Extracting Information from Regression Objects

Quantitative Analysis of Vertebrate Populations

Get the data

```
sally <- read.table("Data/Salamander_Demographics.csv", header = TRUE, stringsAsFactors = FALSE, sep =
str(sally)
```

```
## 'data.frame':    3382 obs. of  20 variables:
##  $ line  : int  1861 1115 360 2897 1432 372 231 2739 2236 543 ...
##  $ page  : int  60 36 12 92 46 12 8 87 72 17 ...
##  $ dates : chr  "4/21/09" "9/9/08" "5/31/08" "5/7/11" ...
##  $ month : int  4 9 5 5 10 5 5 10 5 6 ...
##  $ day   : int  21 9 31 7 16 31 27 24 14 5 ...
##  $ year  : int  2009 2008 2008 2011 2008 2008 2008 2009 2009 2008 ...
##  $ time  : chr  "N" "N" "N" "N" ...
##  $ plot  : chr  "5" NA "3" "7" ...
##  $ mass  : num  0.427 0.633 0.639 0.921 0.943 ...
##  $ svl   : int  33 37 42 43 45 46 47 48 NA NA ...
##  $ tl    : int  63 68 63 79 74 NA 75 89 87 NA ...
##  $ sex   : chr  NA NA NA NA ...
##  $ gravid: chr  "N" "N" "N" "N" ...
##  $ group : chr  NA NA NA NA ...
##  $ clutch: int  NA NA NA NA NA NA NA NA NA NA ...
##  $ color : chr  "R" "R" "R" "R" ...
##  $ recap : chr  NA NA NA "N" ...
##  $ mark  : chr  NA NA NA NA ...
##  $ id    : int  1371 NA 187 2154 1042 198 74 2036 1564 351 ...
##  $ damage: chr  "N" "N" "Y" "N" ...
```

Run a regression

Using the Salamander Demographic Data run a regression of the affect of svl on mass

```
library(lme4)
```

```
## Loading required package: Matrix
```

```
lme1 <- lmer(mass ~ 1 + svl + (1 | plot), data = sally)
summary(lme1)
```

```
## Linear mixed model fit by REML ['lmerMod']
## Formula: mass ~ 1 + svl + (1 | plot)
##    Data: sally
##
## REML criterion at convergence: -4875.6
##
## Scaled residuals:
##     Min      1Q  Median      3Q     Max
## -3.5969 -0.6518 -0.1338  0.5545  5.9471
##
## Random effects:
```

```
##   Groups   Name         Variance  Std.Dev.
##   plot     (Intercept) 7.475e-05 0.008646
##   Residual             1.367e-02 0.116939
## Number of obs: 3373, groups:  plot, 12
##
## Fixed effects:
##                Estimate Std. Error t value
## (Intercept) -0.7566013  0.0127085  -59.54
## svl          0.0384600  0.0003156  121.88
##
## Correlation of Fixed Effects:
##     (Intr)
## svl -0.949
```

Examine object and summary object

```
str(lme1)
```

