 0.18 | 0.00 | [0.34, 1.03]   |
| 26 | Variances.rock.sm      | 0.51***  | 0.13 | 0.00 | [0.25, 0.77]   |
| 27 | Variances.p.A          | 0.84***  | 0.22 | 0.00 | [0.42, 1.27]   |
| 28 | Variances.p.R          | 0.82***  | 0.21 | 0.00 | [0.41, 1.24]   |
| 29 | Variances.p.D          | 0.78***  | 0.20 | 0.00 | [0.38, 1.17]   |
| 30 | Variances.rot.p.X1     | 0.74***  | 0.19 | 0.00 | [0.37, 1.12]   |
| 31 | Variances.rot.p.X2     | 0.96***  | 0.25 | 0.00 | [0.48, 1.45]   |
| 32 | Variances.rot.p.X3     | 0.96***  | 0.25 | 0.00 | [0.48, 1.45]   |
| 33 | p.A.WITH.rot.p.X3      | 0.30     | 0.17 | 0.08 | [-0.04, 0.64]  |
| 34 | p.R.WITH.rot.p.X2      | -0.13    | 0.16 | 0.42 | [-0.46, 0.19]  |
| 35 | p.R.WITH.rot.p.X3      | 0.31     | 0.17 | 0.07 | [-0.03, 0.65]  |
| 36 | p.D.WITH.rot.p.X1      | -0.07    | 0.14 | 0.63 | [-0.34, 0.20]  |
| 37 | p.D.WITH.rot.p.X2      | -0.01    | 0.16 | 0.96 | [-0.32, 0.30]  |
| 38 | p.D.WITH.rot.p.X3      | 0.30     | 0.17 | 0.07 | [-0.03, 0.63]  |
| 39 | rot.p.X1.WITH.rot.p.X2 | -0.11    | 0.16 | 0.49 | [-0.41, 0.20]  |
| 40 | rot.p.X1.WITH.rot.p.X3 | 0.21     | 0.16 | 0.18 | [-0.10, 0.53]  |
| 41 | rot.p.X2.WITH.rot.p.X3 | -0.18    | 0.18 | 0.31 | [-0.53, 0.17]  |
| 42 | Variances.crown        | 0.97     | 0.00 |      | [0.97, 0.97]   |
| 43 | crown.WITH.trunk       | 0.41     | 0.00 |      | [0.41, 0.41]   |
| 44 | Variances.trunk        | 0.97     | 0.00 |      | [0.97, 0.97]   |

|         | $\chi^2$ | df     | p-value |
|---------|----------|--------|---------|
| Lichens | 18.541   | 13.000 | 0.138   |
| Plants  | 12.147   | 14.000 | 0.595   |

|         | $\chi^2$ | df     | p-value |
|---------|----------|--------|---------|
| Lichens | 26.681   | 19.000 | 0.112   |
| Plants  | 30.762   | 22.000 | 0.101   |