Vertical niches 2.0

Brunno F Oliveira[1]; Brett R Scheffers[2];

May 9, 2017 ***1*** *Department of Wildlife Ecology and Conservation, University of Florida/IFAS, Gainesville, FL 32611, USA.* ***Corresponding author:*** *(brunno.oliveira@me.com)*

Contents

Packages versions:

We used R version 3.3.3 (2017-03-06) and the following packages:

```
##          used (Mb) gc trigger (Mb) max used (Mb)
## Ncells 373459 20.0     592000 31.7   460000 24.6
## Vcells 575161  4.4    1308461 10.0   841783  6.5
```

```
##      picante          ape       raster     maptools        rgeos
##         TRUE         TRUE         TRUE         TRUE         TRUE
##      stringr        rgdal      ggplot2         plyr         grid
##         TRUE         TRUE         TRUE         TRUE         TRUE
##    gridExtra multcompView        caper       geiger     phytools
##         TRUE         TRUE         TRUE         TRUE         TRUE
##        knitr         maps     parallel   doParallel  apTreeshape
##         TRUE         TRUE         TRUE         TRUE         TRUE
##   data.table        ppcor    hier.part     relaimpo         MASS
##         TRUE         TRUE         TRUE         TRUE         TRUE
##      bestglm
##         TRUE
```

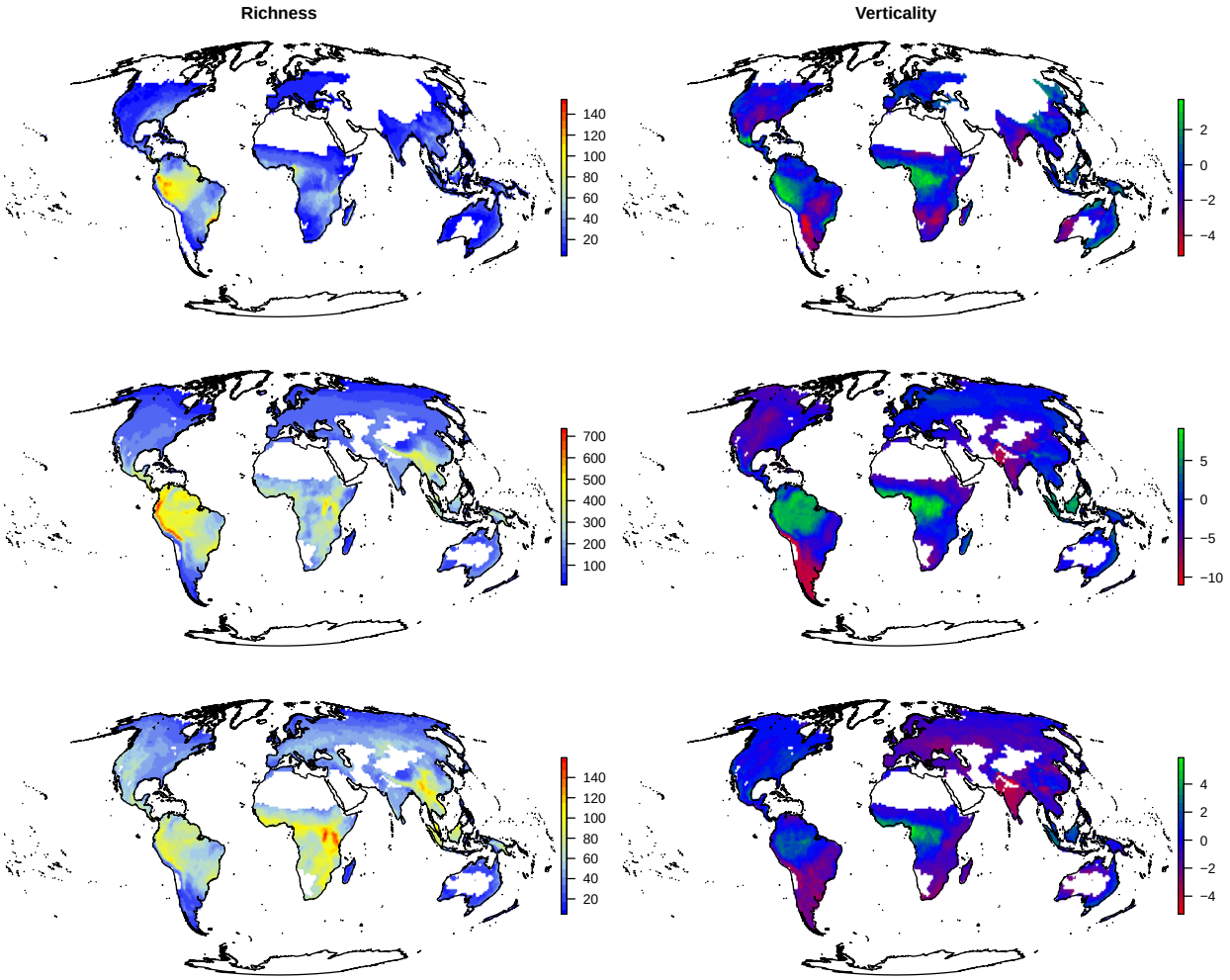
Load community data

```
# birds
birds <- read.csv("Data/birds_comvars.csv")[,-1]
birds.a <- data.frame(birds[,c(1:2)],
                      log(birds[,c(3:5)]+1),birds[,c(6:11)],
                      log(birds[,c(12:17)]+1),
                      birds[,18])
birds.a <- data.frame(birds[,c(1:2)],scale(birds[,c(3:17)]),birds[,18])
names(birds.a) <- names(birds)
# amphibians
amps <- read.csv("Data/amphibians_comvars.csv")[,-1]
amps <- amps[which(amps$Rich>5),]
amps <- data.frame(amps[c(1:49)])
amps$ses.vert <- amps$ses.vert.realm
amps <- amps[,which(names(amps)%in%names(birds))]
amps <- data.frame(amps[,c(1:2)], amps[,c(3,7:10,12:15)],amps[,c(4:6,16,11)])
amps.a <- data.frame(amps[,c(1:2)], log(amps[,c(3:11)]+1),amps[,c(12:16)])
amps.a <- data.frame(amps.a[,c(1:2)],scale(amps.a[,c(3:15)]),amps.a[,16])
names(amps.a) <- names(amps)
# mammals
mammals <- read.csv("Data/mammals_comvars.csv")[,-1]
mammals.a <- data.frame(mammals[,c(1:2)],
                      log(mammals[,c(3:5)]+1),mammals[,c(6:11)],
                      log(mammals[,c(12:17)]+1),
                      mammals[,18])
mammals.a <- data.frame(mammals[,c(1:2)],scale(mammals[,c(3:17)]),mammals[,18])
names(mammals.a) <- names(mammals)
```