```
## Formal class 'lmerMod' [package "lme4"] with 13 slots
##   ..@ resp   :Reference class 'lmerResp' [package "lme4"] with 9 fields
##   .. ..$ Ptr    :<externalptr>
##   .. ..$ mu     : num [1:3373] 0.512 0.858 0.911 0.968 1.045 ...
##   .. ..$ offset : num [1:3373] 0 0 0 0 0 0 0 0 0 0 ...
##   .. ..$ sqrtXwt: num [1:3373] 1 1 1 1 1 1 1 1 1 1 ...
##   .. ..$ sqrtrwt: num [1:3373] 1 1 1 1 1 1 1 1 1 1 ...
##   .. ..$ weights: num [1:3373] 1 1 1 1 1 1 1 1 1 1 ...
##   .. ..$ wtres  : num [1:3373] -0.0851 -0.2188 0.0104 -0.0252 0.0279 ...
##   .. ..$ y      : num [1:3373] 0.427 0.639 0.921 0.943 1.073 ...
##   .. ..$ REML   : int 2
##   .. ..and 28 methods, of which 14 are  possibly relevant:
##   .. ..   allInfo, copy#envRefClass, initialize, initialize#lmResp,
##   .. ..   initializePtr, initializePtr#lmResp, objective, ptr, ptr#lmResp,
##   .. ..   setOffset, setResp, setWeights, updateMu, wrss
##   ..@ Gp     : int [1:2] 0 12
##   ..@ call   : language lmer(formula = mass ~ 1 + svl + (1 | plot), data = sally)
##   ..@ frame  :'data.frame':  3373 obs. of  3 variables:
##   .. ..$ mass: num [1:3373] 0.427 0.639 0.921 0.943 1.073 ...
##   .. ..$ svl : int [1:3373] 33 42 43 45 47 48 32 32 33 33 ...
##   .. ..$ plot: Factor w/ 12 levels "1","3","4","5",..: 4 2 5 7 7 9 3 4 4 4 ...
##   .. ..- attr(*, "terms")=Classes 'terms', 'formula'  language mass ~ 1 + svl + (1 + plot)
##   .. .. .. ..- attr(*, "variables")= language list(mass, svl, plot)
##   .. .. .. ..- attr(*, "factors")= int [1:3, 1:2] 0 1 0 0 0 1
##   .. .. .. .. ..- attr(*, "dimnames")=List of 2
##   .. .. .. .. .. ..$ : chr [1:3] "mass" "svl" "plot"
##   .. .. .. .. .. ..$ : chr [1:2] "svl" "plot"
##   .. .. .. ..- attr(*, "term.labels")= chr [1:2] "svl" "plot"
##   .. .. .. ..- attr(*, "order")= int [1:2] 1 1
##   .. .. .. ..- attr(*, "intercept")= int 1
##   .. .. .. ..- attr(*, "response")= int 1
##   .. .. .. ..- attr(*, ".Environment")=<environment: R_GlobalEnv>
##   .. .. .. ..- attr(*, "predvars")= language list(mass, svl, plot)
##   .. .. .. ..- attr(*, "dataClasses")= Named chr [1:3] "numeric" "numeric" "character"
##   .. .. .. .. ..- attr(*, "names")= chr [1:3] "mass" "svl" "plot"
```

