Climate Water Loss Experiment - Capture Hydration Analysis

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Contents

Packages

```
if (!require("tidyverse")) install.packages("tidyverse")
library("tidyverse") # workflow and plots
if (!require("zoo")) install.packages("zoo")
library("zoo") # interpolation using na.approx
if (!require("weathermetrics")) install.packages("weathermetrics")
library("weathermetrics") # F to C conversion
if (!require("lme4")) install.packages("lme4")
library("lme4") # for LMMs
if (!require("lmerTest")) install.packages("lmerTest")
library("lmerTest") # for p-values
if (!require("UsingR")) install.packages("UsingR")
library("UsingR") # simple.eda model assumption checker
if (!require("ggpubr")) install.packages("ggpubr")
library("ggpubr") # for multi-ggplot figs
if (!require("broom")) install.packages("broom")
library("broom") # lmer model export
if (!require("broom.mixed")) install.packages("broom.mixed")
library("broom.mixed") # lmer model export
```

Background and Goals

This data was collected June - August by Master's student Savannah Weaver, advisor Dr. Emily Taylor, and research assistants Tess McIntyre and Taylor Van Rossum. Adult male *Sceloporus occidentalis* were caught across the Cal Poly campus and in Poly Canyon. This R file analyzes the state and variation of osmotic balance and regulation at the time of capture. Please refer to **doi:** for the published scientific journal article and full details.

Data

Load

Read-in and attach all data. Details described later.

```
        # mass and hematocrit data
full_dat <- read.csv("./data/mass_hct_notes.csv", # filename
                             na.strings=c("","NA") # fix empty cells
                             ) %>%
        # format date to enable joining by date
  mutate(measurement_date = as.character(as.Date(measurement_date,
                                          format = "%m/%d/%y"))
         ) %>%
        # join plasma osmolality data
  left_join(read.csv("./data/osml_means_clean.csv", # filename
                             na.strings=c("","NA") # fix empty cells
            ), by = c("individual_ID",
                      "measurement_date" = "date_blood_drawn")
            ) %>%
        # join CEWL data
  left_join(read.csv("./data/CEWL_dat_all_clean.csv", # filename
                             na.strings=c("","NA") # fix empty cells
            ), by = c("individual_ID",
```

```r
                      "measurement_date" = "date")
            ) %>%
        # select variables of interest only
  dplyr::select(measurement_date,
                time_captured,
                time_processed,
                time_c_temp,
                type, day,
                individual_ID,
                mass_g,
                hemolyzed,
                hematocrit_percent,
                osmolality_mmol_kg_mean,
                CEWL_g_m2h_mean = CEWL_g_m2h,
                cloacal_temp_C
                ) %>%
          # format date-time-related variables
  mutate(measurement_date = as.Date(measurement_date,
                                    format = "%Y-%m-%d")) %>%
  group_by(individual_ID) %>%
          # for each individual, extract capture date
  mutate(capture_date = min(measurement_date),
         day_n = as.numeric(measurement_date - capture_date))

summary(full_dat)
```

```
##  measurement_date     time_captured      time_processed     time_c_temp
##  Min.   :2021-06-16   Length:957         Length:957         Length:957
##  1st Qu.:2021-06-30   Class :character   Class :character   Class :character
##  Median :2021-07-25   Mode  :character   Mode  :character   Mode  :character
##  Mean   :2021-07-22
##  3rd Qu.:2021-08-14
##  Max.   :2021-09-01
##
##      type               day            individual_ID       mass_g
##  Length:957         Length:957         Min.   :201.0   Min.   : 7.00
##  Class :character   Class :character   1st Qu.:236.0   1st Qu.: 9.50
##  Mode  :character   Mode  :character   Median :271.0   Median :10.60
##                                        Mean   :271.3   Mean   :10.62
##                                        3rd Qu.:307.0   3rd Qu.:11.60
##                                        Max.   :341.0   Max.   :17.40
##
##   hemolyzed         hematocrit_percent osmolality_mmol_kg_mean CEWL_g_m2h_mean
##  Length:957         Min.   :13.00      Min.   :295.3           Min.   : 7.152
##  Class :character   1st Qu.:26.00      1st Qu.:336.3           1st Qu.:19.727
##  Mode  :character   Median :32.00      Median :352.0           Median :24.152
##                     Mean   :32.09      Mean   :358.1           Mean   :24.909
##                     3rd Qu.:38.00      3rd Qu.:371.0           3rd Qu.:28.486
##                     Max.   :52.00      Max.   :576.0           Max.   :79.267
##                     NA's   :417        NA's   :414             NA's   :684
##  cloacal_temp_C   capture_date            day_n
##  Min.   :23.00   Min.   :2021-06-16   Min.   : 0.000
##  1st Qu.:25.00   1st Qu.:2021-06-26   1st Qu.: 4.000
##  Median :26.00   Median :2021-07-20   Median : 6.000
```

```
##  Mean   :25.93   Mean   :2021-07-17   Mean   : 5.658
##  3rd Qu.:27.00   3rd Qu.:2021-08-08   3rd Qu.: 8.000
##  Max.   :30.00   Max.   :2021-08-22   Max.   :10.000
##  NA's   :684
```

```
# check
unique(full_dat$capture_date)
```

```
## [1] "2021-06-16" "2021-06-26" "2021-07-20" "2021-08-08" "2021-08-22"
```