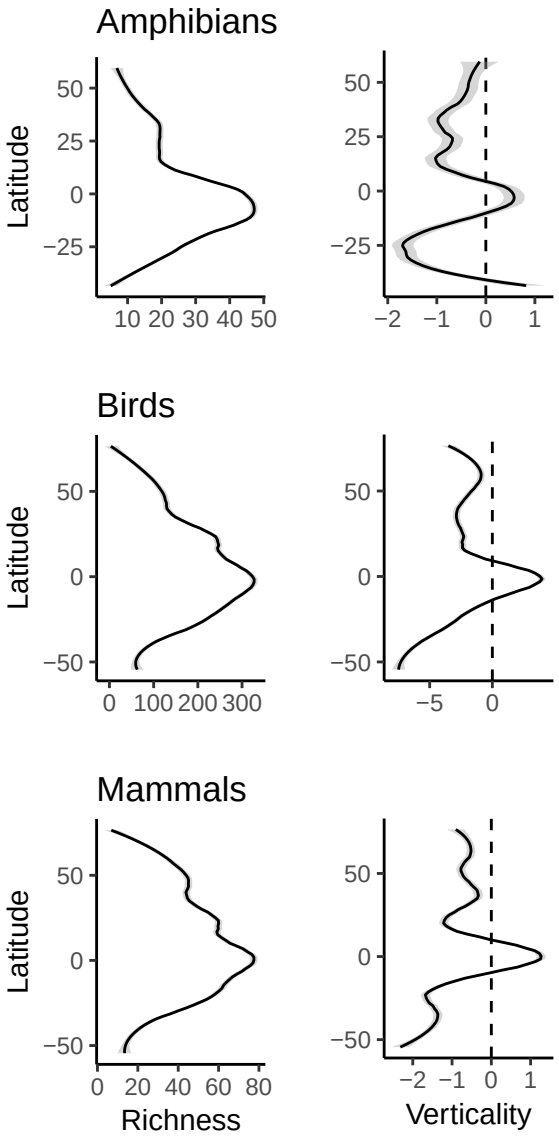
Maps

Maps verticality

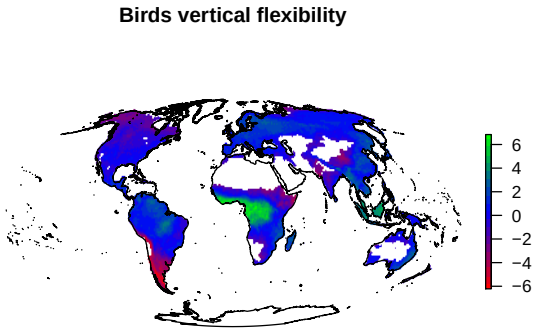
```
par(mfrow=c(3,2),mar=c(0,0,1,0))

# Amphibians
{plot(s.amps$Rich, main='Richness',axes=F,box=F, col=colorRampPalette(c('blue','lightblue','yellow','red
map(mundi,add=T,cex=.5)}
{plot(s.amps$ses.vert, main='Verticality',axes=F,box=F, col=colorRampPalette(c('red','blue','green'))(20
map(mundi,add=T,cex=.5)}

# Birds
{plot(s.birds$Rich, main='',axes=F,box=F, col=colorRampPalette(c('blue','lightblue','yellow','red'))(20)
map(mundi,add=T,cex=.5)}
{plot(s.birds$ses.vert, main='',axes=F,box=F, col=colorRampPalette(c('red','blue','green'))(20))
map(mundi,add=T,cex=.5)}

# Mammals
{plot(s.mammals$Rich, main='',axes=F,box=F, col=colorRampPalette(c('blue','lightblue','yellow','red'))(2
map(mundi,add=T,cex=.5)}
{plot(s.mammals$ses.vert, main='',axes=F,box=F, col=colorRampPalette(c('red','blue','green'))(20))
map(mundi,add=T,cex=.5)}
```

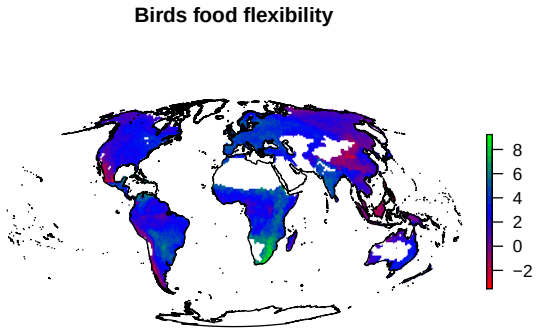

Richness
Verticality
140
120
100
80
60
40
20
2
0
−2
−4
700
600
500
400
300
200
100
5
0
−5
−10
140
120
100
80
60
40
20
4
2
0
−2
−4

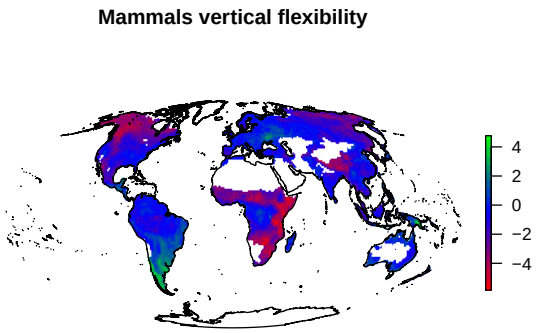
Latitude

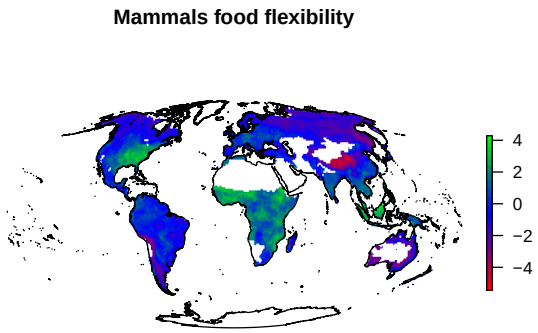

Amphibians
Birds
Mammals
Latitude
50
25
0
−25
10 20 30 40 50
−2 −1 0 1
−50
0 100 200 300
−5 0
0 20 40 60 80
Richness
Verticality