```
##     .. .. .. ..- attr(*, "predvars.fixed")= language list(mass, svl)
##     .. .. .. ..- attr(*, "predvars.random")= language list(mass, plot)
##     .. ..- attr(*, "na.action")=Class 'omit'  Named int [1:9] 2 6 9 10 370 876 970 1059 1184
##     .. .. .. ..- attr(*, "names")= chr [1:9] "2" "6" "9" "10" ...
##     .. ..- attr(*, "formula")=Class 'formula'  language mass ~ 1 + svl + (1 | plot)
##     .. .. .. ..- attr(*, ".Environment")=<environment: R_GlobalEnv>
##     ..@ flist  :List of 1
##     .. ..$ plot: Factor w/ 12 levels "1","3","4","5",..: 4 2 5 7 7 9 3 4 4 4 ...
##     .. ..- attr(*, "assign")= int 1
##     ..@ cnms   :List of 1
##     .. ..$ plot: chr "(Intercept)"
##     ..@ lower  : num 0
##     ..@ theta  : num 0.0739
##     ..@ beta   : num [1:2] -0.7566 0.0385
##     ..@ u      : num [1:12] -0.00605 -0.01184 -0.0346 -0.00715 0.18186 ...
##     ..@ devcomp:List of 2
##     .. ..$ cmp : Named num [1:10] 8.3661 18.5757 46.0437 0.0542 46.0979 ...
##     .. .. ..- attr(*, "names")= chr [1:10] "ldL2" "ldRX2" "wrss" "ussq" ...
##     .. ..$ dims: Named int [1:12] 3373 3373 2 3371 12 1 1 1 0 2 ...
##     .. .. ..- attr(*, "names")= chr [1:12] "N" "n" "p" "nmp" ...
##     ..@ pp     :Reference class 'merPredD' [package "lme4"] with 18 fields
##     .. ..$ Lambdat:Formal class 'dgCMatrix' [package "Matrix"] with 6 slots
##     .. .. .. ..@ i       : int [1:12] 0 1 2 3 4 5 6 7 8 9 ...
##     .. .. .. ..@ p       : int [1:13] 0 1 2 3 4 5 6 7 8 9 ...
##     .. .. .. ..@ Dim     : int [1:2] 12 12
##     .. .. .. ..@ Dimnames:List of 2
##     .. .. .. .. ..$ : NULL
##     .. .. .. .. ..$ : NULL
##     .. .. .. ..@ x       : num [1:12] 0.0739 0.0739 0.0739 0.0739 0.0739 ...
##     .. .. .. ..@ factors : list()
##     .. ..$ LamtUt :Formal class 'dgCMatrix' [package "Matrix"] with 6 slots
##     .. .. .. ..@ i       : int [1:3373] 3 1 4 6 6 8 2 3 3 3 ...
##     .. .. .. ..@ p       : int [1:3374] 0 1 2 3 4 5 6 7 8 9 ...
##     .. .. .. ..@ Dim     : int [1:2] 12 3373
##     .. .. .. ..@ Dimnames:List of 2
##     .. .. .. .. ..$ : NULL
##     .. .. .. .. ..$ : chr [1:3373] "1" "2" "3" "4" ...
##     .. .. .. ..@ x       : num [1:3373] 0.0739 0.0739 0.0739 0.0739 0.0739 ...
##     .. .. .. ..@ factors : list()
##     .. ..$ Lind   : int [1:12] 1 1 1 1 1 1 1 1 1 1 ...
##     .. ..$ Ptr    :<externalptr>
##     .. ..$ RZX    : num [1:12, 1:2] 2.86 21.77 22.96 23.7 21.11 ...
##     .. ..$ Ut     :Formal class 'dgCMatrix' [package "Matrix"] with 6 slots
##     .. .. .. ..@ i       : int [1:3373] 3 1 4 6 6 8 2 3 3 3 ...
##     .. .. .. ..@ p       : int [1:3374] 0 1 2 3 4 5 6 7 8 9 ...
##     .. .. .. ..@ Dim     : int [1:2] 12 3373
##     .. .. .. ..@ Dimnames:List of 2
##     .. .. .. .. ..$ : chr [1:12] "1" "3" "4" "5" ...
##     .. .. .. .. ..$ : chr [1:3373] "1" "2" "3" "4" ...
##     .. .. .. ..@ x       : num [1:3373] 1 1 1 1 1 1 1 1 1 1 ...
##     .. .. .. ..@ factors : list()
##     .. ..$ Utr    : num [1:12] 1.83 32.34 34.5 34.68 32.71 ...
##     .. ..$ V      : num [1:3373, 1:2] 1 1 1 1 1 1 1 1 1 1 ...
##     .. ..$ VtV    : num [1:2, 1:2] 3373 0 128415 5027767
```