Export

Export full_dat to be used in 'experiment_analysis'.

```
write.csv(full_dat, "./data/full_exp_data.csv")
```

Format

Extract only the data from capture day (1 row of observations for each individual) and format the data classes properly for analysis.

```
capture_dat <- full_dat %>%
          # select only data from capture days
  dplyr::filter(day_n == 0) %>%
  left_join(read.csv("./data/tmt_assignments.csv"),
            by = "individual_ID") %>%
          # put date and time together
  mutate(capture_date_time = (paste(capture_date, time_captured)),
         capture_date_time = as.POSIXct(capture_date_time,
                                        format = "%Y-%m-%d %H:%M"),
          # correctly format time-only variables
         time_captured = as.POSIXct(time_captured,
                                     format = "%H:%M"),
         time_processed = as.POSIXct(time_processed,
                                      format = "%H:%M"),
         time_c_temp = as.POSIXct(substr(time_c_temp, 12, 16),
                                   format = "%H:%M"),
          # set categorical variables as factors
         type = as.factor(type),
         day = as.factor(day),
         individual_ID = as.factor(individual_ID),
         hemolyzed = as.factor(hemolyzed),
          # set numeric measurements as numeric
         mass_g = as.numeric(mass_g),
         hematocrit_percent = as.numeric(hematocrit_percent),
         osmolality_mmol_kg_mean = as.numeric(osmolality_mmol_kg_mean),
         CEWL_g_m2h_mean = as.numeric(CEWL_g_m2h_mean),
         cloacal_temp_C = as.numeric(cloacal_temp_C)
               ) %>%
  # make sure only complete data included
  # this removes the data for individuals 304 (recapture) & 254 (escapee)
  dplyr::filter(complete.cases(osmolality_mmol_kg_mean,
                               CEWL_g_m2h_mean, cloacal_temp_C)) %>%
  # remove experiment variables not relevant to capture analysis
  dplyr::select(-trial_number, -temp_tmt, -humidity_tmt,
                -conclusion, -notes,
```

```r
                 -shed, -tail_broken, -died)
summary(capture_dat)
```

```
##  measurement_date     time_captured                   
##  Min.   :2021-06-16   Min.   :2021-11-07 08:28:00  
##  1st Qu.:2021-06-26   1st Qu.:2021-11-07 10:00:00  
##  Median :2021-07-20   Median :2021-11-07 10:40:00  
##  Mean   :2021-07-16   Mean   :2021-11-07 11:09:32  
##  3rd Qu.:2021-08-08   3rd Qu.:2021-11-07 11:56:15  
##  Max.   :2021-08-22   Max.   :2021-11-07 15:54:00  
##                       NA's   :14                   
##  time_processed                  time_c_temp                    type    
##  Min.   :2021-11-07 11:00:00   Min.   :2021-11-07 09:54:00   exp:138  
##  1st Qu.:2021-11-07 12:08:45   1st Qu.:2021-11-07 12:53:00            
##  Median :2021-11-07 13:05:30   Median :2021-11-07 14:01:30            
##  Mean   :2021-11-07 13:34:40   Mean   :2021-11-07 14:04:02            
##  3rd Qu.:2021-11-07 14:19:30   3rd Qu.:2021-11-07 15:12:30            
##  Max.   :2021-11-07 17:52:00   Max.   :2021-11-07 18:09:00            
##                                                                       
##       day      individual_ID     mass_g      hemolyzed hematocrit_percent
##  capture:138   201    :  1   Min.   : 8.80   N:127     Min.   :27.00     
##                202    :  1   1st Qu.:10.60   Y: 11     1st Qu.:34.25     
##                203    :  1   Median :11.65             Median :39.00     
##                204    :  1   Mean   :11.73             Mean   :38.93     
##                205    :  1   3rd Qu.:12.70             3rd Qu.:43.00     
##                206    :  1   Max.   :17.40             Max.   :52.00     
##                (Other):132                                               
##  osmolality_mmol_kg_mean CEWL_g_m2h_mean  cloacal_temp_C   capture_date       
##  Min.   :305.0           Min.   : 7.152   Min.   :25.00   Min.   :2021-06-16  
##  1st Qu.:334.3           1st Qu.:17.255   1st Qu.:26.00   1st Qu.:2021-06-26  
##  Median :344.6           Median :21.030   Median :26.00   Median :2021-07-20  
##  Mean   :348.3           Mean   :20.760   Mean   :26.45   Mean   :2021-07-16  
##  3rd Qu.:361.9           3rd Qu.:24.416   3rd Qu.:27.00   3rd Qu.:2021-08-08  
##  Max.   :395.0           Max.   :34.660   Max.   :30.00   Max.   :2021-08-22  
##                                                                               
##      day_n       SVL_mm      capture_date_time            
##  Min.   :0   Min.   :60.00   Min.   :2021-06-16 08:28:00  
##  1st Qu.:0   1st Qu.:66.00   1st Qu.:2021-06-26 09:44:45  
##  Median :0   Median :67.00   Median :2021-07-20 09:52:00  
##  Mean   :0   Mean   :67.71   Mean   :2021-07-14 14:50:11  
##  3rd Qu.:0   3rd Qu.:70.00   3rd Qu.:2021-08-08 09:56:45  
##  Max.   :0   Max.   :77.00   Max.   :2021-08-22 13:25:00  
##                              NA's   :14
```