Other metrics









Models

For richness

```
## Amphibians
fit <- glm(Rich ~ ., data = na.omit(amps.a[,-1:-2]))
summary(fit)
```

```
##
## Call:
## glm(formula = Rich ~ ., data = na.omit(amps.a[, -1:-2]))
##
## Deviance Residuals:
##       Min         1Q     Median         3Q        Max
## -2.93548  -0.27527   0.02955   0.31120   1.59048
##
## Coefficients:
```

```
##                       Estimate Std. Error t value Pr(>|t|)
## (Intercept)           0.081764   0.023007   3.554 0.000382 ***
## velocity              0.026285   0.010427   2.521 0.011728 *
## mean.prec             0.402812   0.013426  30.003  < 2e-16 ***
## sea.prec             -0.031778   0.009030  -3.519 0.000436 ***
## veg                   0.163622   0.011860  13.796  < 2e-16 ***
## elev                  0.270856   0.016203  16.717  < 2e-16 ***
## WTemp.cell           -0.174204   0.022688  -7.678 1.84e-14 ***
## range.size.cell      -0.109391   0.012141  -9.010  < 2e-16 ***
## body.cell             0.008846   0.011822   0.748 0.454351
## mean.temp             0.390071   0.017315  22.528  < 2e-16 ***
## sea.temp              0.116050   0.020904   5.552 2.94e-08 ***
## diu.temp             -0.009408   0.011281  -0.834 0.404335
## ses.vert              0.027441   0.007942   3.455 0.000553 ***
## RealmAustralian      -0.416480   0.033906 -12.283  < 2e-16 ***
## RealmMadagascan      -0.690163   0.080244  -8.601  < 2e-16 ***
## RealmNearctic         0.071715   0.044757   1.602 0.109127
## RealmNeotropical      0.372036   0.022219  16.744  < 2e-16 ***
## RealmOceanina        -1.517958   0.063995 -23.720  < 2e-16 ***
## RealmOriental        -0.606926   0.035181 -17.252  < 2e-16 ***
## RealmPalearctic      -0.187134   0.044127  -4.241 2.26e-05 ***
## RealmPanamanian      -0.392249   0.052510  -7.470 9.01e-14 ***
## RealmSaharo-Arabian -0.421753   0.109015  -3.869 0.000110 ***
## RealmSino-Japanese  -0.286669   0.051707  -5.544 3.06e-08 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## (Dispersion parameter for gaussian family taken to be 0.247412)
##
##     Null deviance: 7028.8  on 6867  degrees of freedom
## Residual deviance: 1693.5  on 6845  degrees of freedom
## AIC: 9923
##
## Number of Fisher Scoring iterations: 2
```

```
step <- stepAIC(fit, direction="backward")
```

```
## Start:  AIC=9922.96
## Rich ~ velocity + mean.prec + sea.prec + veg + elev + WTemp.cell +
##     range.size.cell + body.cell + mean.temp + sea.temp + diu.temp +
##     ses.vert + Realm
##
##                   Df Deviance     AIC
## - body.cell        1   1693.7  9921.5
## - diu.temp         1   1693.7  9921.7
## <none>                 1693.5  9923.0
## - velocity         1   1695.1  9927.3
## - ses.vert         1   1696.5  9932.9
## - sea.prec         1   1696.6  9933.4
## - sea.temp         1   1701.2  9951.8
## - WTemp.cell       1   1708.1  9979.9
## - range.size.cell  1   1713.6 10001.9
## - veg              1   1740.6 10109.3
## - elev             1   1762.7 10195.8
## - mean.temp        1   1819.1 10412.2
```

```
## - mean.prec        1   1916.3 10769.5
## - Realm           10   2102.1 11387.4
##
## Step:  AIC=9921.53
## Rich ~ velocity + mean.prec + sea.prec + veg + elev + WTemp.cell +
##     range.size.cell + mean.temp + sea.temp + diu.temp + ses.vert +
##     Realm
##
##                   Df Deviance     AIC
## - diu.temp         1   1693.8  9920.2
## <none>                 1693.7  9921.5
## - velocity         1   1695.2  9925.8
## - ses.vert         1   1696.5  9930.9
## - sea.prec         1   1697.0  9933.1
## - sea.temp         1   1701.2  9950.2
## - WTemp.cell       1   1708.2  9978.3
## - range.size.cell  1   1714.2 10002.1
## - veg              1   1741.1 10109.0
## - elev             1   1762.7 10193.8
## - mean.temp        1   1820.2 10414.2
## - mean.prec        1   1916.6 10768.9
## - Realm           10   2136.1 11495.3
##
## Step:  AIC=9920.25
## Rich ~ velocity + mean.prec + sea.prec + veg + elev + WTemp.cell +
##     range.size.cell + mean.temp + sea.temp + ses.vert + Realm
##
##                   Df Deviance     AIC
## <none>                 1693.8  9920.2
## - velocity         1   1695.9  9926.5
## - ses.vert         1   1696.9  9930.7
## - sea.prec         1   1697.7  9933.8
## - sea.temp         1   1701.3  9948.2
## - WTemp.cell       1   1709.3  9980.8
## - range.size.cell  1   1714.2 10000.1
## - veg              1   1741.3 10108.0
## - elev             1   1764.4 10198.4
## - mean.temp        1   1821.1 10415.9
## - mean.prec        1   1935.2 10832.9
## - Realm           10   2178.8 11629.4
```

```
step$anova # display results
```

```
## Stepwise Model Path
## Analysis of Deviance Table
##
## Initial Model:
## Rich ~ velocity + mean.prec + sea.prec + veg + elev + WTemp.cell +
##     range.size.cell + body.cell + mean.temp + sea.temp + diu.temp +
##     ses.vert + Realm
##
## Final Model:
## Rich ~ velocity + mean.prec + sea.prec + veg + elev + WTemp.cell +
##     range.size.cell + mean.temp + sea.temp + ses.vert + Realm
##
```

```
##
##          Step Df  Deviance Resid. Df Resid. Dev      AIC
## 1                                6845   1693.535 9922.964
## 2 - body.cell  1 0.1385107      6846   1693.674 9921.526
## 3  - diu.temp  1 0.1784845      6847   1693.852 9920.250
```

```
## Birds
fit <- glm(Rich ~ ., data = birds.a[,-1:-2])
summary(fit)
```

```
##
## Call:
## glm(formula = Rich ~ ., data = birds.a[, -1:-2])
##
## Deviance Residuals:
##      Min        1Q    Median        3Q       Max
## -1.84167  -0.19731  -0.00927   0.17336   2.88903
##
## Coefficients:
##                       Estimate Std. Error t value Pr(>|t|)
## (Intercept)           0.002996   0.027635   0.108 0.913671
## WTemp.cell            0.423042   0.030889  13.696  < 2e-16 ***
## body.cell            -0.030233   0.005588  -5.411 6.41e-08 ***
## range.size.cell      -0.948373   0.019997 -47.426  < 2e-16 ***
## ses.vert              0.677432   0.010404  65.116  < 2e-16 ***
## ses.vert.plast       -0.240069   0.008685 -27.643  < 2e-16 ***
## ses.food.plast        0.258363   0.005414  47.725  < 2e-16 ***
## mean.temp            -0.086812   0.013753  -6.312 2.85e-10 ***
## sea.temp             -0.097117   0.012534  -7.748 1.01e-14 ***
## diu.temp              0.064136   0.006284  10.205  < 2e-16 ***
## mean.prec             0.043123   0.008425   5.119 3.13e-07 ***
## sea.prec              0.059984   0.005752  10.428  < 2e-16 ***
## veg                  -0.053066   0.006396  -8.297  < 2e-16 ***
## elev                  0.064182   0.004153  15.454  < 2e-16 ***
## velocity             -0.049966   0.004762 -10.493  < 2e-16 ***
## RealmAustralian      -1.093638   0.025831 -42.338  < 2e-16 ***
## RealmMadagascan      -1.849197   0.057054 -32.411  < 2e-16 ***
## RealmNearctic        -0.190328   0.037498  -5.076 3.92e-07 ***
## RealmNeotropical      0.486198   0.019348  25.129  < 2e-16 ***
## RealmOceanina        -0.176942   0.049985  -3.540 0.000402 ***
## RealmOriental         0.151692   0.029157   5.202 2.00e-07 ***
## RealmPalearctic       0.037791   0.044257   0.854 0.393177
## RealmPanamanian       0.464272   0.040757  11.391  < 2e-16 ***
## RealmSaharo-Arabian -0.107745   0.048069  -2.241 0.025014 *
## RealmSino-Japanese  -0.160679   0.043766  -3.671 0.000242 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## (Dispersion parameter for gaussian family taken to be 0.1494052)
##
##     Null deviance: 11366.0  on 11366  degrees of freedom
## Residual deviance:  1694.6  on 11342  degrees of freedom
## AIC: 10675
##
## Number of Fisher Scoring iterations: 2
```

```
step <- stepAIC(fit, direction="backward")
```

```
## Start:  AIC=10675.39
## Rich ~ WTemp.cell + body.cell + range.size.cell + ses.vert +
##     ses.vert.plast + ses.food.plast + mean.temp + sea.temp +
##     diu.temp + mean.prec + sea.prec + veg + elev + velocity +
##     Realm
##
##                   Df Deviance   AIC
## <none>                 1694.5 10675
## - mean.prec        1   1698.5 10700
## - body.cell        1   1698.9 10703
## - mean.temp        1   1700.5 10713
## - sea.temp         1   1703.5 10733
## - veg              1   1704.8 10742
## - diu.temp         1   1710.1 10777
## - sea.prec         1   1710.8 10782
## - velocity         1   1711.0 10783
## - WTemp.cell       1   1722.6 10860
## - elev             1   1730.2 10910
## - ses.vert.plast   1   1808.7 11414
## - range.size.cell  1   2030.6 12730
## - ses.food.plast   1   2034.8 12754
## - ses.vert         1   2328.0 14284
## - Realm           10   2542.6 15268
```

```
step$anova # display results
```

```
## Stepwise Model Path
## Analysis of Deviance Table
##
## Initial Model:
## Rich ~ WTemp.cell + body.cell + range.size.cell + ses.vert +
##     ses.vert.plast + ses.food.plast + mean.temp + sea.temp +
##     diu.temp + mean.prec + sea.prec + veg + elev + velocity +
##     Realm
##
## Final Model:
## Rich ~ WTemp.cell + body.cell + range.size.cell + ses.vert +
##     ses.vert.plast + ses.food.plast + mean.temp + sea.temp +
##     diu.temp + mean.prec + sea.prec + veg + elev + velocity +
##     Realm
##
##
##   Step Df Deviance Resid. Df Resid. Dev      AIC
## 1                      11342   1694.553 10675.39
```

```
## Mammals
fit <- glm(Rich ~ ., data = mammals.a[,-1:-2])
summary(fit)
```

```
##
## Call:
## glm(formula = Rich ~ ., data = mammals.a[, -1:-2])
##
```

```
## Deviance Residuals:
##     Min       1Q   Median       3Q      Max
## -2.3133  -0.2628  -0.0068   0.2502   3.7287
##
## Coefficients:
##                       Estimate Std. Error t value Pr(>|t|)
## (Intercept)           0.661774   0.031351  21.108  < 2e-16 ***
## WTemp.cell            0.099613   0.032586   3.057  0.00224 **
## body.cell            -0.191216   0.009763 -19.586  < 2e-16 ***
## range.size.cell      -0.867218   0.020203 -42.925  < 2e-16 ***
## ses.vert             -0.051344   0.007977  -6.436 1.27e-10 ***
## ses.vert.plast       -0.260802   0.009538 -27.345  < 2e-16 ***
## ses.food.plast       -0.026706   0.009065  -2.946  0.00322 **
## mean.temp            -0.078696   0.018738  -4.200 2.69e-05 ***
## sea.temp             -0.105804   0.017118  -6.181 6.60e-10 ***
## diu.temp             -0.062925   0.008119  -7.750 9.94e-15 ***
## mean.prec             0.129443   0.011205  11.552  < 2e-16 ***
## sea.prec              0.013525   0.007797   1.735  0.08284 .
## veg                   0.268975   0.007441  36.146  < 2e-16 ***
## elev                  0.099403   0.005591  17.778  < 2e-16 ***
## velocity              0.011230   0.006357   1.766  0.07734 .
## RealmAustralian      -1.615369   0.040654 -39.735  < 2e-16 ***
## RealmMadagascan      -2.920956   0.081377 -35.894  < 2e-16 ***
## RealmNearctic        -0.935597   0.043568 -21.475  < 2e-16 ***
## RealmNeotropical     -0.994753   0.030746 -32.354  < 2e-16 ***
## RealmOceanina        -2.064709   0.067935 -30.392  < 2e-16 ***
## RealmOriental        -0.644743   0.035571 -18.126  < 2e-16 ***
## RealmPalearctic      -0.462422   0.046586  -9.926  < 2e-16 ***
## RealmPanamanian      -0.761809   0.059507 -12.802  < 2e-16 ***
## RealmSaharo-Arabian -0.554883   0.055299 -10.034  < 2e-16 ***
## RealmSino-Japanese  -0.845402   0.047366 -17.848  < 2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## (Dispersion parameter for gaussian family taken to be 0.2695346)
##
##     Null deviance: 11293.0  on 11293  degrees of freedom
## Residual deviance:  3037.4  on 11269  degrees of freedom
## AIC: 17271
##
## Number of Fisher Scoring iterations: 2
```

```
step <- stepAIC(fit, direction="backward")
```

```
## Start:  AIC=17270.86
## Rich ~ WTemp.cell + body.cell + range.size.cell + ses.vert +
##     ses.vert.plast + ses.food.plast + mean.temp + sea.temp +
##     diu.temp + mean.prec + sea.prec + veg + elev + velocity +
##     Realm
##
##                   Df Deviance   AIC
## <none>                 3037.4 17271
## - sea.prec         1   3038.2 17272
## - velocity         1   3038.2 17272
## - ses.food.plast   1   3039.7 17278
```

```
## - WTemp.cell       1   3039.9 17278
## - mean.temp        1   3042.1 17287
## - sea.temp         1   3047.7 17307
## - ses.vert         1   3048.6 17310
## - diu.temp         1   3053.6 17329
## - mean.prec        1   3073.4 17402
## - elev             1   3122.6 17581
## - body.cell        1   3140.8 17647
## - ses.vert.plast   1   3238.9 17994
## - veg              1   3389.5 18508
## - range.size.cell  1   3534.0 18979
## - Realm           10   4187.6 20878
```

```
step$anova # display results
```

```
## Stepwise Model Path
## Analysis of Deviance Table
##
## Initial Model:
## Rich ~ WTemp.cell + body.cell + range.size.cell + ses.vert +
##     ses.vert.plast + ses.food.plast + mean.temp + sea.temp +
##     diu.temp + mean.prec + sea.prec + veg + elev + velocity +
##     Realm
##
## Final Model:
## Rich ~ WTemp.cell + body.cell + range.size.cell + ses.vert +
##     ses.vert.plast + ses.food.plast + mean.temp + sea.temp +
##     diu.temp + mean.prec + sea.prec + veg + elev + velocity +
##     Realm
##
##
##   Step Df Deviance Resid. Df Resid. Dev      AIC
## 1                     11269   3037.385 17270.86
```