```
##     .. ..$ Vtr    : num [1:2] 2388 96249
##     .. ..$ X      : num [1:3373, 1:2] 1 1 1 1 1 1 1 1 1 1 ...
##     .. .. ..- attr(*, "dimnames")=List of 2
##     .. .. .. ..$ : chr [1:3373] "1" "3" "4" "5" ...
##     .. .. .. ..$ : chr [1:2] "(Intercept)" "svl"
##     .. .. ..- attr(*, "assign")= int [1:2] 0 1
##     .. .. ..- attr(*, "msgScaleX")= chr(0)
##     .. ..$ Xwts   : num [1:3373] 1 1 1 1 1 1 1 1 1 1 ...
##     .. ..$ Zt     :Formal class 'dgCMatrix' [package "Matrix"] with 6 slots
##     .. .. .. ..@ i       : int [1:3373] 3 1 4 6 6 8 2 3 3 3 ...
##     .. .. .. ..@ p       : int [1:3374] 0 1 2 3 4 5 6 7 8 9 ...
##     .. .. .. ..@ Dim     : int [1:2] 12 3373
##     .. .. .. ..@ Dimnames:List of 2
##     .. .. .. .. ..$ : chr [1:12] "1" "3" "4" "5" ...
##     .. .. .. .. ..$ : chr [1:3373] "1" "2" "3" "4" ...
##     .. .. .. ..@ x       : num [1:3373] 1 1 1 1 1 1 1 1 1 1 ...
##     .. .. .. ..@ factors : list()
##     .. ..$ beta0  : num [1:2] 0 0
##     .. ..$ delb   : num [1:2] -0.7566 0.0385
##     .. ..$ delu   : num [1:12] -0.00605 -0.01184 -0.0346 -0.00715 0.18186 ...
##     .. ..$ theta  : num 0.0739
##     .. ..$ u0     : num [1:12] 0 0 0 0 0 0 0 0 0 0 ...
##     .. ..and 45 methods, of which 31 are  possibly relevant:
##     .. ..  b, beta, CcNumer, copy#envRefClass, initialize, initializePtr,
##     .. ..  installPars, L, ldL2, ldRX2, linPred, P, ptr, RX, RXdiag, RXi,
##     .. ..  setBeta0, setDelb, setDelu, setTheta, setZt, solve, solveU, sqrL,
##     .. ..  u, unsc, updateDecomp, updateL, updateLamtUt, updateRes,
##     .. ..  updateXwts
##     ..@ optinfo:List of 7
##     .. ..$ optimizer: chr "bobyqa"
##     .. ..$ control  :List of 1
##     .. .. ..$ iprint: int 0
##     .. ..$ derivs   :List of 2
##     .. .. ..$ gradient: num -9.4e-05
##     .. .. ..$ Hessian : num [1, 1] 1817
##     .. ..$ conv     :List of 2
##     .. .. ..$ opt : int 0
##     .. .. ..$ lme4: list()
##     .. ..$ feval    : int 17
##     .. ..$ warnings : list()
##     .. ..$ val      : num 0.0739
```

Examine object and summary object

```
lme1_sum <- summary(lme1)
lme1_sum
```

```
## Linear mixed model fit by REML ['lmerMod']
## Formula: mass ~ 1 + svl + (1 | plot)
##    Data: sally
##
## REML criterion at convergence: -4875.6
##
```

```
## Scaled residuals:
##     Min      1Q  Median      3Q     Max
## -3.5969 -0.6518 -0.1338  0.5545  5.9471
##
## Random effects:
##  Groups   Name        Variance  Std.Dev.
##  plot     (Intercept) 7.475e-05 0.008646
##  Residual             1.367e-02 0.116939
## Number of obs: 3373, groups:  plot, 12
##
## Fixed effects:
##               Estimate Std. Error t value
## (Intercept) -0.7566013  0.0127085  -59.54
## svl          0.0384600  0.0003156  121.88
##
## Correlation of Fixed Effects:
##     (Intr)
## svl -0.949
```

```r
str(lme1_sum)
```

