Scripps's Murrelet Egg Size model

Amelia J. DuVall & Marcela Todd

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Introduction

This document details steps taken to model Scripps's Murrelet (*Synthliboramphus scrippsi*) egg size at Santa Barbara Island within Channel Islands National Park from 2009-2017.

Load and format data

```
egg <- read.csv(here("data", "SCMU_egg_data.csv"))
covars <- read.csv(here("data", "covariates", "covars.csv"))

## join covariate data with egg data by year
SCMUdf <- left_join(egg, covars, by = "Year") %>%
  filter(TrueOrder == TRUE) %>% # egg order known only
  select(Year, Observer, Plot, Size, EggOrder, ANCHL, BEUTI, NPGO, ONI, PDO, SST) %>%
  as_tibble()
```

Null Intercept-Only Model with 2 random effects

This model includes observer and plot as random effects, but does not include any covariates.

```
## run model
nm <- lmer(Size ~ 1 + (1 | Observer) + (1 | Plot), data = SCMUdf, REML = TRUE)

## look at model output and estimates
sumary(nm)
```

```
## Fixed Effects:
## coef.est  coef.se
##  1884.29    12.20
##
## Random Effects:
##  Groups   Name        Std.Dev.
##  Observer (Intercept)  17.22
##  Plot     (Intercept)  24.49
##  Residual             111.96
## ---
## number of obs: 753, groups: Observer, 27; Plot, 8
## AIC = 9263.1, DIC = 9268.5
## deviance = 9261.8
```

```r
coef(nm) # these are the coefficients
```

```
## $Observer
##     (Intercept)
## AAY    1899.553
## AJB    1880.127
## AJD    1895.666
## AML    1886.089
## CAC    1876.699
## CEH    1880.914
## CEK    1880.307
## CLE    1879.914
## DLW    1874.348
## EWW    1891.898
## GRK    1882.978
## JAH    1902.680
## KMR    1885.299
## KWB    1880.009
## LAH    1883.315
## MEJ    1878.435
## MGB    1886.816
## NAG    1869.396
## PTL    1876.981
## RER    1893.489
## REW    1881.330
## SAA    1887.456
## SFC    1885.064
## SJK    1893.394
## SKT    1862.709
## SLA    1884.647
## SMC    1896.380
##
## $Plot
##      (Intercept)
## APNC    1905.622
## BH      1898.588
## BT      1850.797
## CC      1903.414
## DO      1885.298
## ESC     1882.827
## LC      1873.535
## WC      1874.258
##
## attr(,"class")
## [1] "coef.mer"
```

```r
ranef(nm) # these are the random effects
```

```
## $Observer
##     (Intercept)
## AAY  15.2610062
## AJB  -4.1654786
## AJD  11.3739567
## AML   1.7970244
```

```
## CAC  -7.5934214
## CEH  -3.3784652
## CEK  -3.9853109
## CLE  -4.3779272
## DLW  -9.9445690
## EWW   7.6052536
## GRK  -1.3144290
## JAH  18.3876524
## KMR   1.0067101
## KWB  -4.2835217
## LAH  -0.9770916
## MEJ  -5.8572070
## MGB   2.5241208
## NAG -14.8959509
## PTL  -7.3117215
## RER   9.1963408
## REW  -2.9625711
## SAA   3.1632622
## SFC   0.7713125
## SJK   9.1015277
## SKT -21.5831481
## SLA   0.3551011
## SMC  12.0875447
##
## $Plot
##      (Intercept)
## APNC   21.329246
## BH     14.295406
## BT    -33.494909
## CC     19.121674
## DO      1.005254
## ESC    -1.464948
## LC    -10.757089
## WC    -10.034635
##
## with conditional variances for "Observer" "Plot"
```

```r
## you can store the model results to objects
obs.ranef <- ranef(nm)$Observer
plot.ranef <- ranef(nm)$Plot
## the mean of these values should be close to 0
mean(obs.ranef[[1]])
```

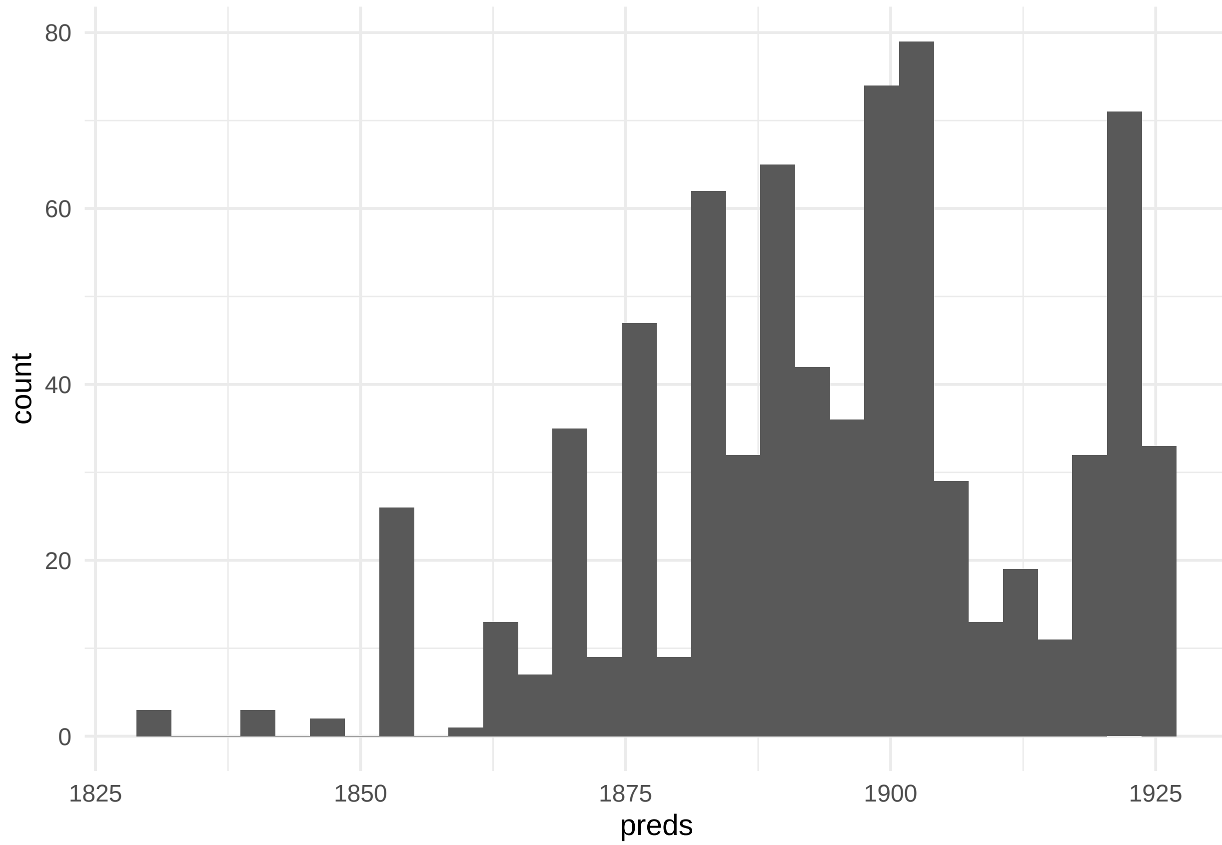
```
## [1] 3.494283e-13
```

```r
mean(plot.ranef[[1]])
```

```
## [1] -7.280149e-12
```

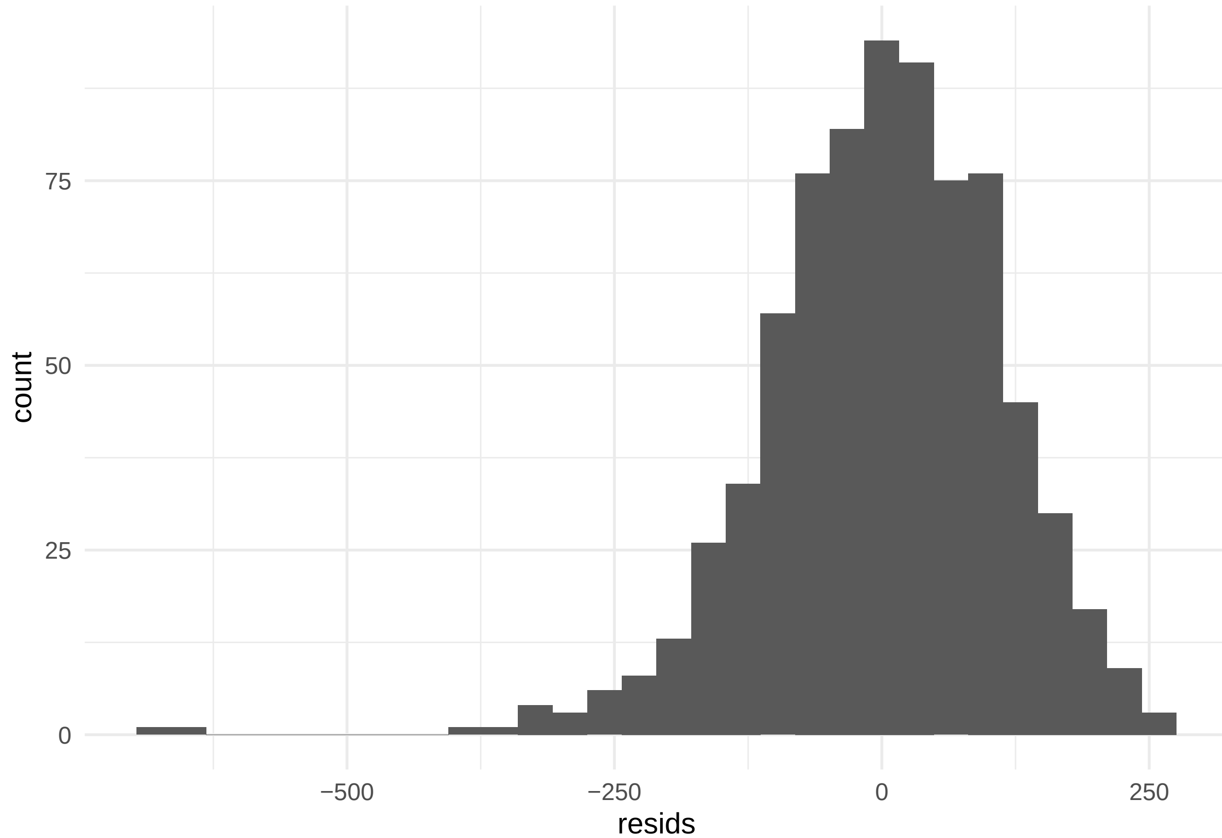
```r
## quick model diagnostics
## extract predicted values and plot
preds <- predict(nm)
ggplot() +
  geom_histogram(mapping = aes(preds)) +
  theme_minimal()
```

```
## `stat_bin()` using `bins = 30`. Pick better value with `binwidth`.
```

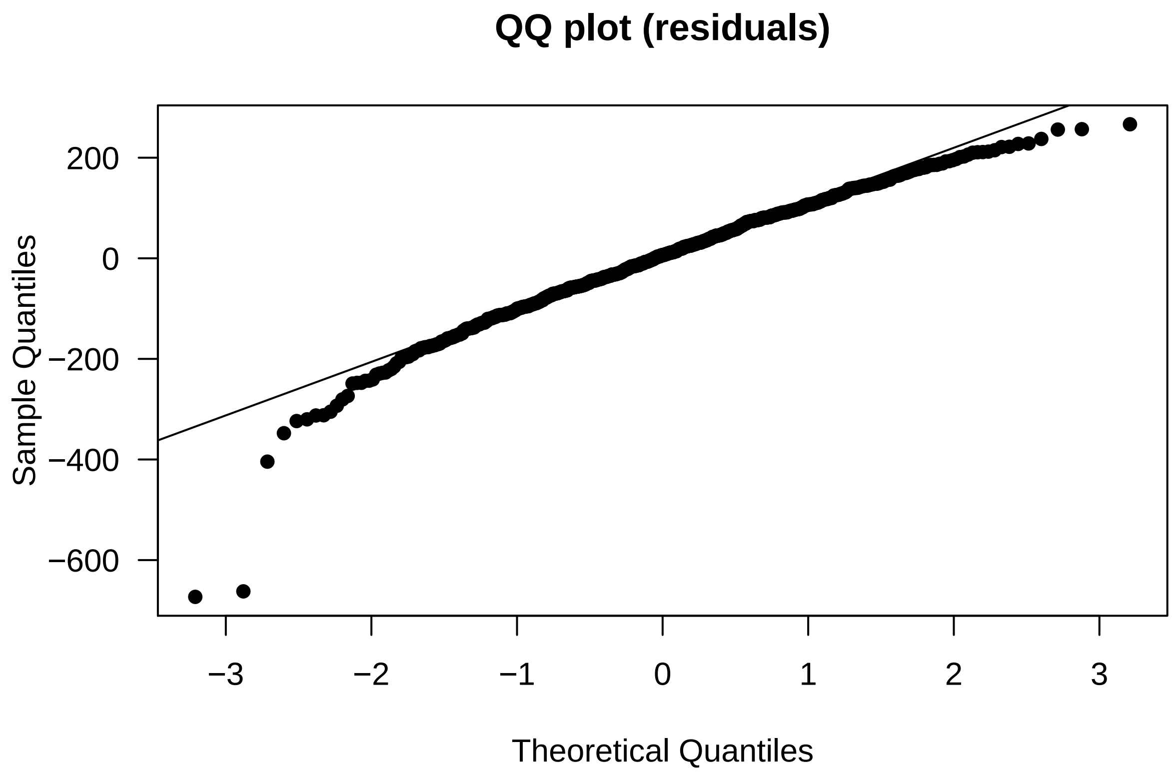



```
# we want these to look normally distributed

## extract residuals and plot
resids <- residuals(nm)
ggplot() +
  geom_histogram(mapping = aes(resids)) +
  theme_minimal()
```