For verticality

```
## Amphibians
fit <- glm(ses.vert ~ ., data = na.omit(amps.a[,-1:-2]))
summary(fit)
```

```
##
## Call:
## glm(formula = ses.vert ~ ., data = na.omit(amps.a[, -1:-2]))
##
## Deviance Residuals:
##     Min       1Q   Median       3Q      Max
## -2.7891  -0.4896  -0.0246   0.4784   3.2770
##
## Coefficients:
##                     Estimate Std. Error t value Pr(>|t|)
## (Intercept)         -0.22590    0.03491  -6.471 1.04e-10 ***
## velocity            -0.13901    0.01577  -8.813  < 2e-16 ***
## mean.prec            0.07188    0.02170   3.313 0.000928 ***
## sea.prec             0.06310    0.01372   4.599 4.33e-06 ***
```

```
## veg                  0.37158    0.01772  20.967  < 2e-16 ***
## elev                -0.10044    0.02511  -4.001 6.38e-05 ***
## Rich                 0.06345    0.01836   3.455 0.000553 ***
## WTemp.cell          -0.36689    0.03436 -10.677  < 2e-16 ***
## range.size.cell      0.06354    0.01856   3.424 0.000620 ***
## body.cell           -0.27416    0.01767 -15.516  < 2e-16 ***
## mean.temp           -0.13030    0.02724  -4.783 1.76e-06 ***
## sea.temp             0.02176    0.03186   0.683 0.494622
## diu.temp            -0.19730    0.01699 -11.614  < 2e-16 ***
## RealmAustralian      0.63283    0.05156  12.274  < 2e-16 ***
## RealmMadagascan     -0.72685    0.12236  -5.940 2.99e-09 ***
## RealmNearctic        0.85451    0.06728  12.701  < 2e-16 ***
## RealmNeotropical    -0.45409    0.03403 -13.344  < 2e-16 ***
## RealmOceanina       -0.41317    0.10111  -4.087 4.43e-05 ***
## RealmOriental       -0.12801    0.05462  -2.344 0.019131 *
## RealmPalearctic      0.90018    0.06630  13.577  < 2e-16 ***
## RealmPanamanian     -0.17143    0.08014  -2.139 0.032470 *
## RealmSaharo-Arabian  0.79948    0.16567   4.826 1.42e-06 ***
## RealmSino-Japanese   0.49486    0.07857   6.298 3.20e-10 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## (Dispersion parameter for gaussian family taken to be 0.5720587)
##
##     Null deviance: 6867.0  on 6867  degrees of freedom
## Residual deviance: 3915.7  on 6845  degrees of freedom
## AIC: 15680
##
## Number of Fisher Scoring iterations: 2
```

```
step <- stepAIC(fit, direction="backward")
```

```
## Start:  AIC=15679.63
## ses.vert ~ velocity + mean.prec + sea.prec + veg + elev + Rich +
##     WTemp.cell + range.size.cell + body.cell + mean.temp + sea.temp +
##     diu.temp + Realm
##
##                   Df Deviance   AIC
## - sea.temp         1   3916.0 15678
## <none>                 3915.7 15680
## - mean.prec        1   3922.0 15689
## - range.size.cell  1   3922.4 15689
## - Rich             1   3922.6 15690
## - elev             1   3924.9 15694
## - sea.prec         1   3927.8 15699
## - mean.temp        1   3928.8 15700
## - velocity         1   3960.2 15755
## - WTemp.cell       1   3981.0 15791
## - diu.temp         1   3992.9 15812
## - body.cell        1   4053.5 15915
## - veg              1   4167.2 16105
## - Realm           10   4393.2 16450
##
## Step:  AIC=15678.1
## ses.vert ~ velocity + mean.prec + sea.prec + veg + elev + Rich +
```

```
##     WTemp.cell + range.size.cell + body.cell + mean.temp + diu.temp +
##     Realm
##
##                   Df Deviance   AIC
## <none>                 3916.0 15678
## - mean.prec         1   3922.1 15687
## - range.size.cell   1   3922.8 15688
## - Rich              1   3923.1 15688
## - elev              1   3925.2 15692
## - sea.prec          1   3928.9 15699
## - mean.temp         1   3938.5 15715
## - velocity          1   3969.5 15769
## - WTemp.cell        1   3984.2 15795
## - diu.temp          1   3993.1 15810
## - body.cell         1   4054.3 15914
## - veg               1   4167.6 16104
## - Realm            10   4400.6 16459
```

```
step$anova # display results
```

```
## Stepwise Model Path
## Analysis of Deviance Table
##
## Initial Model:
## ses.vert ~ velocity + mean.prec + sea.prec + veg + elev + Rich +
##     WTemp.cell + range.size.cell + body.cell + mean.temp + sea.temp +
##     diu.temp + Realm
##
## Final Model:
## ses.vert ~ velocity + mean.prec + sea.prec + veg + elev + Rich +
##     WTemp.cell + range.size.cell + body.cell + mean.temp + diu.temp +
##     Realm
##
##
##         Step Df  Deviance Resid. Df Resid. Dev      AIC
## 1                               6845   3915.742 15679.63
## 2 - sea.temp  1 0.2668695      6846   3916.009 15678.10
```

```
## Birds
fit <- glm(ses.vert ~ ., data = birds.a[,-1:-2])
summary(fit)
```

```
##
## Call:
## glm(formula = ses.vert ~ ., data = birds.a[, -1:-2])
##
## Deviance Residuals:
##      Min        1Q    Median        3Q       Max
## -1.80336  -0.17273   0.00219   0.17643   1.66615
##
## Coefficients:
##                      Estimate Std. Error t value Pr(>|t|)
## (Intercept)         -0.188808   0.021206  -8.904  < 2e-16 ***
## WTemp.cell          -0.795026   0.022790 -34.886  < 2e-16 ***
## body.cell           -0.020619   0.004304  -4.791 1.68e-06 ***
```

```
## range.size.cell      0.841337   0.014890  56.503  < 2e-16 ***
## ses.vert.plast       0.463147   0.005369  86.268  < 2e-16 ***
## ses.food.plast      -0.213874   0.004103 -52.127  < 2e-16 ***
## mean.temp            0.064276   0.010592   6.068 1.33e-09 ***
## sea.temp             0.075183   0.009652   7.790 7.30e-15 ***
## diu.temp            -0.088919   0.004789 -18.567  < 2e-16 ***
## mean.prec            0.136755   0.006366  21.481  < 2e-16 ***
## sea.prec             0.060585   0.004414  13.726  < 2e-16 ***
## veg                  0.239916   0.004396  54.570  < 2e-16 ***
## elev                -0.018413   0.003227  -5.706 1.18e-08 ***
## velocity             0.043360   0.003662  11.841  < 2e-16 ***
## Rich                 0.401679   0.006169  65.116  < 2e-16 ***
## RealmAustralian      0.759716   0.020181  37.644  < 2e-16 ***
## RealmMadagascan      0.580167   0.045599  12.723  < 2e-16 ***
## RealmNearctic        0.298747   0.028771  10.384  < 2e-16 ***
## RealmNeotropical    -0.292700   0.015059 -19.437  < 2e-16 ***
## RealmOceanina       -0.720128   0.037913 -18.994  < 2e-16 ***
## RealmOriental       -0.256357   0.022350 -11.470  < 2e-16 ***
## RealmPalearctic      0.388596   0.033884  11.468  < 2e-16 ***
## RealmPanamanian     -0.517188   0.031187 -16.583  < 2e-16 ***
## RealmSaharo-Arabian  0.545435   0.036666  14.876  < 2e-16 ***
## RealmSino-Japanese   0.253740   0.033637   7.543 4.93e-14 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## (Dispersion parameter for gaussian family taken to be 0.08858892)
##
##     Null deviance: 11366.0  on 11366  degrees of freedom
## Residual deviance:  1004.8  on 11342  degrees of freedom
## AIC: 4734.4
##
## Number of Fisher Scoring iterations: 2
```

```
step <- stepAIC(fit, direction="backward")
```

```
## Start:  AIC=4734.37
## ses.vert ~ WTemp.cell + body.cell + range.size.cell + ses.vert.plast +
##     ses.food.plast + mean.temp + sea.temp + diu.temp + mean.prec +
##     sea.prec + veg + elev + velocity + Rich + Realm
##
##                   Df Deviance     AIC
## <none>                 1004.8  4734.4
## - body.cell        1   1006.8  4755.3
## - elev             1   1007.7  4765.0
## - mean.temp        1   1008.0  4769.2
## - sea.temp         1   1010.1  4793.0
## - velocity         1   1017.2  4872.0
## - sea.prec         1   1021.5  4919.6
## - diu.temp         1   1035.3  5072.7
## - mean.prec        1   1045.7  5185.6
## - WTemp.cell       1   1112.6  5891.0
## - ses.food.plast   1   1245.5  7173.6
## - veg              1   1268.6  7382.4
## - range.size.cell  1   1287.6  7551.6
## - Realm           10   1332.2  7921.0
```