```
## List of 18
##  $ methTitle  : chr "Linear mixed model fit by REML"
##  $ objClass   : atomic [1:1] lmerMod
##   ..- attr(*, "package")= chr "lme4"
##  $ devcomp    :List of 2
##   ..$ cmp : Named num [1:10] 8.3661 18.5757 46.0437 0.0542 46.0979 ...
##   .. ..- attr(*, "names")= chr [1:10] "ldL2" "ldRX2" "wrss" "ussq" ...
##   ..$ dims: Named int [1:12] 3373 3373 2 3371 12 1 1 1 0 2 ...
##   .. ..- attr(*, "names")= chr [1:12] "N" "n" "p" "nmp" ...
##  $ isLmer     : logi TRUE
##  $ useScale   : logi TRUE
##  $ logLik     :Class 'logLik' : 2438 (df=4)
##  $ family     : NULL
##  $ link       : NULL
##  $ ngrps      : Named num 12
##   ..- attr(*, "names")= chr "plot"
##  $ coefficients: num [1:2, 1:3] -7.57e-01 3.85e-02 1.27e-02 3.16e-04 -5.95e+01 ...
##   ..- attr(*, "dimnames")=List of 2
##   .. ..$ : chr [1:2] "(Intercept)" "svl"
##   .. ..$ : chr [1:3] "Estimate" "Std. Error" "t value"
##  $ sigma      : num 0.117
##  $ vcov       :Formal class 'dpoMatrix' [package "Matrix"] with 5 slots
##   .. ..@ x       : num [1:4] 1.62e-04 -3.81e-06 -3.81e-06 9.96e-08
##   .. ..@ Dim     : int [1:2] 2 2
##   .. ..@ Dimnames:List of 2
##   .. .. ..$ : chr [1:2] "(Intercept)" "svl"
##   .. .. ..$ : chr [1:2] "(Intercept)" "svl"
##   .. ..@ uplo    : chr "U"
##   .. ..@ factors :List of 1
##   .. .. ..$ correlation:Formal class 'corMatrix' [package "Matrix"] with 6 slots
##   .. .. .. .. ..@ sd      : num [1:2] 0.012708 0.000316
##   .. .. .. .. ..@ x       : num [1:4] 1 -0.949 -0.949 1
##   .. .. .. .. ..@ Dim     : int [1:2] 2 2
##   .. .. .. .. ..@ Dimnames:List of 2
```