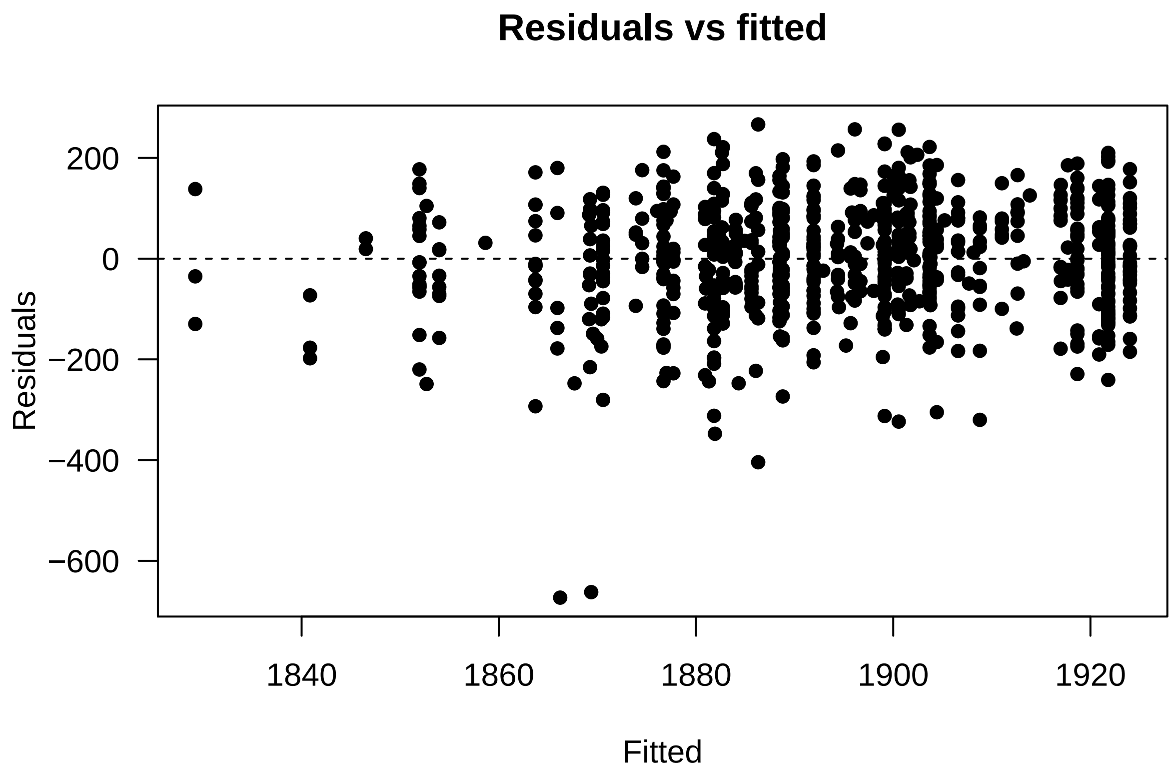
```
## `stat_bin()` using `bins = 30`. Pick better value with `binwidth`.
```




```r
# we want these to look normally distributed

# qq resids
qqnorm(resids, main = "QQ plot (residuals)", las = 1, pch = 16)
qqline(resids)
```




```
## plot residuals versus fitted values
yh <- fitted(nm)
plot(yh, resids, las = 1, pch = 16,
     xlab = "Fitted", ylab = "Residuals",
     main = "Residuals vs fitted")
abline(h=0, lty = "dashed")
```



Remove Correlated Predictos & Find Global Model

```
## create data frame specifying predictors to include
predictors <- as.data.frame(matrix(c(FALSE, TRUE), 2, 7)) # 7 potential predictors (includes EggOrder)

## add column names
cov_names <- colnames(predictors) <- colnames(SCMUdf[,5:11])

## create set of all possible combinations
full_set <- expand.grid(predictors) # 128 combinations

## select models with correlated predictors (see SCMU_egg_covariates.Rmd)
ii <- which(full_set$ANCHL + full_set$NPGO == 2 |
              full_set$ANCHL + full_set$ONI == 2 |
              full_set$ANCHL + full_set$PDO == 2 |
              full_set$BEUTI + full_set$ONI == 2 |
              full_set$BEUTI + full_set$PDO == 2 |
              full_set$NPGO + full_set$PDO == 2 |
              full_set$NPGO + full_set$SST == 2 |
              full_set$ONI + full_set$PDO == 2) # 98 models

## create reduced set of models and convert to a matrix for easier indexing
use_set <- as.matrix(full_set[-ii,])

## number of models in set
```

```r
(n_mods <- nrow(use_set)) # 30 models out of potential 128
```

```
## [1] 30
```

```r
## find max number of predictors in a model
rowSums(use_set) # only one model with 4 predictors (72)
```

```
##  1  2  3  4  5  6  7  8  9 10 13 14 17 18 25 26 33 34 65 66 67 68 69 70 71 72
##  0  1  1  2  1  2  2  3  1  2  2  3  1  2  2  3  1  2  1  2  2  3  2  3  3  4
## 81 82 97 98
##  2  3  2  3
```

```r
## which predictors are included in this model?
cov_names[use_set[26,]] # "EggOrder" "ANCHL"    "BEUTI"    "SST"
```

```
## [1] "EggOrder" "ANCHL"    "BEUTI"    "SST"
```

Likelihood Ratio Tests

We used LRTs using the global model to test the support for inclusion of random effects (Plot, Observer). There are NAs in the observer data from 2015. These NAs need to be removed prior to completing LRT tests. See https://cran.r-project.org/web/packages/RLRsim/RLRsim.pdf for info.

```r
SCMUdf2 <- SCMUdf[-c(which(is.na(SCMUdf$Observer==TRUE))),]

## global model
bm_both <- lmer(Size ~ EggOrder + ANCHL + BEUTI + SST + (1 | Observer) + (1 | Plot), data = SCMUdf2, REM

## run model with plot RE only
bm_plot <- lmer(Size ~ EggOrder + ANCHL + BEUTI + SST + (1 | Plot), data = SCMUdf2, REML = FALSE)

## run model with obs RE only
bm_obs <- lmer(Size ~ EggOrder + ANCHL + BEUTI + SST + (1 | Observer), data = SCMUdf2, REML = FALSE)

## Exact RLRT test
# m is the reduced model containing only the RE to be tested (the random effect set to zero under the n

# observer set to zero under the null hypothesis
exactRLRT(m = bm_obs, mA = bm_both, m0 = bm_plot, seed = 16)
```

```
## Using restricted likelihood evaluated at ML estimators.

## Refit with method="REML" for exact results.

##
##  simulated finite sample distribution of RLRT.
##
##  (p-value based on 10000 simulated values)
##
## data:
## RLRT = 1.2984, p-value = 0.0946
```

```r
# plot set to zero under the null hypothesis
exactRLRT(m = bm_plot, mA = bm_both, m0 = bm_obs, seed = 16)
```

```
## Using restricted likelihood evaluated at ML estimators.
## Refit with method="REML" for exact results.
```

```
##
##  simulated finite sample distribution of RLRT.
##
##  (p-value based on 10000 simulated values)
##
## data:
## RLRT = 3.8766, p-value = 0.0138
```

Model Diagnostics

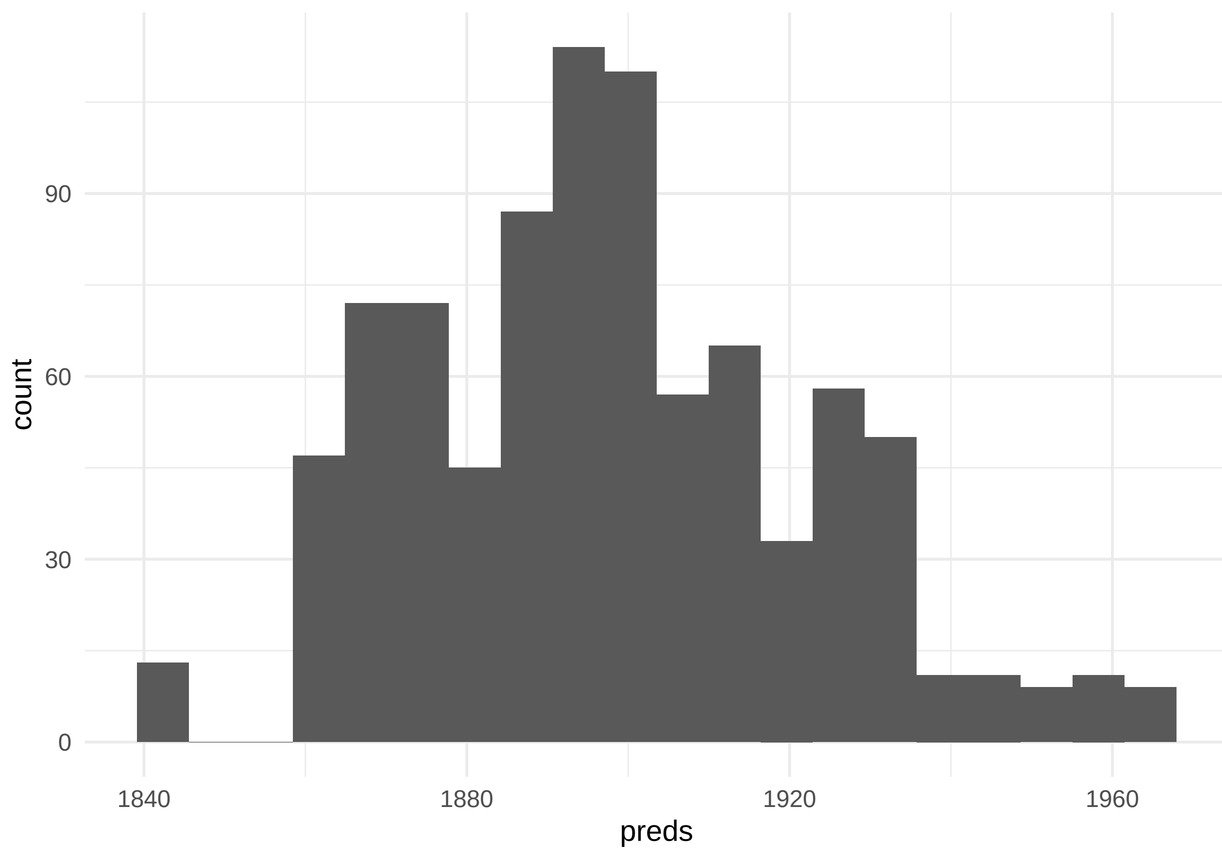
These diagnostics are done for the global model.

```
## run global model
global_mod <- lmer(Size ~ EggOrder + ANCHL + BEUTI + SST + (1 | Plot), data = SCMUdf, REML = TRUE)
```

Residuals/Fitted Plots

Histogram of Predicted Values

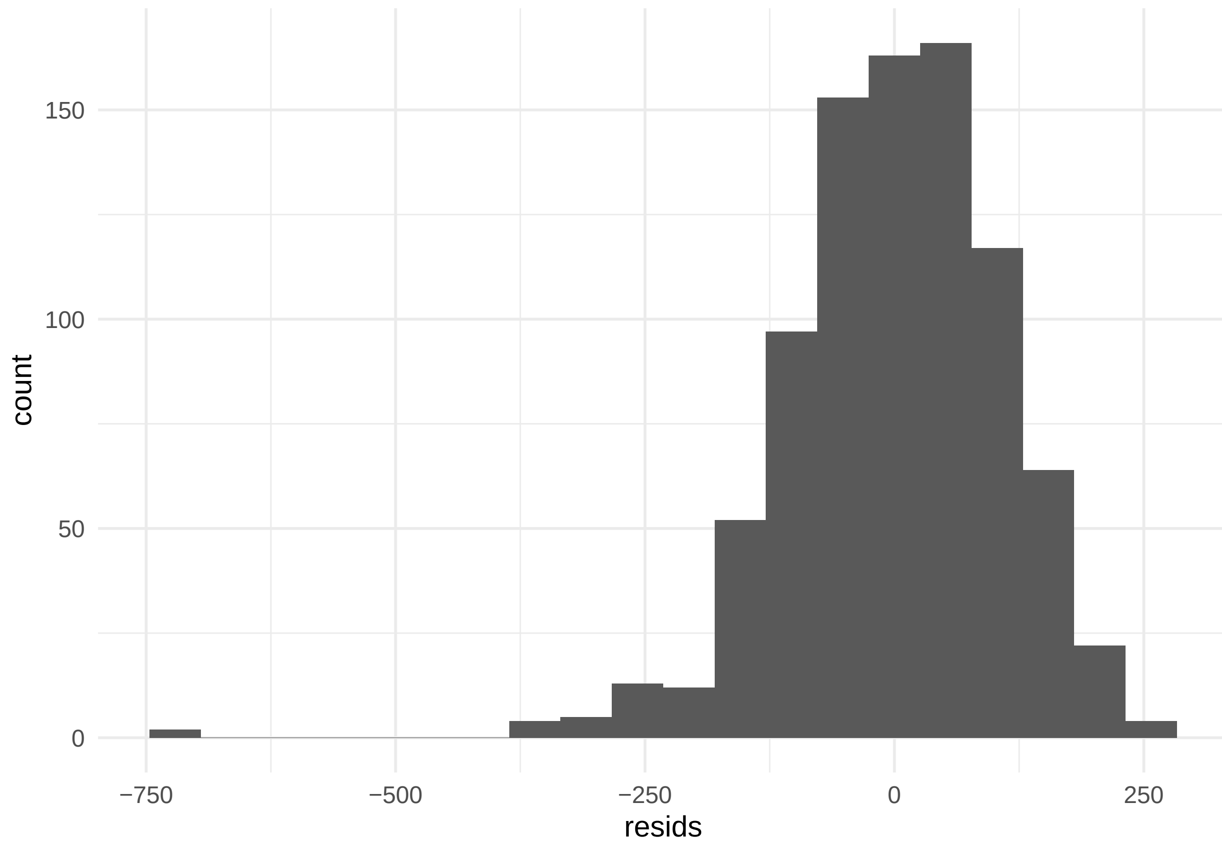
```
## extract predicted values and plot
preds <- predict(global_mod)
ggplot() +
  geom_histogram(mapping = aes(preds), bins = 20) + # set bins
  theme_minimal()
```



Since we assumed our data are normal, we want to see an approximately normal distribution of predicted values.