```
## - Rich             1   1380.4  8342.6
## - ses.vert.plast   1   1664.1 10467.0
```

```
step$anova # display results
```

```
## Stepwise Model Path
## Analysis of Deviance Table
##
## Initial Model:
## ses.vert ~ WTemp.cell + body.cell + range.size.cell + ses.vert.plast +
##     ses.food.plast + mean.temp + sea.temp + diu.temp + mean.prec +
##     sea.prec + veg + elev + velocity + Rich + Realm
##
## Final Model:
## ses.vert ~ WTemp.cell + body.cell + range.size.cell + ses.vert.plast +
##     ses.food.plast + mean.temp + sea.temp + diu.temp + mean.prec +
##     sea.prec + veg + elev + velocity + Rich + Realm
##
##
##   Step Df Deviance Resid. Df Resid. Dev      AIC
## 1                     11342   1004.775 4734.371
```

```
## Mammals
fit <- glm(ses.vert ~ ., data = mammals.a[,-1:-2])
summary(fit)
```

```
##
## Call:
## glm(formula = ses.vert ~ ., data = mammals.a[, -1:-2])
##
## Deviance Residuals:
##     Min       1Q   Median       3Q      Max
## -2.7681  -0.3635  -0.0031   0.3369   3.4985
##
## Coefficients:
##                     Estimate Std. Error t value Pr(>|t|)
## (Intercept)         -0.474464   0.037412 -12.682  < 2e-16 ***
## WTemp.cell          -1.224313   0.036654 -33.402  < 2e-16 ***
## body.cell           -0.002838   0.011702  -0.242    0.808
## range.size.cell      0.178916   0.025632   6.980 3.11e-12 ***
## ses.vert.plast      -0.140135   0.011534 -12.150  < 2e-16 ***
## ses.food.plast       0.054172   0.010677   5.074 3.96e-07 ***
## mean.temp           -0.280354   0.021945 -12.775  < 2e-16 ***
## sea.temp             0.234794   0.020090  11.687  < 2e-16 ***
## diu.temp            -0.078190   0.009567  -8.173 3.33e-16 ***
## mean.prec            0.341520   0.012891  26.493  < 2e-16 ***
## sea.prec             0.011640   0.009191   1.266    0.205
## veg                  0.314932   0.008778  35.877  < 2e-16 ***
## elev                -0.036286   0.006674  -5.437 5.53e-08 ***
## velocity            -0.002357   0.007494  -0.315    0.753
## Rich                -0.071337   0.011083  -6.436 1.27e-10 ***
## RealmAustralian      0.417023   0.051016   8.174 3.29e-16 ***
## RealmMadagascan     -1.962856   0.099554 -19.716  < 2e-16 ***
## RealmNearctic        1.605948   0.050163  32.015  < 2e-16 ***
## RealmNeotropical    -0.914925   0.036894 -24.799  < 2e-16 ***
```

```
## RealmOceanina       -1.890655   0.081368 -23.236  < 2e-16 ***
## RealmOriental       -0.659691   0.042079 -15.677  < 2e-16 ***
## RealmPalearctic      0.747974   0.054700  13.674  < 2e-16 ***
## RealmPanamanian     -0.290908   0.070598  -4.121 3.81e-05 ***
## RealmSaharo-Arabian  1.481635   0.063968  23.162  < 2e-16 ***
## RealmSino-Japanese   0.557430   0.056372   9.888  < 2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## (Dispersion parameter for gaussian family taken to be 0.3744917)
##
##     Null deviance: 11293.0  on 11293  degrees of freedom
## Residual deviance:  4220.1  on 11269  degrees of freedom
## AIC: 20985
##
## Number of Fisher Scoring iterations: 2
```

```
step <- stepAIC(fit, direction="backward")
```

```
## Start:  AIC=20985.15
## ses.vert ~ WTemp.cell + body.cell + range.size.cell + ses.vert.plast +
##     ses.food.plast + mean.temp + sea.temp + diu.temp + mean.prec +
##     sea.prec + veg + elev + velocity + Rich + Realm
##
##                   Df Deviance   AIC
## - body.cell        1   4220.2 20983
## - velocity         1   4220.2 20983
## - sea.prec         1   4220.7 20985
## <none>                 4220.1 20985
## - ses.food.plast   1   4229.8 21009
## - elev             1   4231.2 21013
## - Rich             1   4235.7 21025
## - range.size.cell  1   4238.4 21032
## - diu.temp         1   4245.2 21050
## - sea.temp         1   4271.3 21119
## - ses.vert.plast   1   4275.4 21130
## - mean.temp        1   4281.3 21146
## - mean.prec        1   4483.0 21666
## - WTemp.cell       1   4638.0 22049
## - veg              1   4702.2 22205
## - Realm           10   6112.6 25149
##
## Step:  AIC=20983.21
## ses.vert ~ WTemp.cell + range.size.cell + ses.vert.plast + ses.food.plast +
##     mean.temp + sea.temp + diu.temp + mean.prec + sea.prec +
##     veg + elev + velocity + Rich + Realm
##
##                   Df Deviance   AIC
## - velocity         1   4220.2 20981
## - sea.prec         1   4220.8 20983
## <none>                 4220.2 20983
## - ses.food.plast   1   4229.8 21007
## - elev             1   4231.5 21012
## - Rich             1   4236.0 21024
## - range.size.cell  1   4238.4 21030
```

```
## - diu.temp         1   4245.2 21048
## - sea.temp         1   4272.0 21119
## - mean.temp        1   4281.3 21144
## - ses.vert.plast   1   4303.0 21201
## - mean.prec        1   4484.5 21667
## - WTemp.cell       1   4638.0 22047
## - veg              1   4704.6 22209
## - Realm           10   6202.7 25313
##
## Step:  AIC=20981.31
## ses.vert ~ WTemp.cell + range.size.cell + ses.vert.plast + ses.food.plast +
##     mean.temp + sea.temp + diu.temp + mean.prec + sea.prec +
##     veg + elev + Rich + Realm
##
##                   Df Deviance   AIC
## - sea.prec         1   4220.8 20981
## <none>                 4220.2 20981
## - ses.food.plast   1   4229.8 21005
## - elev             1   4231.7 21010
## - Rich             1   4236.1 21022
## - range.size.cell  1   4238.5 21028
## - diu.temp         1   4245.4 21047
## - sea.temp         1   4273.4 21121
## - mean.temp        1   4286.0 21154
## - ses.vert.plast   1   4305.9 21206
## - mean.prec        1   4484.6 21666
## - WTemp.cell       1   4639.6 22049
## - veg              1   4708.7 22216
## - Realm           10   6323.1 25528
##
## Step:  AIC=20980.98
## ses.vert ~ WTemp.cell + range.size.cell + ses.vert.plast + ses.food.plast +
##     mean.temp + sea.temp + diu.temp + mean.prec + veg + elev +
##     Rich + Realm
##
##                   Df Deviance   AIC
## <none>                 4220.8 20981
## - ses.food.plast   1   4229.9 21003
## - elev             1   4233.0 21012
## - Rich             1   4236.7 21021
## - range.size.cell  1   4238.7 21027
## - diu.temp         1   4246.2 21047
## - sea.temp         1   4277.9 21131
## - mean.temp        1   4287.9 21157
## - ses.vert.plast   1   4321.3 21245
## - mean.prec        1   4484.7 21664
## - WTemp.cell       1   4643.1 22056
## - veg              1   4713.8 22227
## - Realm           10   6739.2 26246
```

```
step$anova # display results
```

```
## Stepwise Model Path
## Analysis of Deviance Table
##
```

```
## Initial Model:
## ses.vert ~ WTemp.cell + body.cell + range.size.cell + ses.vert.plast +
##     ses.food.plast + mean.temp + sea.temp + diu.temp + mean.prec +
##     sea.prec + veg + elev + velocity + Rich + Realm
##
## Final Model:
## ses.vert ~ WTemp.cell + range.size.cell + ses.vert.plast + ses.food.plast +
##     mean.temp + sea.temp + diu.temp + mean.prec + veg + elev +
##     Rich + Realm
##
##
##          Step Df   Deviance Resid. Df Resid. Dev      AIC
## 1                                11269   4220.147 20985.15
## 2 - body.cell  1 0.02201893     11270   4220.169 20983.21
## 3  - velocity  1 0.03667512     11271   4220.206 20981.31
## 4  - sea.prec  1 0.62401441     11272   4220.830 20980.98
```