```
##    .. .. .. .. .. .. ..$ : chr [1:2] "(Intercept)" "svl"
##    .. .. .. .. .. .. ..$ : chr [1:2] "(Intercept)" "svl"
##    .. .. .. .. ..@ uplo    : chr "U"
##    .. .. .. .. ..@ factors :List of 1
##    .. .. .. .. .. ..$ Cholesky:Formal class 'Cholesky' [package "Matrix"] with 5 slots
##    .. .. .. .. .. .. .. ..@ x       : num [1:4] 1 0 -0.949 0.316
##    .. .. .. .. .. .. .. ..@ Dim     : int [1:2] 2 2
##    .. .. .. .. .. .. .. ..@ Dimnames:List of 2
##    .. .. .. .. .. .. .. .. ..$ : NULL
##    .. .. .. .. .. .. .. .. ..$ : NULL
##    .. .. .. .. .. .. .. ..@ uplo    : chr "U"
##    .. .. .. .. .. .. .. ..@ diag    : chr "N"
##  $ varcor       :List of 1
##   ..$ plot: num [1, 1] 7.47e-05
##   .. ..- attr(*, "dimnames")=List of 2
##   .. .. ..$ : chr "(Intercept)"
##   .. .. ..$ : chr "(Intercept)"
##   .. ..- attr(*, "stddev")= Named num 0.00865
##   .. .. ..- attr(*, "names")= chr "(Intercept)"
##   .. ..- attr(*, "correlation")= num [1, 1] 1
##   .. .. ..- attr(*, "dimnames")=List of 2
##   .. .. .. ..$ : chr "(Intercept)"
##   .. .. .. ..$ : chr "(Intercept)"
##   ..- attr(*, "sc")= num 0.117
##   ..- attr(*, "useSc")= logi TRUE
##   ..- attr(*, "class")= chr "VarCorr.merMod"
##  $ AICtab       : Named num -4876
##   ..- attr(*, "names")= chr "REML"
##  $ call         : language lmer(formula = mass ~ 1 + svl + (1 | plot), data = sally)
##  $ residuals    : Named num [1:3373] -0.7273 -1.8714 0.0887 -0.2155 0.2384 ...
##   ..- attr(*, "names")= chr [1:3373] "1" "3" "4" "5" ...
##  $ fitMsgs      : chr(0)
##  $ optinfo      :List of 7
##   ..$ optimizer: chr "bobyqa"
##   ..$ control  :List of 1
##   .. ..$ iprint: int 0
##   ..$ derivs   :List of 2
##   .. ..$ gradient: num -9.4e-05
##   .. ..$ Hessian : num [1, 1] 1817
##   ..$ conv     :List of 2
##   .. ..$ opt : int 0
##   .. ..$ lme4: list()
##   ..$ feval    : int 17
##   ..$ warnings : list()
##   ..$ val      : num 0.0739
##  - attr(*, "class")= chr "summary.merMod"
```