Histogram of Residuals

```
## extract residuals and plot
resids <- residuals(global_mod)
ggplot() +
  geom_histogram(mapping = aes(resids), bins = 20) +
  theme_minimal()
```



Since we assumed our data are normal, we want to see an approximately normal distribution of residuals (differences between observed and predicted values of data).

Model Coefficients

```
## extract coeffs and random effects
coef(global_mod) # this include fixed and random effects
```

```
## $Plot
##      (Intercept) EggOrderEgg2    ANCHL    BEUTI      SST
## APNC    1895.298     32.93263 4.806984 -11.3738 7.697737
## BH      1899.198     32.93263 4.806984 -11.3738 7.697737
## BT      1854.966     32.93263 4.806984 -11.3738 7.697737
## CC      1902.741     32.93263 4.806984 -11.3738 7.697737
## DO      1883.361     32.93263 4.806984 -11.3738 7.697737
## ESC     1883.376     32.93263 4.806984 -11.3738 7.697737
## LC      1876.946     32.93263 4.806984 -11.3738 7.697737
## WC      1874.641     32.93263 4.806984 -11.3738 7.697737
##
```

```
## attr(,"class")
## [1] "coef.mer"
```

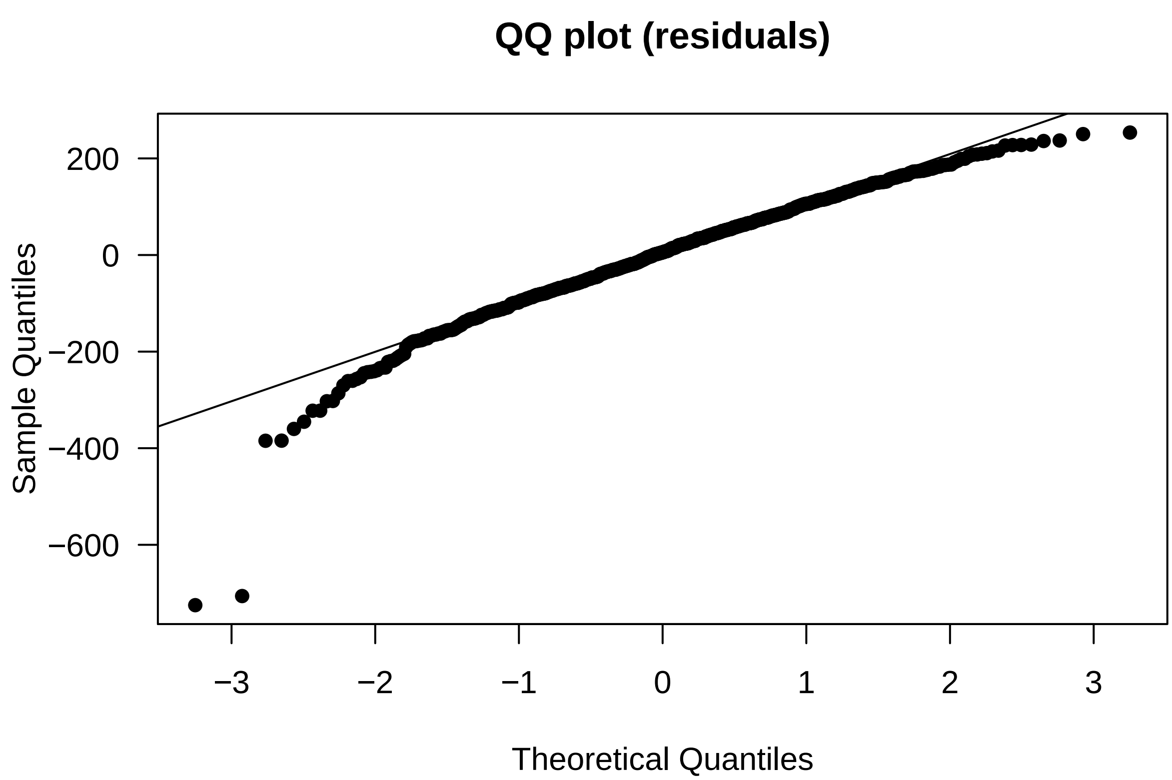
```r
ranef_pl <- ranef(global_mod)$Plot # plot random effect only

## look at data going into random effects
table(SCMUdf$Plot)
```

```
##
## APNC   BH   BT   CC   DO  ESC   LC   WC
##  115   31   16  275  192    1  240    4
```

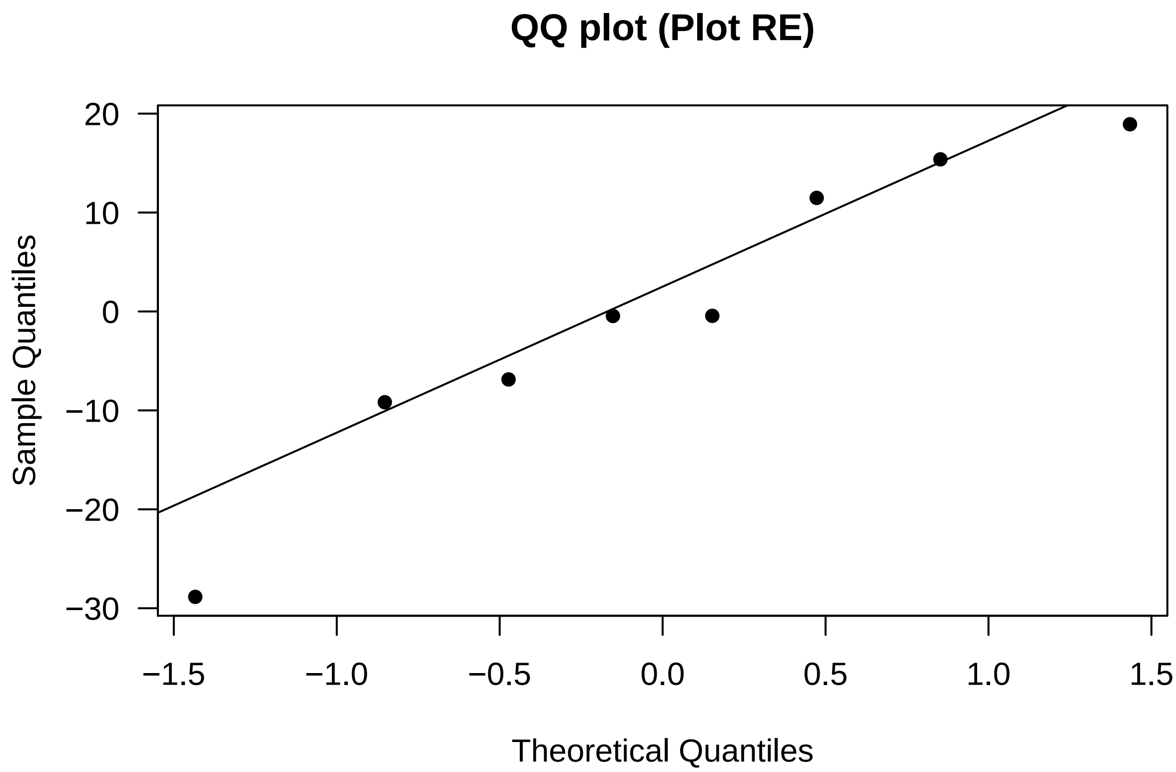
We can extract our model coefficients (for fixed and random effects) and look at them.

Q-Q Plots

```r
# qq resids
qqnorm(resids, main = "QQ plot (residuals)", las = 1, pch = 16)
qqline(resids)
```



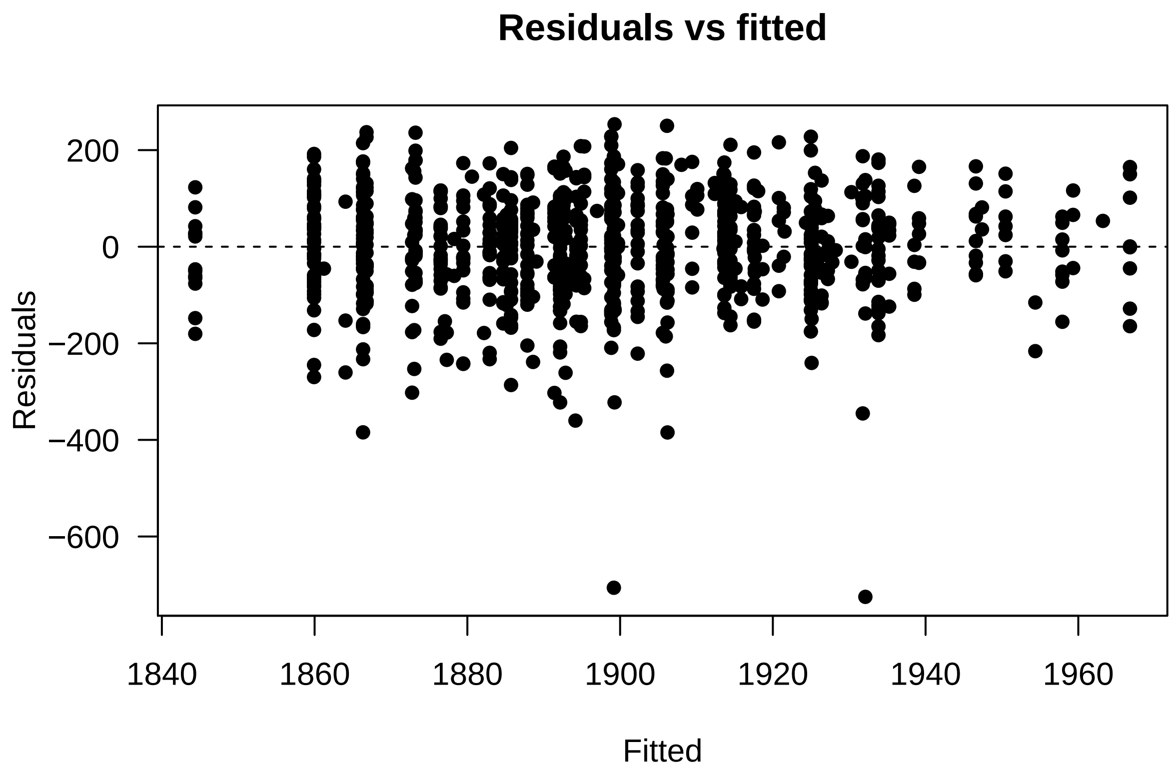

```r
# qq Plot RE
qqnorm(unlist(ranef_pl), main = "QQ plot (Plot RE)", las = 1, pch = 16)
qqline(unlist(ranef_pl))
```



We want our points to fall approximately on the diagonal lines.

Fitted v Residuals

```
## plot residuals versus fitted values
yh <- fitted(global_mod)
plot(yh, resids, las = 1, pch = 16,
     xlab = "Fitted", ylab = "Residuals",
     main = "Residuals vs fitted")
abline(h=0, lty = "dashed")
```



We assume our errors are normally distributed with constant variance. We want this plot to look like a scattershot of points, without any evidence of trends.