Hierarchical Partitioning

calc.relimp calculates several relative importance metrics for the linear model.

For richness

```
## Amphibians
limod <- lm(Rich ~ ., amps.a[,-1:-2])
metrics <- calc.relimp(limod, type = "lmg", rela = T)
as.matrix(100*metrics$lmg[order(100*metrics$lmg, decreasing = T)])
```

```
##                       [,1]
## Realm           21.4773923
## mean.prec       19.8239150
## WTemp.cell      14.3844439
## veg             11.7318349
## sea.temp        11.3089215
## mean.temp       10.1259373
## elev             2.3491800
## ses.vert         1.7677771
## body.cell        1.6853433
## diu.temp         1.6788406
## range.size.cell  1.4915522
## velocity         1.4860156
## sea.prec         0.6888463
```

```
## Birds
limod <- lm(Rich ~ ., birds.a[,-1:-2])
metrics <- calc.relimp(limod, type = "lmg", rela = T)
as.matrix(100*metrics$lmg[order(100*metrics$lmg, decreasing = T)])
```

```
##                       [,1]
## Realm           19.9828880
## range.size.cell 12.5464289
## WTemp.cell      10.7163621
```

```
## mean.temp       10.3295253
## sea.temp         9.6315880
## mean.prec        9.2379318
## ses.vert         9.2163741
## veg              5.2015365
## ses.vert.plast   3.6292353
## ses.food.plast   3.1881093
## velocity         1.5048875
## sea.prec         1.4345027
## elev             1.3347295
## diu.temp         1.2702856
## body.cell        0.7756153
```

```
## Mammals
limod <- lm(Rich ~ ., mammals.a[,-1:-2])
metrics <- calc.relimp(limod, type = "lmg", rela = T)
as.matrix(100*metrics$lmg[order(100*metrics$lmg, decreasing = T)])
```

```
##                      [,1]
## Realm           24.876115
## range.size.cell 15.442807
## veg              9.990887
## WTemp.cell       8.339483
## mean.temp        7.466124
## sea.temp         6.891017
## ses.food.plast   6.241111
## mean.prec        5.793924
## body.cell        3.357995
## elev             3.335052
## ses.vert.plast   2.933964
## ses.vert         1.380126
## velocity         1.368338
## diu.temp         1.292688
## sea.prec         1.290368
```

For verticality

```
## Amphibians
limod <- lm(ses.vert ~ ., amps.a[,-1:-2])
metrics <- calc.relimp(limod, type = "lmg", rela = T)
as.matrix(100*metrics$lmg[order(100*metrics$lmg, decreasing = T)])
```

```
##                      [,1]
## veg             25.160276
## Realm           20.848356
## diu.temp        12.143747
## mean.prec        9.779868
## WTemp.cell       6.220068
## body.cell        5.857209
## Rich             4.202255
## mean.temp        3.798613
## velocity         3.649180
## sea.prec         2.591421
## range.size.cell  2.204848
```

```
## sea.temp         2.103539
## elev             1.440619
```

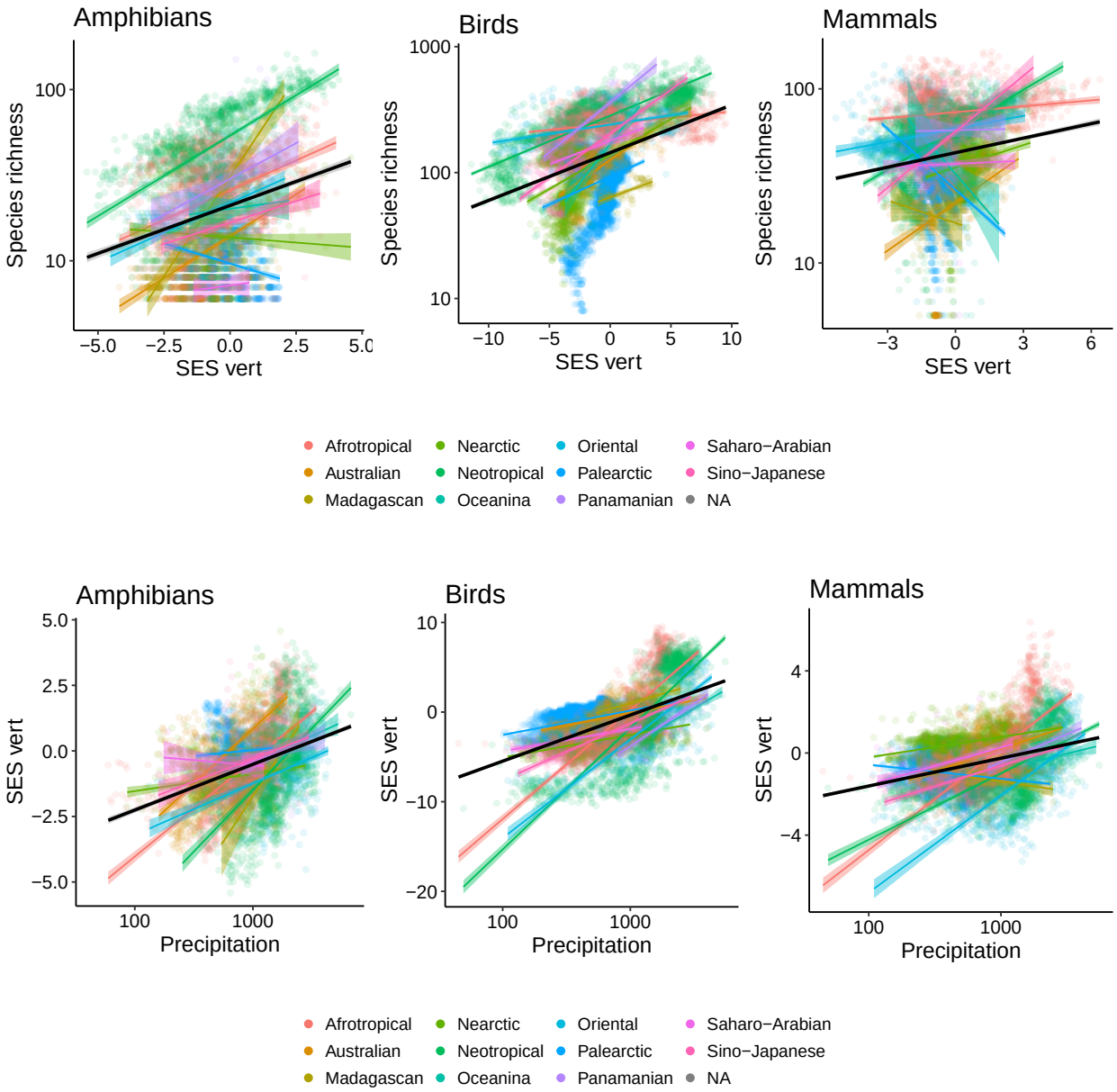
```
## Birds
limod <- lm(ses.vert ~ ., birds.a[,-1:-2])
metrics <- calc.relimp(limod, type = "lmg", rela = T)
as.matrix(100*metrics$lmg[order(100*metrics$lmg, decreasing = T)])
```