Get Fitted and Residuals and Plot

```
lme1_resids <- lme1_sum$residuals # or resid(lme1)
lme1_fits <- fitted(lme1)
par(mfrow = c(1, 2))
```

```
hist(lme1_resids)
plot(lme1_fits, lme1_resids)
abline(h = 0, col = "red")
```

Histogram of lme1_resids
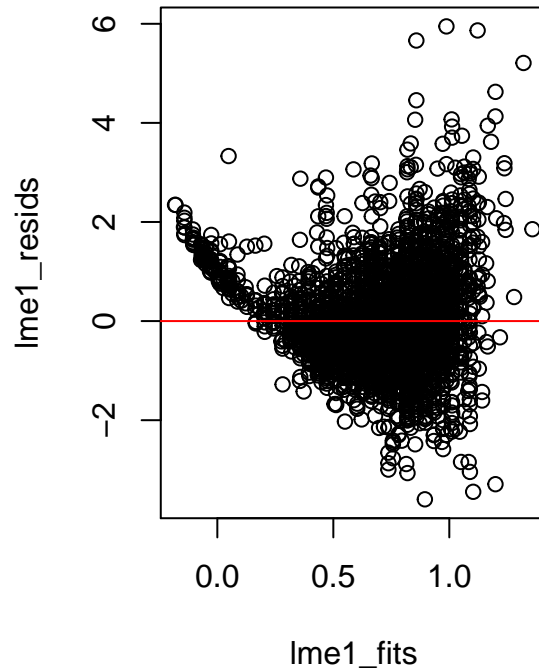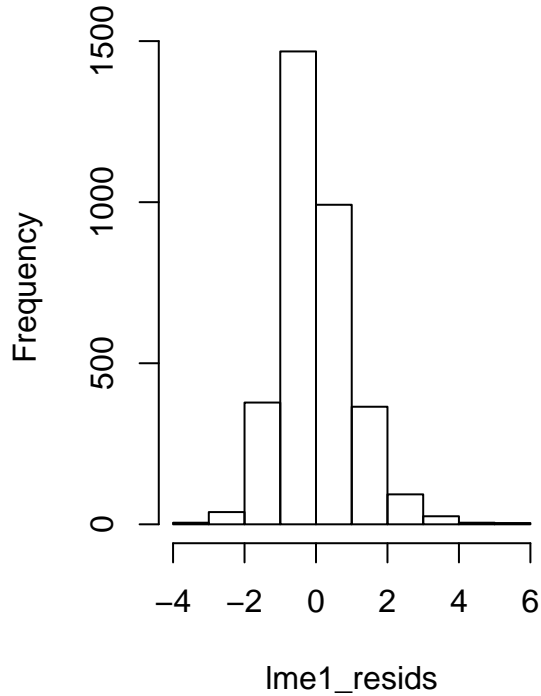

```
par(mfrow = c(1,1))
```

Get random effects

```
lme1_ints <- ranef(lme1)
lme1_ints
```

```
## $plot
##       (Intercept)
## 1   -4.469993e-04
## 3   -8.752929e-04
## 4   -2.557974e-03
## 5   -5.282905e-04
## 7    1.344498e-02
## 8    3.561947e-03
## 9   -5.901732e-03
## Off  4.735069e-04
## T   -3.444650e-04
## T1  -7.681686e-03
## T2   7.829357e-04
## T3   7.307164e-05
```

```
mean(lme1_ints$plot[[1]]) # should approximate 0
```

```
## [1] -2.53264e-14
```

Get Coefficients

```
coef(lme1)
```

```
## $plot
##     (Intercept)      svl
## 1    -0.7570483 0.03846
## 3    -0.7574765 0.03846
## 4    -0.7591592 0.03846
## 5    -0.7571295 0.03846
## 7    -0.7431563 0.03846
## 8    -0.7530393 0.03846
## 9    -0.7625030 0.03846
## Off  -0.7561277 0.03846
## T    -0.7569457 0.03846
## T1   -0.7642829 0.03846
## T2   -0.7558183 0.03846
## T3   -0.7565282 0.03846
##
## attr(,"class")
## [1] "coef.mer"
```

```
fixef(lme1)
```

```
## (Intercept)         svl
##  -0.7566013   0.0384600
```

Plot Random Effects

```
Intercepts <- fixef(lme1)[1] + lme1_ints$plot[[1]]
Slope <- fixef(lme1)[2]
X <- seq(0, 60)
overall_intercept <- fixef(lme1)[1]
fit_line <- overall_intercept + Slope * X
plot(X, fit_line, type = "l", lwd = 2, xlab = "SVL (mm)", ylab = "Mass (g)",
     xlim = c(30, 35),
     ylim = c(0.35, 0.6))
for(i in 1:length(Intercepts)) {
  rand_line <- Intercepts[i] + Slope * X
  lines(X, rand_line, col = "blue", lwd = 1)
}
lines(X, fit_line, lwd = 3)
```
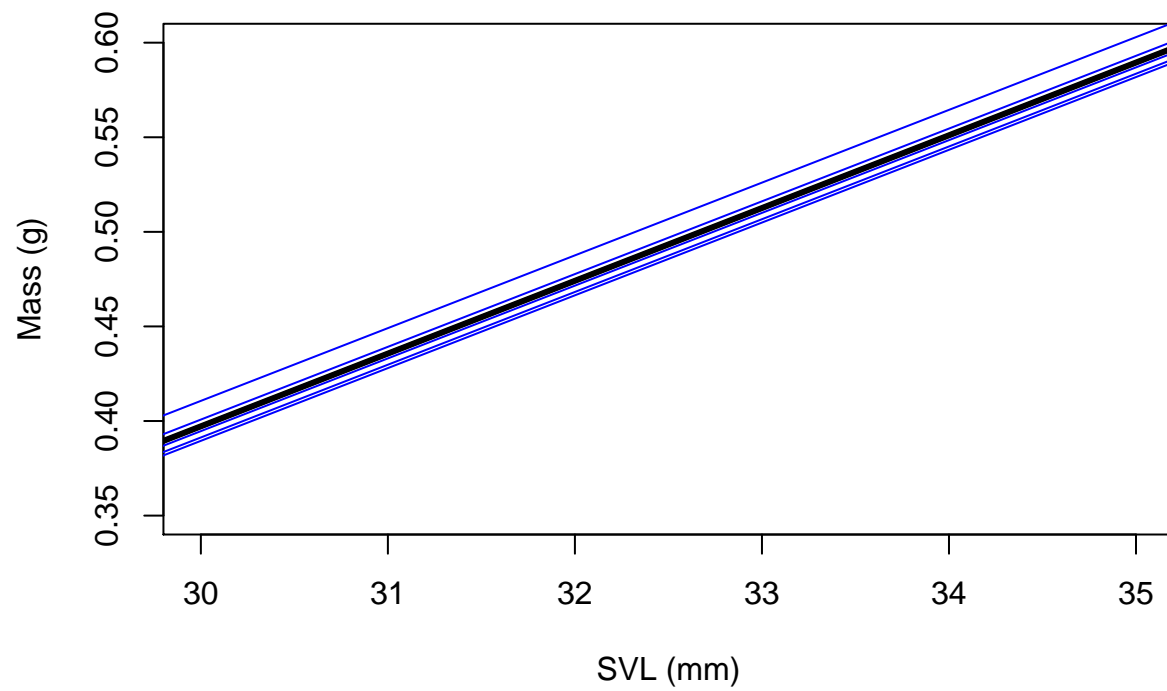
Exercise

- Simulate data with random slopes and intercepts
- Run a linear mixed model on the data
- Plot the expected lines for each group