Levene's test

We can formally test the assumption of homogenous variance via the Levene's Test, which compares the absolute values of the residuals among groups.

```
## split residuals into 2 groups
g1 <- resids[yh <= median(yh)]
g2 <- resids[yh > median(yh)]

## Levene's test
var.test(g1, g2)
```

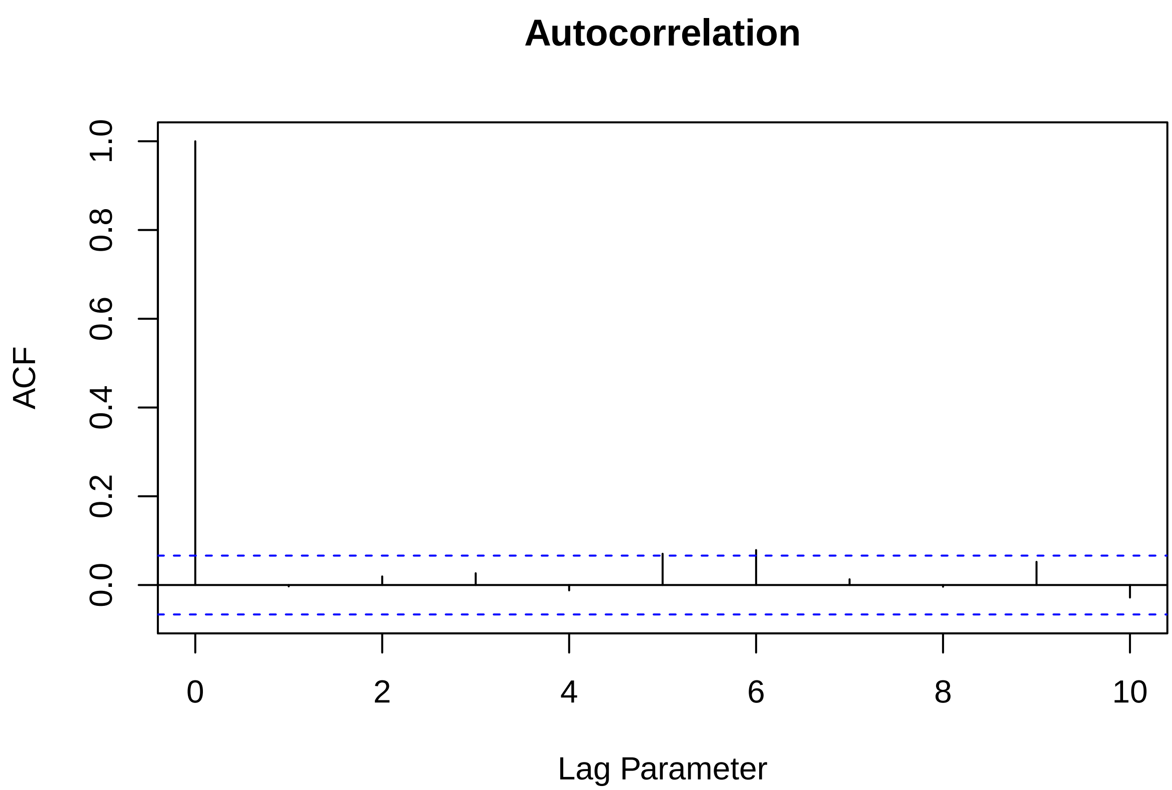
```
##
##  F test to compare two variances
##
## data:  g1 and g2
## F = 0.90516, num df = 442, denom df = 430, p-value = 0.2983
## alternative hypothesis: true ratio of variances is not equal to 1
## 95 percent confidence interval:
##  0.7499399 1.0922349
## sample estimates:
## ratio of variances
##          0.9051588
```

There is no justification to reject the null hypothesis that the residuals are equal. F is close to 1 and it is within the 95% confidence interval.

Autocorrelation

We also assume our errors are independent (e.g., not correlated). An ACF plot can be used to look for autocorrelation.

```
# calculate the ACF for lags between 1 and 10
autocorrelation <- acf(resids, lag.max= 10, plot = FALSE)

# Plot figure
plot(autocorrelation,
     main="Autocorrelation",
     xlab="Lag Parameter",
     ylab="ACF")
```



The first value with 0 lag will always be autocorrelated because it's stacked on itself. But after that, we want to see the values within the blue dotted lines. There does not appear to be autocorrelation in the residuals.