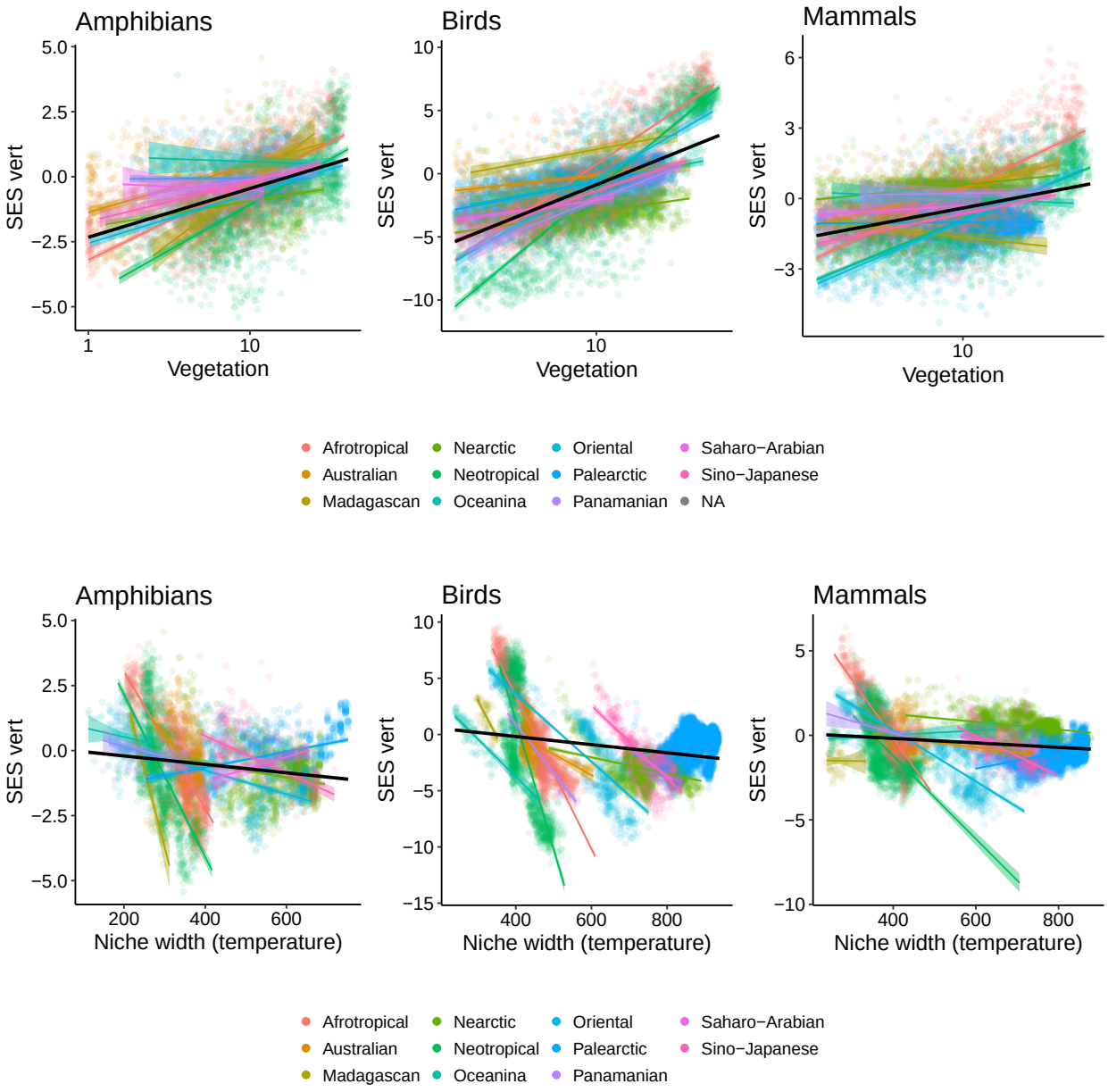
```
##                      [,1]
## ses.vert.plast  30.4048072
## veg             17.2247675
## Realm           11.9924505
## Rich             9.4889454
## mean.prec        9.3918452
## diu.temp         4.0337895
## body.cell        4.0136917
## WTemp.cell       3.4924206
## range.size.cell  3.3561556
## ses.food.plast   2.2164929
## mean.temp        1.5132580
## sea.temp         1.2101981
## sea.prec         1.0634770
## velocity         0.3525302
## elev             0.2451706
```

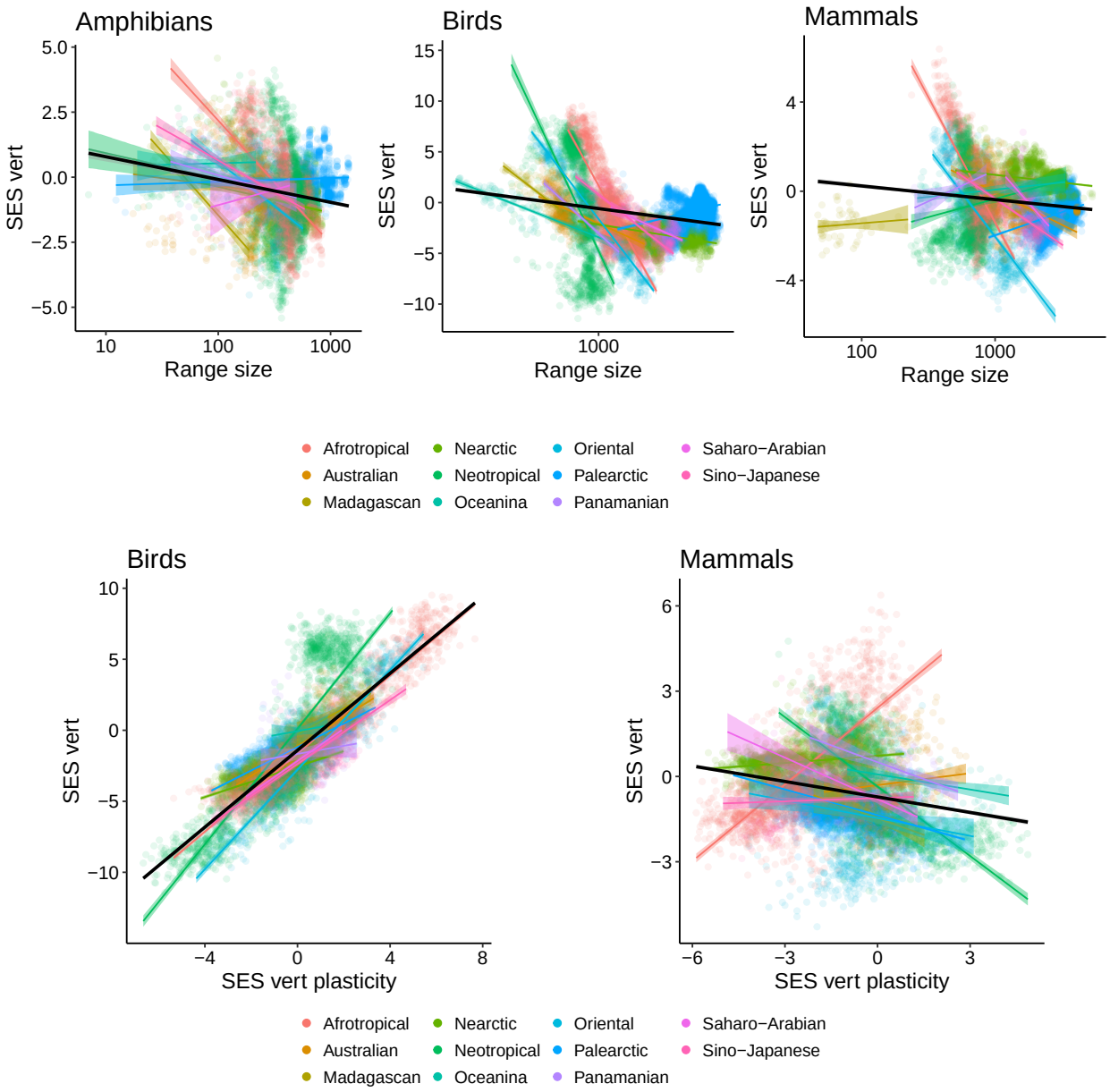
```
## Mammals
limod <- lm(ses.vert ~ ., mammals.a[,-1:-2])
metrics <- calc.relimp(limod, type = "lmg", rela = T)
as.matrix(100*metrics$lmg[order(100*metrics$lmg, decreasing = T)])
```

```
##                      [,1]
## Realm           35.5069868
## veg             17.6865763
## mean.prec       12.2922099
## ses.vert.plast   7.5510296
## WTemp.cell       6.3543712
## sea.prec         4.6607912
## ses.food.plast   4.1086283
## mean.temp        2.0352553
## Rich             1.9975036
## diu.temp         1.5817686
## velocity         1.5195393
## range.size.cell  1.5146348
## sea.temp         1.5017420
## body.cell        1.1404892
## elev             0.5484738
```

Plot correlations




Amphibians
Birds
Mammals
SES vert
Vegetation
Niche width (temperature)
Afrotropical
Australian
Madagascan
Nearctic
Neotropical
Oceanina
Oriental
Palearctic
Panamanian
Saharo−Arabian
Sino−Japanese
NA


Amphibians
Birds
Mammals
SES vert
Range size
Afrotropical
Australian
Madagascan
Nearctic
Neotropical
Oceanina
Oriental
Palearctic
Panamanian
Saharo−Arabian
Sino−Japanese
Birds
Mammals
SES vert plasticity