Identifying Outliers

https://qerm514.github.io/website/labs/week_03/diagnostics_and_errors.html#unusual_observations https://qerm514.github.io/website/homework/week_03/hw_03_diagnostics_key.pdf Calculate the studentized residuals to look for outliers

```
## get studentized residuals
(stud_e <- rstudent(global_mod))
```

```
##            1            2            3            4            5            6 
##  1.334692028 -1.432303962 -0.417831919  0.076619990 -1.126837630  0.216916981 
##            7            8            9           10           11           12 
## -0.826880478 -1.450616843 -0.203144114 -0.467319488  1.489091460  0.805841181 
##           13           14           15           16           17           18 
##  0.227967785 -1.138748660 -0.957882066  0.845018269 -1.216715706 -0.822294182 
##           19           20           21           22           23           24 
## -0.267352269  1.390594022 -1.216715706 -0.583806748 -1.077365634  1.381562004 
##           25           26           27           28           29           30 
##  0.133713679  0.214145892 -1.673382506 -0.708532092  0.712224053  1.372633482 
##           31           32           33           34           35           36 
##  0.056400801 -1.525830123  0.056400801 -1.076384817 -0.186666559  0.531278615 
##           37           38           39           40           41           42 
##  0.048685340 -1.461142191  0.245649304  0.461868921 -0.742033988  0.874635633 
##           43           44           45           46           47           48 
## -0.900261227  0.970947865 -1.622487352  0.475627812 -0.267352269 -0.019692242 
##           49           50           51           52           53           54 
##  0.260957027 -0.563804529 -0.598130938 -0.259450616  0.086953468  0.506459533 
##           55           56           57           58           59           60 
## -0.482167262  1.393179553 -1.182784114  0.498141330 -2.136341951 -1.468502916 
##           61           62           63           64           65           66 
##  0.974369907  1.288339556  0.152710509 -0.997215541 -1.138748660 -2.957215340 
##           67           68           69           70           71           72 
## -0.247204090 -2.431092485  0.870721913  1.140919160  0.902205474 -0.216310733 
##           73           74           75           76           77           78 
## -0.435312431 -0.308078585  0.790189055 -1.493543440 -2.773955087  0.904905192 
##           79           80           81           82           83           84 
## -2.008493985 -0.468816730  0.351797798 -1.428092365 -0.759021397  0.725122357 
##           85           86           87           88           89           90 
## -0.821010018 -1.896404891  1.461956800  0.973425978  0.434759960 -0.275249650 
##           91           92           93           94           95           96 
## -0.620142977  0.382019338  1.108469710  0.084835095  0.757298346 -0.208697740 
##           97           98           99          100          101          102 
##  0.379606443  0.127803063  0.957647605  0.436294735  0.393623959  0.196942913 
##          103          104          105          106          107          108 
## -1.057142678 -1.950051458 -0.245369619 -2.206043836 -0.722974893 -1.371681203 
##          109          110          111          112          113          114 
##  0.325043321 -0.164160591 -0.775055325  0.216410317 -0.038489038  0.524860316 
##          115          116          117          118          119          120 
## -0.450357972  0.129414760  1.589527955  0.973662110 -1.200511770 -1.231340008 
##          121          122          123          124          125          126 
##  1.471268881 -0.360534027 -1.920754837  0.874032701 -0.992297001  1.052309305 
##          127          128          129          130          131          132 
## -0.792496355 -0.233827956 -0.961959926  0.714295624 -0.356344443 -0.191620972 
##          133          134          135          136          137          138 
##  1.588709789 -0.578417428  0.759537822  1.524609141  0.612482243 -0.677440977 
##          139          140          141          142          143          144 
## -0.081153118  0.553672027  2.088498840  1.008845307  1.434094862 -1.585426134 
##          145          146          147          148          149          150 
##  0.220123333  0.543951564  0.186424001  0.483670760  0.068859292  0.712811644 
##          151          152          153          154          155          156 
##  0.866426016 -0.022065661 -1.250882909  1.097201240 -0.448696911  1.377438964 
##          157          158          159          160          161          162 
## -0.191956057 -0.584394548 -2.219988421  0.388703524 -0.584394548  0.639995429 
```

```
##          163          164          165          166          167          168 
## -1.429888543 -0.617355406  0.202494199  0.766049993 -1.287583193  0.784033132 
##          169          170          171          172          173          174 
##  2.097926225 -2.228252612  1.924884388  0.179418896 -2.783974589 -0.307287428 
##          175          176          177          178          179          180 
##  1.332289773  1.492884429  0.748692478 -0.867415899  0.018688978 -0.209494506 
##          181          182          183          184          185          186 
##  1.919784087 -2.322523709  1.283363429  0.577983977  0.309588486 -1.060247012 
##          187          188          189          190          191          192 
##  0.477076081  0.771646431  0.480120579  1.042083079 -0.318155687  1.129659592 
##          193          194          195          196          197          198 
##  0.528938013  0.487467725  0.319585433 -0.842365750 -0.555558992  0.561951510 
##          199          200          201          202          203          204 
##  1.764146945  1.054168325  0.375417742 -0.059894672 -1.492542275 -0.185182744 
##          205          206          207          208          209          210 
##  1.970780078  0.025533881  1.008612129  1.168977287 -0.763946396 -0.223150262 
##          211          212          213          214          215          216 
## -0.032383691 -2.248839586  0.368804746  1.473175112  0.998332220  0.270726910 
##          217          218          219          220          221          222 
##  1.320450433 -1.007768380  0.310401500 -1.299725605 -0.618838111 -0.906103777 
##          223          224          225          226          227          228 
##  1.622311938 -1.349318843 -2.629283562  0.699065538  0.379005478 -0.168999794 
##          229          230          231          232          233          234 
## -0.219144068  1.269938803  1.878282514  0.980690589 -0.032383691  1.262799170 
##          235          236          237          238          239          240 
##  0.731049982 -2.478824898  0.521448276  0.432731485  0.704826204  0.310042679 
##          241          242          243          244          245          246 
## -3.531928835 -1.653605688 -0.732534664  0.565541383  1.228494252 -0.683391873 
##          247          248          249          250          251          252 
##  0.188898068  0.071435567  0.071435567  1.600992158  1.708487560 -0.844312670 
##          253          254          255          256          257          258 
## -1.583085378 -0.576486323  1.292603577  0.147215416 -0.908309271 -0.674119864 
##          259          260          261          262          263          264 
## -1.539426252 -1.209221474  0.463038464 -0.427327667 -0.409499920 -0.141681823 
##          265          266          267          268          269          270 
##  0.524761239 -0.542135482  0.039750999 -0.525152710 -0.860733616  0.883203391 
##          271          272          273          274          275          276 
##  0.081139411  0.426668462 -0.973633484 -0.621307742  0.243157818 -0.905850273 
##          277          278          279          280          281          282 
##  0.328575685  0.936374330 -0.172909860 -0.313436030 -0.120304446  0.416748968 
##          283          284          285          286          287          288 
##  0.131563507 -0.142600294 -0.365001715  1.203179772 -0.284082902 -0.102167523 
##          289          290          291          292          293          294 
## -0.176324254  0.285503306  2.166220788 -0.497547716  0.550558552  0.863179727 
##          295          296          297          298          299          300 
##  0.222359952  0.684095734 -0.669172823  0.665097660 -0.746912331 -1.030868927 
##          301          302          303          304          305          306 
## -0.353537059  1.508550861  0.785540750  0.677680812  1.709687632  0.606925846 
##          307          308          309          310          311          312 
## -1.108031312  1.125220112 -0.072385519 -0.740125254  0.313247326  0.179798732 
##          313          314          315          316          317          318 
## -1.035271355  2.174832285  0.427251864 -0.388939916 -0.807445714  0.319277659 
##          319          320          321          322          323          324 
##  1.640882760  1.824439024  1.640882760  0.576017238  1.034645844  1.020429611 
```

```
##         325          326          327          328          329          330 
##  0.599904258  1.313601941  1.056157025 -0.333817851 -0.332900678  0.259317585 
##         331          332          333          334          335          336 
##  0.552119371 -0.857431613 -0.115897672 -0.878618297 -0.452555595 -0.091814872 
##         337          338          339          340          341          342 
##  0.589186177 -0.135024094  0.468325345 -0.022878337  0.881326939 -1.088938400 
##         343          344          345          346          347          348 
##  2.079446348  0.459628052  0.210035235  0.319277659  0.819480670 -0.623604980 
##         349          350          351          352          353          354 
## -0.689593457 -0.461992703 -1.080442099 -0.110565683 -0.490343260  0.059661674 
##         355          356          357          358          359          360 
##  0.037636999 -0.352366111 -1.436415778 -1.034452258  0.267560435 -0.251294926 
##         361          362          363          364          365          366 
##  0.012087687 -1.752631038 -0.100562438  0.065167725  0.131459790 -2.144567779 
##         367          368          369          370          371          372 
## -0.579338464  0.822658886 -0.561245098 -0.759414158  0.783210849  0.737264134 
##         373          374          375          376          377          378 
## -0.596095624  0.045280105 -0.630714814  0.047029479 -0.160409441 -0.503608986 
##         379          380          381          382          383          384 
##  0.920398795  0.354061758 -0.172444299  1.920587709  0.414445712  0.416217239 
##         385          386          387          388          389          390 
##  0.310178454 -1.337472815  1.149652173 -0.094094416  0.682050584  0.778700519 
##         391          392          393          394          395          396 
## -2.037402438  0.417928820 -0.651062247 -0.165157216  1.069483293  1.054022679 
##         397          398          399          400          401          402 
##  1.070311541  1.048869140  0.762755743 -0.327125560  1.589885223 -2.023032326 
##         403          404          405          406          407          408 
##  0.777070846  1.111753703 -1.010513104  1.458379679  0.812758115  0.764688320 
##         409          410          411          412          413          414 
## -0.233809707 -0.796833756 -0.539340901  0.370718729 -0.128184132  0.495230698 
##         415          416          417          418          419          420 
## -1.226647557 -0.316481314  0.209302551  0.264043920 -1.515356358  0.019742813 
##         421          422          423          424          425          426 
##  0.919533281 -1.624344748  0.412648633  0.810953458  0.191173140 -0.776403658 
##         427          428          429          430          431          432 
##  0.545601052 -0.100562438  0.503899407  0.053918055  1.221081077 -0.280743716 
##         433          434          435          436          437          438 
##  0.389216250 -0.424306566  0.322594290 -0.853302666  0.349644439  0.268371319 
##         439          440          441          442          443          444 
##  0.138891446 -0.722096326  1.105936102 -1.880365718  0.120598877 -0.147005096 
##         445          446          447          448          449          450 
## -0.294112394  1.246460135 -0.232380362 -1.163175978  0.211015784 -0.129844332 
##         451          452          453          454          455          456 
## -1.444540992 -0.328928391  0.195580589 -0.924757336 -0.298529413 -0.911894674 
##         457          458          459          460          461          462 
## -0.861458391 -0.477888209 -0.915723238  0.025209823 -0.312127085 -0.570574317 
##         463          464          465          466          467          468 
##  0.798247124  0.631270332  0.191237612 -0.926567081 -0.526171988 -0.591614371 
##         469          470          471          472          473          474 
##  0.270000280 -0.395183136 -0.521418900  1.303560865  0.984032761  1.361759335 
##         475          476          477          478          479          480 
##  0.727945943 -1.102917364 -0.350464984  1.126377991  0.976711722 -1.261391596 
##         481          482          483          484          485          486 
##  0.828699224  0.122539040 -0.438502640 -0.815444928  1.325261184 -0.652042464 
```

```
##          487          488          489          490          491          492 
## -0.054548086  0.250724984  0.034215726  1.180722307  0.398311516  0.663434271 
##          493          494          495          496          497          498 
##  1.367920422  0.262190807  1.601837131  0.804535794 -0.325357252 -0.279419171 
##          499          500          501          502          503          504 
##  0.644120014  0.241334918  0.477272903 -0.115879602  0.599100694 -0.152482955 
##          505          506          507          508          509          510 
##  0.712992352 -0.432096857 -0.500440837 -0.801587203 -0.279419171  1.301677709 
##          511          512          513          514          515          516 
##  0.392379329  0.029284735  0.113443300  0.618334574 -1.032720500  1.285897893 
##          517          518          519          520          521          522 
## -0.737004730  0.008529960 -0.184106347 -1.428840326  0.950470928  0.489982802 
##          523          524          525          526          527          528 
## -0.168750613  0.565563999 -0.866098875  0.235194397  0.543508727  1.384917371 
##          529          530          531          532          533          534 
## -1.022323722  0.611880071  0.675725414 -3.539073821  0.530900776  0.606484091 
##          535          536          537          538          539          540 
##  0.045769914  0.194089974 -6.483703648 -0.087662229 -0.694788801 -1.585320450 
##          541          542          543          544          545          546 
## -0.709704500  0.603173024 -0.801571288 -0.260162370 -0.725128940 -1.535642411 
##          547          548          549          550          551          552 
##  0.650374956  0.793532189  0.328340053 -0.239683398  1.112543369 -0.625394850 
##          553          554          555          556          557          558 
## -0.677953758  0.659491776 -0.512252679 -0.194499503  0.656160014 -1.388804235 
##          559          560          561          562          563          564 
## -1.096712603  0.326595353 -1.610838280 -0.252714049 -0.350352169  0.401425456 
##          565          566          567          568          569          570 
## -1.637888713  1.077826474 -0.537094251 -0.351723040  0.098406948  0.163603635 
##          571          572          573          574          575          576 
## -1.066134438  0.014844998  0.675994499 -0.743824056 -0.154525338 -0.681106680 
##          577          578          579          580          581          582 
## -0.034741215 -0.659600727  0.454428203 -0.336220336 -1.425115602  1.239797926 
##          583          584          585          586          587          588 
##  0.270099722 -0.731152024 -0.020049004  1.717304965  1.229523555  2.090600841 
##          589          590          591          592          593          594 
## -1.028680164  0.223822379 -0.228488049  1.092563061  1.162919645 -0.706150530 
##          595          596          597          598          599          600 
##  0.759265940 -0.193691499  0.473149512 -0.422253224 -0.641558018 -0.733302359 
##          601          602          603          604          605          606 
##  0.618067001  0.746637650  0.710153890 -0.427298732  0.129627897 -0.648691989 
##          607          608          609          610          611          612 
##  0.204925479  0.809877274  0.211536974  0.328982837  1.002712545  0.444592174 
##          613          614          615          616          617          618 
## -0.878808746 -0.137915845 -0.370540503  0.077824024  1.829253691 -0.825236825 
##          619          620          621          622          623          624 
## -0.905714862 -1.205511609  0.952529441 -1.003720043  0.151603205 -0.657948955 
##          625          626          627          628          629          630 
##  0.670076307  0.679932497  0.223052762  1.794093943  0.317646172 -0.037561735 
##          631          632          633          634          635          636 
##  0.603632662  0.075601032  0.744606568 -0.753781827  1.376174650  1.018472737 
##          637          638          639          640          641          642 
## -0.627598919  0.285069019  1.681989123  1.164767768 -0.496945402  1.264056613 
##          643          644          645          646          647          648 
## -0.645871064  1.190862364  0.948209881  1.598028663 -0.289341532  1.943238083 
```

```
##         649         650         651         652         653         654 
## -0.628599301 -1.080872128  1.661721948 -0.616969776 -0.171484945 -0.450649303 
##         655         656         657         658         659         660 
## -1.685028860  1.050100730 -1.331792914 -1.496377981  0.580046380  0.546044375 
##         661         662         663         664         665         666 
## -0.169016874  0.356653889 -1.266696515 -0.741331322 -0.043479587  0.688910145 
##         667         668         669         670         671         672 
##  0.368305435  0.190450336  0.342111202 -1.518064091  0.375706649  0.175882771 
##         673         674         675         676         677         678 
## -0.258464938  0.407369207 -0.042625697  0.596608218  1.162208276  1.562332633 
##         679         680         681         682         683         684 
##  0.613087131 -1.061229615  0.705764688 -0.261851827  1.087248374 -0.575825242 
##         685         686         687         688         689         690 
## -0.761225209  0.317741808 -0.645042683  0.004873608 -0.430732612 -0.549760568 
##         691         692         693         694         695         696 
## -1.185791315 -1.119520844  1.048421199 -0.143749041 -1.051777697 -0.932492769 
##         697         698         699         700         701         702 
## -3.320518439  1.392883927 -0.037754587  1.202943521 -2.178443845  0.692587177 
##         703         704         705         706         707         708 
## -1.374866270 -0.563712616 -0.532787375 -0.204833693 -0.581718391  0.354982088 
##         709         710         711         712         713         714 
##  0.973608783 -1.653135423  0.038822209  0.025005701 -2.211480498 -0.420387147 
##         715         716         717         718         719         720 
## -0.202998063  1.105977053  0.422080351 -0.496383556 -0.567930030 -0.805269491 
##         721         722         723         724         725         726 
##  0.572637822 -1.211386898 -0.275157155  0.672118818  0.291510377 -0.085337378 
##         727         728         729         730         731         732 
##  0.524818845  1.202236851  0.827854913  1.006412640 -0.715091473  0.506798497 
##         733         734         735         736         737         738 
##  1.681488706  0.013077719 -1.708287059  1.722620390 -0.625449432  0.457209997 
##         739         740         741         742         743         744 
##  1.213358500 -3.173489960 -0.067386333 -2.968176046  2.334709316  0.998735725 
##         745         746         747         748         749         750 
## -0.226577683  0.099573803  0.303680786  0.871487192  0.791472429 -1.191860476 
##         751         752         753         754         755         756 
## -0.218013354 -0.418396308 -0.902263924  0.358006859 -0.320681238  1.448666666 
##         757         758         759         760         761         762 
##  0.657205847  0.913131024  0.156680027 -2.402716419 -1.006579834 -0.543621651 
##         763         764         765         766         767         768 
## -0.428534785  0.563532474 -0.457906664 -0.696053247  0.018458497  0.472316891 
##         769         770         771         772         773         774 
##  2.302618349  0.711623679 -1.049792006  1.405722546  0.719037420  0.628666445 
##         775         776         777         778         779         780 
## -1.064783169  1.020647110 -0.539815463  1.570582173  0.871235849  1.060353044 
##         781         782         783         784         785         786 
##  0.491630659 -2.360920974  0.067567271 -0.018620710 -0.280920080  0.412712878 
##         787         788         789         790         791         792 
## -0.209777394 -0.004403171  1.619241133 -0.298997587 -0.516884736 -1.143123762 
##         793         794         795         796         797         798 
##  0.312197068  0.458310284  0.213865826 -0.776958440  0.801415821  0.268957771 
##         799         800         801         802         803         804 
##  0.423995816  0.757956837  0.969278916 -1.001084437 -0.757859889  0.942571409 
##         805         806         807         808         809         810 
## -0.420848873  0.542797779 -0.544159727 -0.306812869 -0.302136580 -0.172672305 
```

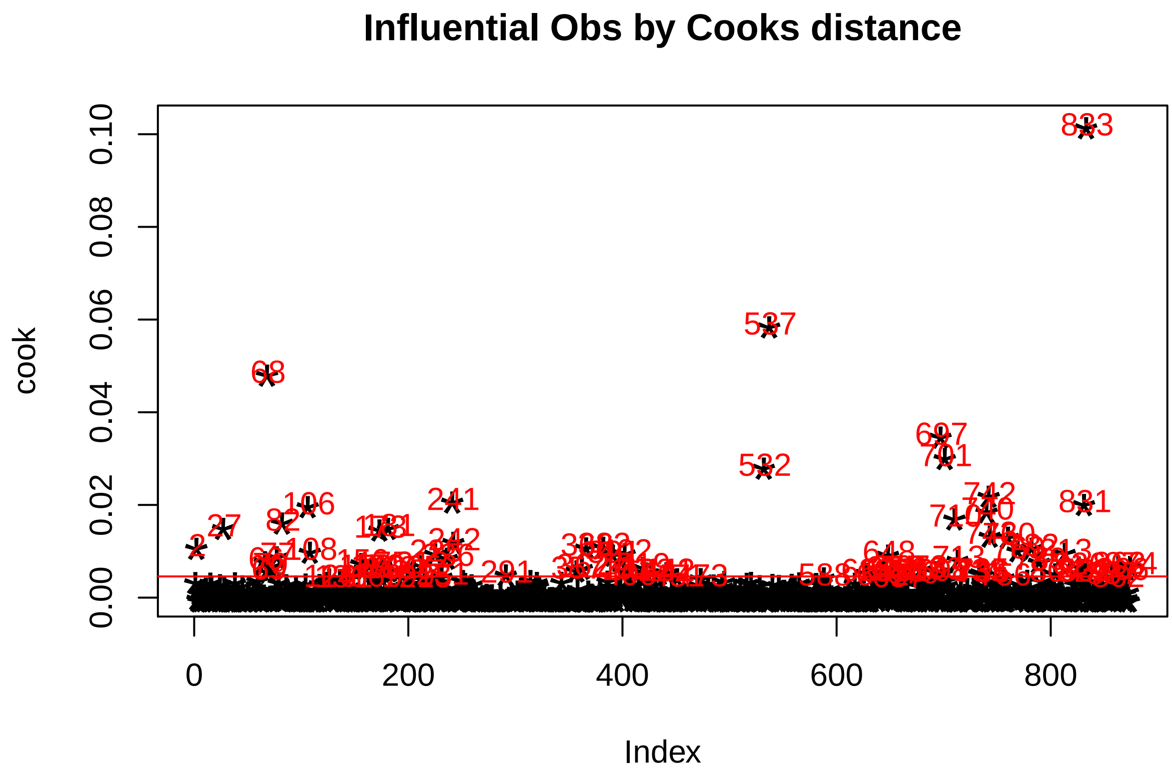
```
##         811         812         813         814         815         816 
## -0.616484276  0.242339785  1.990859498  0.494657073 -0.361841915  0.577207509 
##         817         818         819         820         821         822 
## -0.518749435  0.443198444 -0.063901024  0.928432367  0.624161309 -0.457352831 
##         823         824         825         826         827         828 
##  1.205283640  0.108774299 -0.307946541  1.524957889  0.103339030 -0.848204405 
##         829         830         831         832         833         834 
##  1.532303051  0.587828398 -2.004063992 -1.070193659 -6.671648537 -1.429125982 
##         835         836         837         838         839         840 
## -0.469176808  1.055296759  0.033576640 -0.277926679 -0.006865249 -0.802801123 
##         841         842         843         844         845         846 
## -0.499400841  0.963297348 -0.474700782 -0.069076969 -0.286323129  0.140656156 
##         847         848         849         850         851         852 
##  1.269751669 -1.272346739  0.572785243  0.454987895 -0.536771984  0.222953353 
##         853         854         855         856         857         858 
##  1.160220188 -0.597871149  0.136907466 -0.665052470  1.393024587  0.390066905 
##         859         860         861         862         863         864 
##  0.574223459 -0.914802854  0.608953652  1.076139169  1.522288597  0.936751371 
##         865         866         867         868         869         870 
## -0.408318552  1.383929139 -1.182638805  0.330590954  0.496854396  0.005407740 
##         871         872         873         874 
## -0.413636938  0.751023077 -0.010734196 -1.517560932
```

```r
## get sample size
n <- nrow(SCMUdf)

## Bonferroni correction: alpha/n
alpha <- 0.05/n

## critical t value
degf <- n - length(coef(global_mod))-1 # should be more due to REs?
t_crit <- qt(1 - alpha/2, degf)

## compare t_stud to t_crit
sum(stud_e > t_crit, na.rm = TRUE)
```

```
## [1] 0
```

Cook's Distance

```r
## Cook's D
cook <- cooks.distance(global_mod)

# Plot the Cook's Distance using the traditional 4/n criterion
sample_size <- nrow(SCMUdf)
plot(cook, pch="*", cex=2, main="Influential Obs by Cooks distance")  # plot cook's distance
abline(h = 4/sample_size, col="red")  # add cutoff line
text(x=1:length(cook)+1, y=cook, labels=ifelse(cook>4/sample_size, names(cook),""), col="red")  # add l
```



Fit Candidate Models

```
## create empty matrix for storing results
mod_res <- matrix(NA, n_mods, 1)
colnames(mod_res) <- c("AIC")

## fit models and store AIC & BIC
for(i in 1:n_mods) {
  if(i == 1) {
    fmla <- "Size ~ 1 + (1 | Plot)"
  } else {
    fmla <- paste("Size ~ (1 | Plot) +", paste(cov_names[use_set[i,]], collapse = " + "))
  }
  mod_fit <- lmer(as.formula(fmla), data = SCMUdf, REML = TRUE)
  mod_res[i,"AIC"] <- AIC(mod_fit)
}

## create empty matrix for storing results
delta_res <- matrix(NA, n_mods, 1)
colnames(delta_res) <- c("deltaAIC")

## convert IC to deltaIC
delta_res[,"deltaAIC"] <- mod_res[,"AIC"] - min(mod_res[,"AIC"])
(delta_res <- round(delta_res, 2)) # round results
```

```
##       deltaAIC
##  [1,]    46.71
##  [2,]    30.00
##  [3,]    33.15
##  [4,]    16.13
##  [5,]    35.29
##  [6,]    18.40
##  [7,]    27.49
##  [8,]    10.44
##  [9,]    24.40
## [10,]     7.37
## [11,]    17.14
## [12,]     0.00
## [13,]    31.96
## [14,]    14.62
## [15,]    18.42
## [16,]     1.09
## [17,]    26.12
## [18,]     9.04
## [19,]    36.41
## [20,]    19.58
## [21,]    28.84
## [22,]    11.83
## [23,]    25.65
## [24,]     8.64
## [25,]    21.66
## [26,]     4.61
## [27,]    26.89
## [28,]     9.60
## [29,]    22.92
## [30,]     5.84
```

```
## "best" models from our set
cov_names[use_set[12,]] # Egg order, BEUTI, NPGO
```

```
## [1] "EggOrder" "BEUTI"    "NPGO"
```

```
cov_names[use_set[16,]] # Egg order, NPGO, ONI
```

```
## [1] "EggOrder" "NPGO"     "ONI"
```

```
cov_names[use_set[26,]] # Egg order, ANCHL, BEUTI, SST (>2 AIC)
```

```
## [1] "EggOrder" "ANCHL"    "BEUTI"    "SST"
```

```
cov_names[use_set[30,]] # Egg order, PDO, SST (>2 AIC)
```

```
## [1] "EggOrder" "PDO"      "SST"
```

```
cov_names[use_set[10,]] # Egg order, NPGO (>2 AIC)
```

```
## [1] "EggOrder" "NPGO"
```

```
cov_names[use_set[24,]] # Egg order, BEUTI, SST (>2 AIC)
```

```
## [1] "EggOrder" "BEUTI"    "SST"
```

```
## run top models
topmod1 <- lmer(Size ~ EggOrder + BEUTI + NPGO + (1 | Plot), data = SCMUdf, REML = TRUE)
```

```r
topmod2 <- lmer(Size ~ EggOrder + NPGO + ONI + (1 | Plot), data = SCMUdf, REML = TRUE)
topmod3 <- lmer(Size ~ EggOrder + ANCHL + BEUTI + SST + (1 | Plot), data = SCMUdf, REML = TRUE)
topmod4 <- lmer(Size ~ EggOrder + PDO + SST + (1 | Plot), data = SCMUdf, REML = TRUE)
topmod5 <- lmer(Size ~ EggOrder + NPGO + (1 | Plot), data = SCMUdf, REML = TRUE)
topmod6 <-lmer(Size ~ EggOrder + BEUTI + SST + (1 | Plot), data = SCMUdf, REML = TRUE)

## Model selection table
AIC.tab <- matrix(NA, nrow = 6, ncol = 3) # 6 rows for 6 top models
AIC.tab[1,1] <- AIC(topmod1) # AIC for topmod1 in first row, first column
AIC.tab[2,1] <- AIC(topmod2) # AIC for topmod2 in second row, first column
AIC.tab[3,1] <- AIC(topmod3) # AIC for topmod3 in second row, first column
AIC.tab[4,1] <- AIC(topmod4) # AIC for topmod4 in second row, first column
AIC.tab[5,1] <- AIC(topmod5) # AIC for topmod5 in second row, first column
AIC.tab[6,1] <- AIC(topmod6) # AIC for topmod6 in second row, first column
AIC.tab[,2] <- AIC.tab[,1] - min(AIC.tab[,1]) # calculate delta AIC
AIC.tab[,3] <- exp(-0.5*AIC.tab[,2])/(sum(exp(-0.5*AIC.tab[,2]))) # calculate model weights
colnames(AIC.tab) <- c("AIC", "deltaAIC", "model_weights")
print(AIC.tab)
```

```
##           AIC deltaAIC model_weights
## [1,] 10672.18 0.000000   0.564433704
## [2,] 10673.27 1.090108   0.327264573
## [3,] 10676.79 4.610461   0.056294240
## [4,] 10678.02 5.844698   0.030370563
## [5,] 10679.55 7.374504   0.014133824
## [6,] 10680.82 8.641014   0.007503096
```

Top Models

Here we look at the top competitive models.

Top Model 1

```r
topmod1 <- lmer(Size ~ EggOrder + BEUTI + NPGO + (1 | Plot), data = SCMUdf, REML = TRUE)
summary(topmod1)
```

```
## Linear mixed model fit by REML ['lmerMod']
## Formula: Size ~ EggOrder + BEUTI + NPGO + (1 | Plot)
##    Data: SCMUdf
##
## REML criterion at convergence: 10660.2
##
## Scaled residuals:
##     Min      1Q  Median      3Q     Max
## -6.6372 -0.6084  0.0419  0.6738  2.3199
##
## Random effects:
##  Groups   Name        Variance Std.Dev.
##  Plot     (Intercept)   239.4   15.47
##  Residual             11850.7  108.86
## Number of obs: 874, groups:  Plot, 8
##
## Fixed effects:
```

```
##              Estimate Std. Error t value
## (Intercept)  1887.427      8.104 232.901
## EggOrderEgg2   32.931      9.148   3.600
## BEUTI         -10.404      4.954  -2.100
## NPGO          -15.062      3.711  -4.059
##
## Correlation of Fixed Effects:
##             (Intr) EggOE2 BEUTI
## EggOrdrEgg2 -0.236
## BEUTI        0.078 -0.002
## NPGO        -0.065  0.000 -0.230
```

Top Model 2

```
topmod2 <- lmer(Size ~ EggOrder + NPGO + ONI + (1 | Plot), data = SCMUdf, REML = TRUE)
summary(topmod2)
```

```
## Linear mixed model fit by REML ['lmerMod']
## Formula: Size ~ EggOrder + NPGO + ONI + (1 | Plot)
##    Data: SCMUdf
##
## REML criterion at convergence: 10661.3
##
## Scaled residuals:
##     Min      1Q  Median      3Q     Max
## -6.6268 -0.6169  0.0493  0.6724  2.3808
##
## Random effects:
##  Groups   Name        Variance Std.Dev.
##  Plot     (Intercept)   257.1   16.03
##  Residual             11863.3  108.92
## Number of obs: 874, groups:  Plot, 8
##
## Fixed effects:
##              Estimate Std. Error t value
## (Intercept)  1887.453      8.301 227.380
## EggOrderEgg2   33.196      9.154   3.626
## NPGO          -13.532      4.052  -3.340
## ONI             9.174      5.103   1.798
##
## Correlation of Fixed Effects:
##             (Intr) EggOE2 NPGO
## EggOrdrEgg2 -0.232
## NPGO        -0.079  0.009
## ONI         -0.077  0.019  0.452
```

Prediction

```
topmod1 <- lmer(Size ~ EggOrder + BEUTI + NPGO + (1 | Plot), data = SCMUdf, REML = TRUE)
topmod2 <- lmer(Size ~ EggOrder + NPGO + ONI + (1 | Plot), data = SCMUdf, REML = TRUE)

# AIC tab for 2 top models
AIC.tab2 <- matrix(NA, nrow = 2, ncol = 3)
```

```
AIC.tab2[1,1] <- AIC(topmod1)
AIC.tab2[2,1] <- AIC(topmod2)
AIC.tab2[,2] <- AIC.tab2[,1] - min(AIC.tab2[,1])
AIC.tab2[,3] <- exp(-0.5*AIC.tab2[,2])/(sum(exp(-0.5*AIC.tab2[,2])))
print(AIC.tab2)
```

```
##          [,1]     [,2]      [,3]
## [1,] 10672.18 0.000000 0.6329873
## [2,] 10673.27 1.090108 0.3670127
```

```
#we want predictions with all predictors but one held constant, and then we'll do this one-at-a-time fo
# this will allow us to produce nice plots looking at the marginal effect of each predictor

#first, set up a dataset with everything at its mean value (except EggOrder)
set.seed(1)
SCMU.null <- SCMUdf[c(1:200),]
SCMU.null$EggOrder <- c(rep("Egg1",100),rep("Egg2",100))
SCMU.null$BEUTI <- mean(SCMUdf$BEUTI)
SCMU.null$NPGO <- mean(SCMUdf$NPGO)
SCMU.null$ONI <- mean(SCMUdf$ONI)
SCMU.null$ANCHL <- mean(SCMUdf$ANCHL)
SCMU.null$PDO <- mean(SCMUdf$PDO)
SCMU.null$SST <- mean(SCMUdf$SST)
#I'm pretty sure you need some values of plot and observer but it doesn't matter which ones because we'

SCMU.null$Plot <- sample(SCMUdf$Plot,200,replace = TRUE)
#SCMU.null$Observer <- sample(SCMUdf$Observer,200,replace = TRUE)
```

BEUTI

```
#then vary just one predictor at a time for prediction. For example, create the dataset SCMU. BEUTI tha
SCMU.BEUTI <- SCMU.null
SCMU.BEUTI$BEUTI <- rep(seq(from = min(SCMUdf$BEUTI),to = max(SCMUdf$BEUTI),length.out = 100),2)

#PREDICT FOR SCMU.BEUTI
#Pull together the random effects (do we want the models with)

# obs.sd.1 <- as.data.frame(VarCorr(bm1))$sdcor[1]
# plot.sd.1 <- as.data.frame(VarCorr(bm1))$sdcor[2]
# resid.sd.1 <- as.data.frame(VarCorr(bm1))$sdcor[3]
#
# obs.sd.2 <- as.data.frame(VarCorr(bm2))$sdcor[1]
# plot.sd.2 <- as.data.frame(VarCorr(bm2))$sdcor[2]
# resid.sd.2 <- as.data.frame(VarCorr(bm2))$sdcor[3]
#
# obs.sd.3 <- as.data.frame(VarCorr(bm3))$sdcor[1]
# plot.sd.3 <- as.data.frame(VarCorr(bm3))$sdcor[2]
# resid.sd.3 <- as.data.frame(VarCorr(bm3))$sdcor[3]

plot.sd.1 <- as.data.frame(VarCorr(topmod1))$sdcor[1]
resid.sd.1 <- as.data.frame(VarCorr(topmod1))$sdcor[2]

plot.sd.2 <- as.data.frame(VarCorr(topmod2))$sdcor[1]
resid.sd.2 <- as.data.frame(VarCorr(topmod2))$sdcor[2]
```

```r
sims <- 10000

# pv <- matrix(nrow = sims, ncol = nrow(SCMU.BEUTI))
# for(i in 1:sims){
#   #choose a model
#   model <- which(rmultinom(n = 1, size = 1,prob = c(AIC.tab[,3]))==1)
#   if(model == 1){
#     #we simulate conditioning on no specific random effects levels
#     y <- unlist(simulate(bm1))
#     bmod <- refit(bm1,y)
#     pv[i,] <- predict(bmod, re.form = ~0, newdata = SCMU.BEUTI) + rnorm(1,0,sd=obs.sd.1) + rnorm(1,0,
#   }
#   if(model == 2){
#     #we simulate conditioning on no specific random effects levels
#     y <- unlist(simulate(bm2))
#     bmod <- refit(bm2,y)
#     pv[i,] <- predict(bmod, re.form = ~0, newdata = SCMU.BEUTI) + rnorm(1,0,sd=obs.sd.2) + rnorm(1,0,
#   }
#   if(model == 3){
#     #we simulate conditioning on no specific random effects levels
#     y <- unlist(simulate(bm3))
#     bmod <- refit(bm3,y)
#     pv[i,] <- predict(bmod, re.form = ~0, newdata = SCMU.BEUTI) + rnorm(1,0,sd=obs.sd.3) + rnorm(1,0,
#   }
# }

## Marcela tried updating
pv.BEUTI <- matrix(nrow = sims, ncol = nrow(SCMU.BEUTI))
for(i in 1:sims){
  #choose a model
  model <- which(rmultinom(n = 1, size = 1,prob = c(AIC.tab2[,3]))==1)
  if(model == 1){
    #we simulate conditioning on no specific random effects levels
    y <- unlist(simulate(topmod1))
    bmod <- refit(topmod1,y)
    pv.BEUTI[i,] <- predict(bmod, re.form = ~0, newdata = SCMU.BEUTI) + rnorm(1,0,sd=plot.sd.1) + rnorm
  }
  if(model == 2){
    #we simulate conditioning on no specific random effects levels
    y <- unlist(simulate(topmod2))
    bmod2 <- refit(topmod2,y)
    pv.BEUTI[i,] <- predict(bmod, re.form = ~0, newdata = SCMU.BEUTI) + rnorm(1,0,sd=plot.sd.2) + rnorm
  }
}
```

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## Warning in checkConv(attr(opt, "derivs"), opt$par, ctrl = control$checkConv, :
## Model failed to converge with max|grad| = 0.00594867 (tol = 0.002, component 1)
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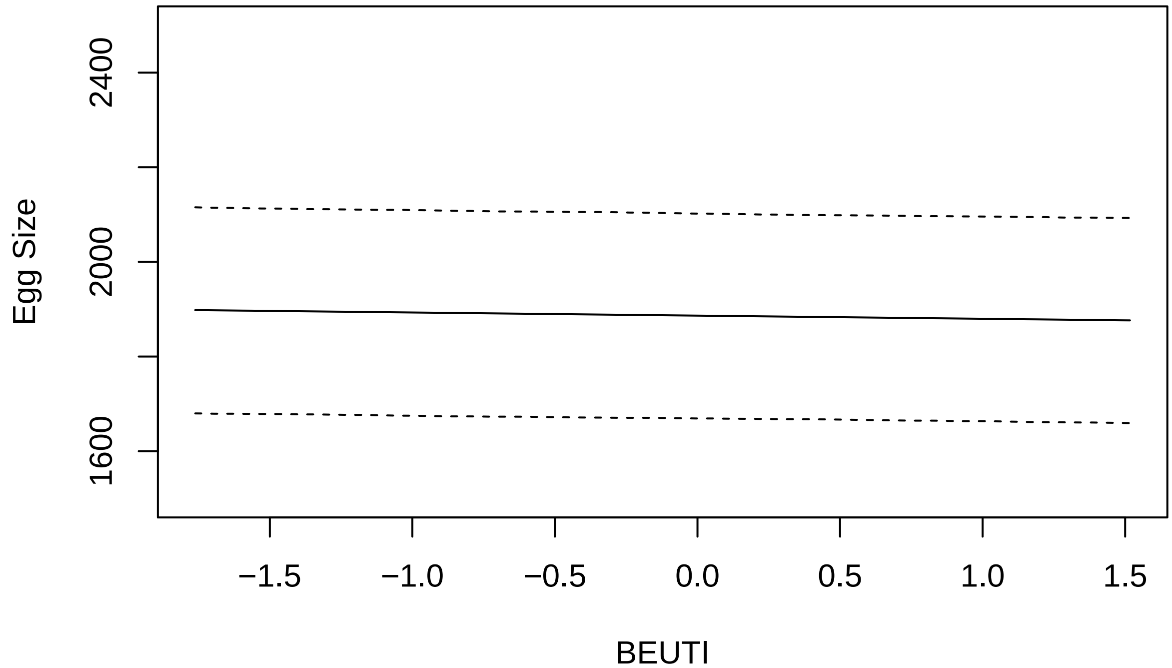
```
##SJC added - you can do plots like this of the predictions and 95% CIs against the individual predicto
plot(SCMU.BEUTI$BEUTI[1:100],y = apply(pv.BEUTI,2,mean)[1:100],xlab = "BEUTI",ylab = "Egg Size",type =
lines(SCMU.BEUTI$BEUTI[1:100],y = apply(pv.BEUTI,2,function(x)quantile(x,probs= 0.025))[1:100],lty=2)
lines(SCMU.BEUTI$BEUTI[1:100],y = apply(pv.BEUTI,2,function(x)quantile(x,probs= 0.975))[1:100],lty=2)
```



NPGO

```
SCMU.NPGO <- SCMU.null
SCMU.NPGO$NPGO <- rep(seq(from = min(SCMUdf$NPGO),to = max(SCMUdf$NPGO),length.out = 100),2)

plot.sd.1 <- as.data.frame(VarCorr(topmod1))$sdcor[1]
resid.sd.1 <- as.data.frame(VarCorr(topmod1))$sdcor[2]

plot.sd.2 <- as.data.frame(VarCorr(topmod2))$sdcor[1]
resid.sd.2 <- as.data.frame(VarCorr(topmod2))$sdcor[2]

sims <- 10000

pv.NPGO <- matrix(nrow = sims, ncol = nrow(SCMU.NPGO))
for(i in 1:sims){
  #choose a model
  model <- which(rmultinom(n = 1, size = 1,prob = c(AIC.tab2[,3]))==1)
  if(model == 1){
    #we simulate conditioning on no specific random effects levels
    y <- unlist(simulate(topmod1))
```

```
    bmod <- refit(topmod1,y)
    pv.NPGO[i,] <- predict(bmod, re.form = ~0, newdata = SCMU.NPGO) + rnorm(1,0,sd=plot.sd.1) + rnorm(1
  }
  if(model == 2){
    #we simulate conditioning on no specific random effects levels
    y <- unlist(simulate(topmod2))
    bmod <- refit(topmod2,y)
    pv.NPGO[i,] <- predict(bmod, re.form = ~0, newdata = SCMU.NPGO) + rnorm(1,0,sd=plot.sd.2) + rnorm(1
  }
}
```

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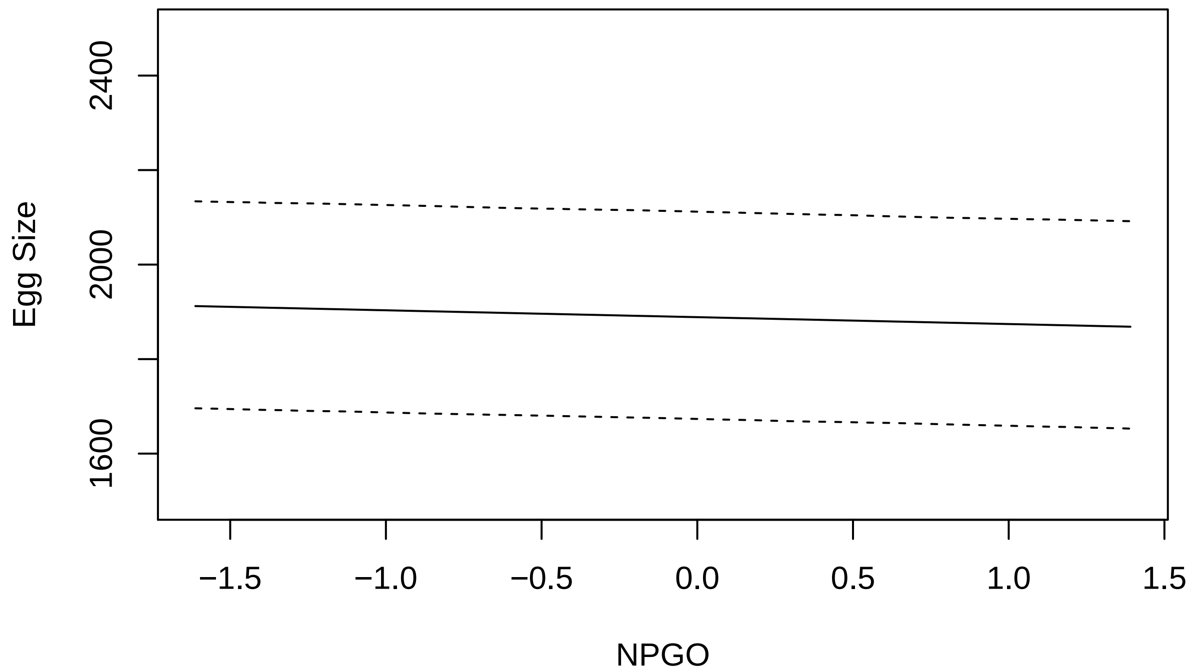
```r
plot(SCMU.NPGO$NPGO[1:100],y = apply(pv.NPGO,2,mean)[1:100],xlab = "NPGO",ylab = "Egg Size",type = "l",
lines(SCMU.NPGO$NPGO[1:100],y = apply(pv.NPGO,2,function(x)quantile(x,probs= 0.025))[1:100],lty=2)
lines(SCMU.NPGO$NPGO[1:100],y = apply(pv.NPGO,2,function(x)quantile(x,probs= 0.975))[1:100],lty=2)
```



ONI

```
SCMU.ONI <- SCMU.null
SCMU.ONI$ONI <- rep(seq(from = min(SCMUdf$ONI),to = max(SCMUdf$ONI),length.out = 100),2)

plot.sd.1 <- as.data.frame(VarCorr(topmod1))$sdcor[1]
resid.sd.1 <- as.data.frame(VarCorr(topmod1))$sdcor[2]

plot.sd.2 <- as.data.frame(VarCorr(topmod2))$sdcor[1]
resid.sd.2 <- as.data.frame(VarCorr(topmod2))$sdcor[2]

sims <- 10000

pv.ONI <- matrix(nrow = sims, ncol = nrow(SCMU.ONI))
for(i in 1:sims){
  #choose a model
  model <- which(rmultinom(n = 1, size = 1,prob = c(AIC.tab2[,3]))==1)
  if(model == 1){
    #we simulate conditioning on no specific random effects levels
    y <- unlist(simulate(topmod1))
    bmod <- refit(topmod1,y)
    pv.ONI[i,] <- predict(bmod, re.form = ~0, newdata = SCMU.ONI) + rnorm(1,0,sd=plot.sd.1) + rnorm(1,0
  }
  if(model == 2){
    #we simulate conditioning on no specific random effects levels
```

```r
    y <- unlist(simulate(topmod2))
    bmod <- refit(topmod2,y)
    pv.ONI[i,] <- predict(bmod, re.form = ~0, newdata = SCMU.ONI) + rnorm(1,0,sd=plot.sd.2) + rnorm(1,0
  }
}
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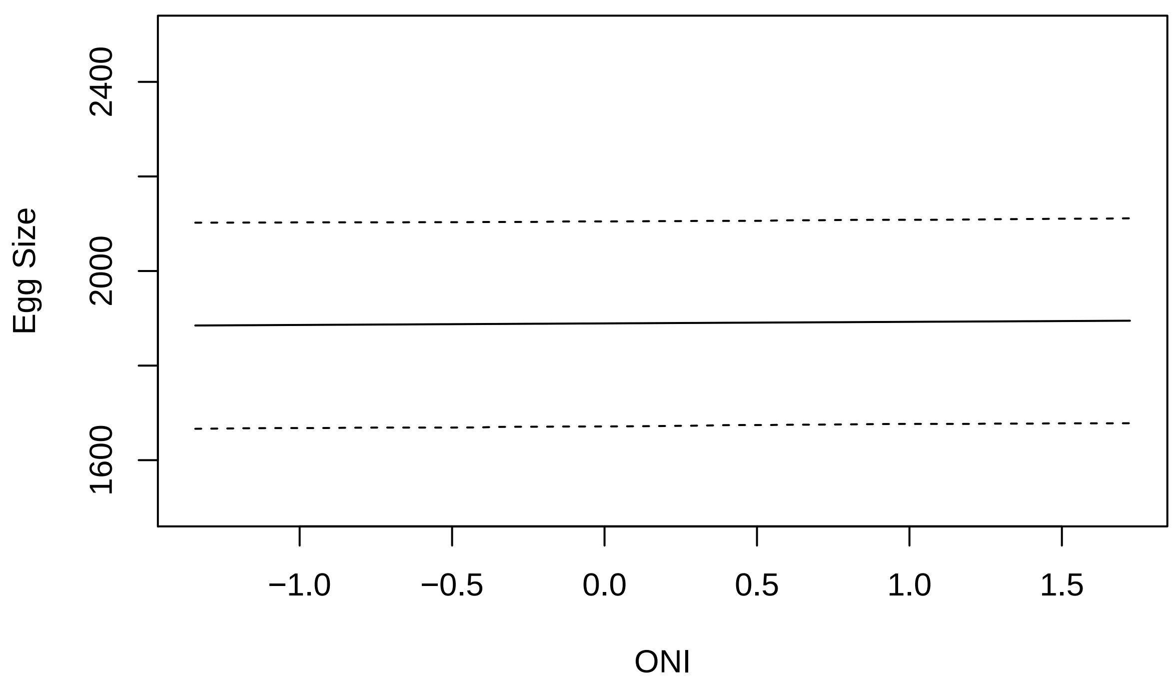
```
plot(SCMU.ONI$ONI[1:100],y = apply(pv.ONI,2,mean)[1:100],xlab = "ONI",ylab = "Egg Size",type = "l",ylim
lines(SCMU.ONI$ONI[1:100],y = apply(pv.ONI,2,function(x)quantile(x,probs= 0.025))[1:100],lty=2)
lines(SCMU.ONI$ONI[1:100],y = apply(pv.ONI,2,function(x)quantile(x,probs= 0.975))[1:100],lty=2)
```



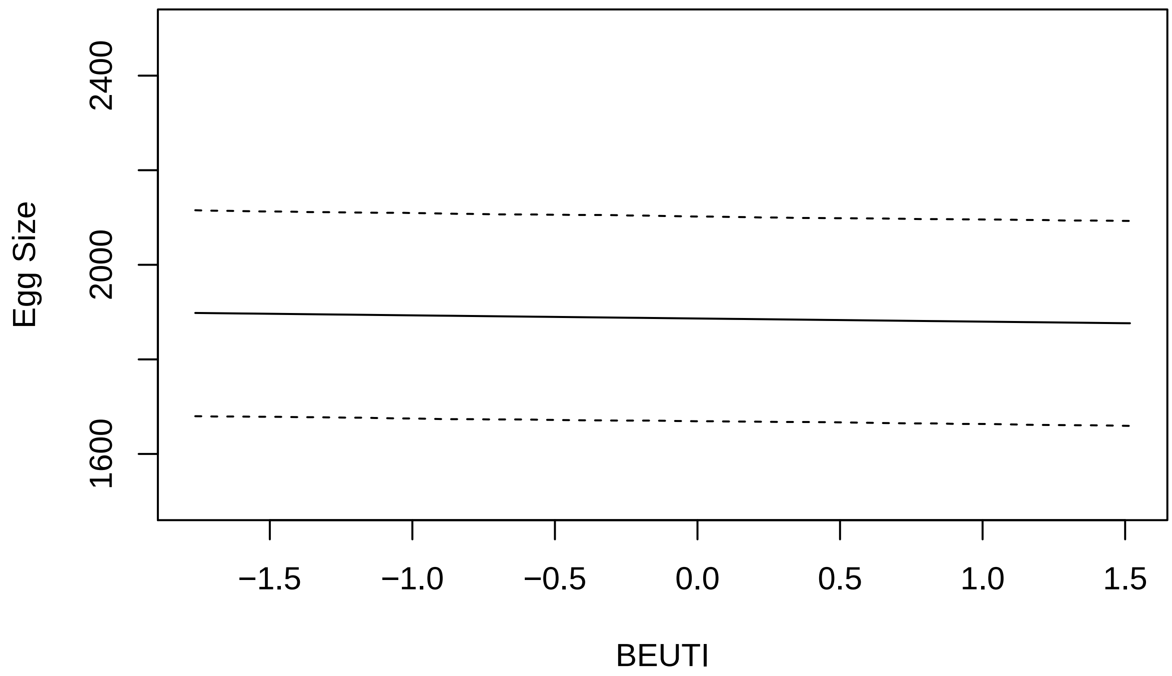
SST

```
# SCMU.SST <- SCMU.null
# SCMU.SST$SST <- rep(seq(from = min(SCMUdf$SST),to = max(SCMUdf$SST),length.out = 100),2)
#
# plot.sd.1 <- as.data.frame(VarCorr(topmod1))$sdcor[1]
# resid.sd.1 <- as.data.frame(VarCorr(topmod1))$sdcor[2]
#
```

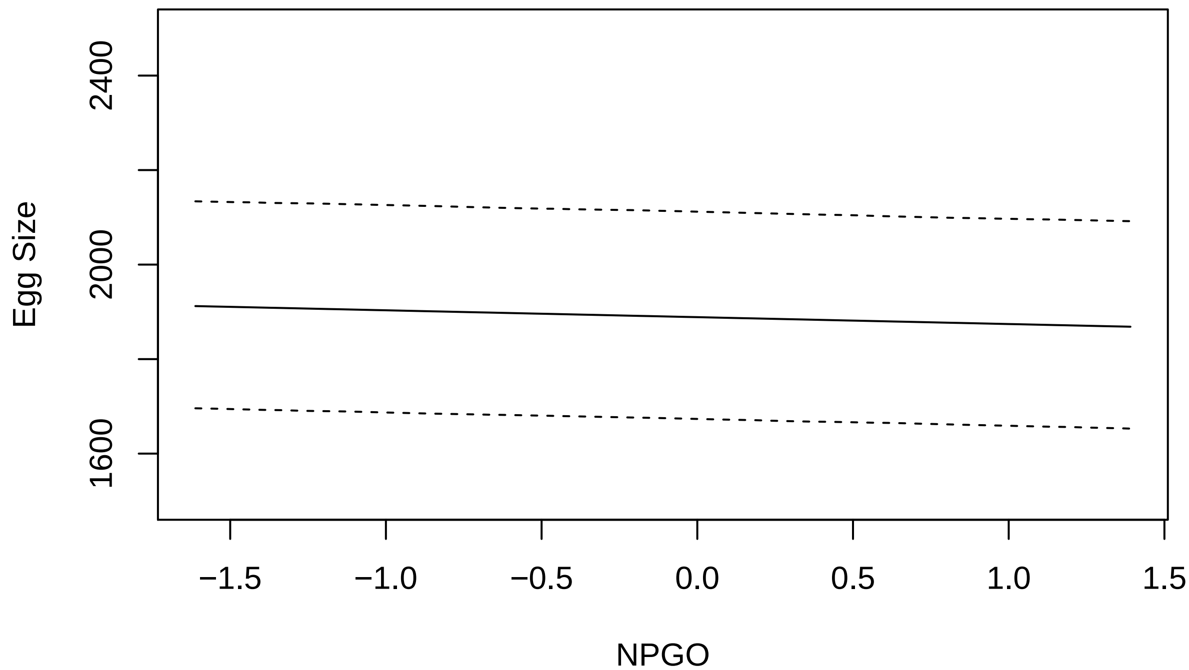
```
# plot.sd.2 <- as.data.frame(VarCorr(topmod2))$sdcor[1]
# resid.sd.2 <- as.data.frame(VarCorr(topmod2))$sdcor[2]
#
# sims <- 10000
#
# pv.SST <- matrix(nrow = sims, ncol = nrow(SCMU.SST))
# for(i in 1:sims){
#   #choose a model
#   model <- which(rmultinom(n = 1, size = 1,prob = c(AIC.tab2[,3]))==1)
#   if(model == 1){
#     #we simulate conditioning on no specific random effects levels
#     y <- unlist(simulate(topmod1))
#     bmod <- refit(topmod1,y)
#     pv.SST[i,] <- predict(bmod, re.form = ~0, newdata = SCMU.SST) + rnorm(1,0,sd=plot.sd.1) + rnorm(1
#   }
#   if(model == 2){
#     #we simulate conditioning on no specific random effects levels
#     y <- unlist(simulate(topmod2))
#     bmod <- refit(topmod2,y)
#     pv.SST[i,] <- predict(bmod, re.form = ~0, newdata = SCMU.SST) + rnorm(1,0,sd=plot.sd.2) + rnorm(1
#   }
# }
#
# plot(SCMU.SST$SST[1:100],y = apply(pv.SST,2,mean)[1:100],xlab = "SST",ylab = "Egg Size",type = "l",yl
# lines(SCMU.SST$SST[1:100],y = apply(pv.SST,2,function(x)quantile(x,probs= 0.025))[1:100],lty=2)
# lines(SCMU.SST$SST[1:100],y = apply(pv.SST,2,function(x)quantile(x,probs= 0.975))[1:100],lty=2)
```

Plots

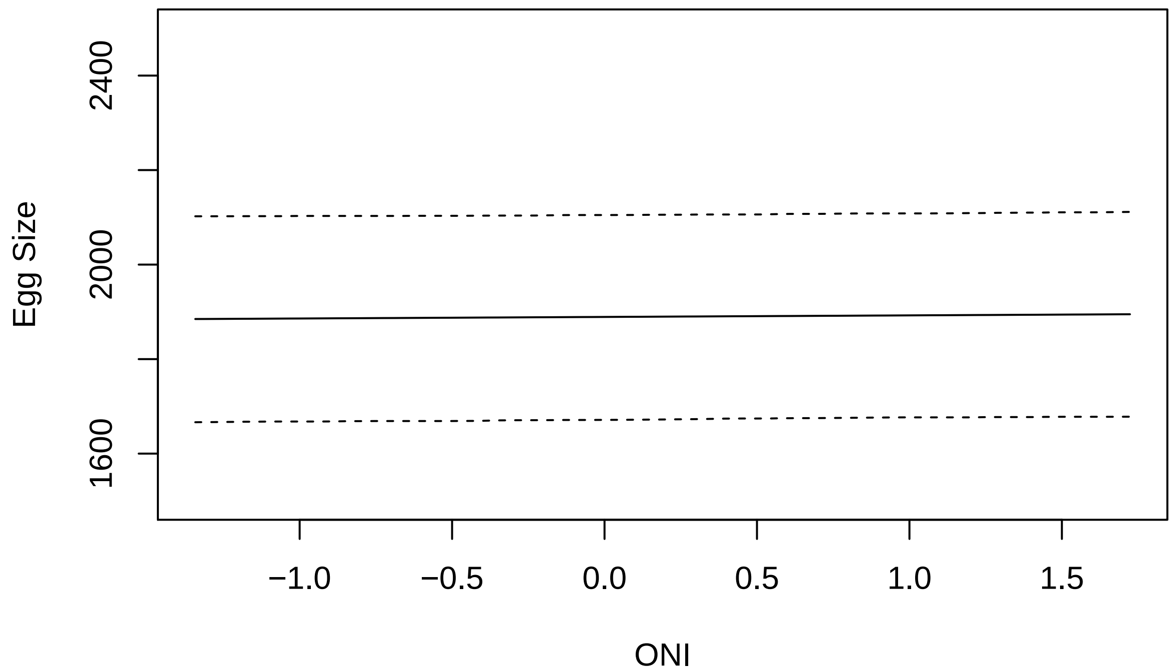
```
plot(SCMU.BEUTI$BEUTI[1:100],y = apply(pv.BEUTI,2,mean)[1:100],xlab = "BEUTI",ylab = "Egg Size",type =
lines(SCMU.BEUTI$BEUTI[1:100],y = apply(pv.BEUTI,2,function(x)quantile(x,probs= 0.025))[1:100],lty=2)
lines(SCMU.BEUTI$BEUTI[1:100],y = apply(pv.BEUTI,2,function(x)quantile(x,probs= 0.975))[1:100],lty=2)
```




```
plot(SCMU.NPGO$NPGO[1:100],y = apply(pv.NPGO,2,mean)[1:100],xlab = "NPGO",ylab = "Egg Size",type = "l",y
lines(SCMU.NPGO$NPGO[1:100],y = apply(pv.NPGO,2,function(x)quantile(x,probs= 0.025))[1:100],lty=2)
lines(SCMU.NPGO$NPGO[1:100],y = apply(pv.NPGO,2,function(x)quantile(x,probs= 0.975))[1:100],lty=2)
```




```
plot(SCMU.ONI$ONI[1:100],y = apply(pv.ONI,2,mean)[1:100],xlab = "ONI",ylab = "Egg Size",type = "l",ylim
lines(SCMU.ONI$ONI[1:100],y = apply(pv.ONI,2,function(x)quantile(x,probs= 0.025))[1:100],lty=2)
lines(SCMU.ONI$ONI[1:100],y = apply(pv.ONI,2,function(x)quantile(x,probs= 0.975))[1:100],lty=2)
```




```
# plot(SCMU.SST$SST[1:100],y = apply(pv.SST,2,mean)[1:100],xlab = "SST",ylab = "Egg Size",type = "l",yl
# lines(SCMU.SST$SST[1:100],y = apply(pv.SST,2,function(x)quantile(x,probs= 0.025))[1:100],lty=2)x
# lines(SCMU.SST$SST[1:100],y = apply(pv.SST,2,function(x)quantile(x,probs= 0.975))[1:100],lty=2)
```