Variable Summary

- measurement_date = date measurements were taken, including capture day
- collection/capture time for each lizard
- time_processed = when mass and blood draw were recorded
- time_c_temp = the time when cloacal temperature was recorded, immediately after CEWL measurements
- type = whether measurements were during experiment (exp) or after rehydration (post-rehab). For this R script/analysis, I'm only going to use capture day data, which is listed as "exp"
- day = whether measurements are from capture day or post-experiment, which was recorded in relation

to CEWL & cloacal temp data. All observations used for this analysis will be from capture day
- individual ID for each lizard
- mass in grams
- hemolyzed = whether or not red blood cells burst and contaminated plasma
- hematocrit_percent = percent of blood that's red blood cells (measured in CRITOCAP microhematocrit capillary tubes)
- osmolality_mmol_kg_mean = the mean of 1-3 technical replicates of plasma osmolality measurements taken from plasma extracted from our blood samples and run on a VAPRO vapor pressure osmometer
- CEWL_g_m2h_mean = the mean of 3-5 technical replicates, after outliers were omitted, of CEWL measurements taken in the same area of the dorsum
- cloacal_temp_C = cloacal temperature recorded immediately after CEWL measurements
- capture_date = date of capture. For this dataset, it should be the same as measurement date
- day_n = numeric day of measurement. In this dataset, it should always be zero
- capture_date_time = combination of capture date and time
- SVL_mm = snout-to-vent length in mm

Weather Data

This data was obtained from http://www.itrc.org/databases/precip/ (Adcon Server Data) to test the effect of ambient conditions on CEWL.

Load and format:

```
weather <- read.csv("./data/weather.csv", sep = ';') %>%
         # add a variable for combined date-time
  mutate(capture_date_time = as.POSIXct(paste(date, time),
                              format = "%m/%d/%y %I:%M %p"))
```

The weather data is only every 15 minutes, but I want to match it to any minute measurement, so I need to interpolate the values for each minute.

First, make a separate dataframe with every minute on each capture day.

```
all_times <- data.frame(capture_date_time = c(
                           # June 16
                           seq(from = as.POSIXct("2021-06-16 07:00"),
                               to = as.POSIXct("2021-06-16 19:00"),
                               by="min"),
                           # June 26
                           seq(from = as.POSIXct("2021-06-26 07:00"),
                               to = as.POSIXct("2021-06-26 19:00"),
                               by="min"),
                           # July 20
                           seq(from = as.POSIXct("2021-07-20 07:00"),
                               to = as.POSIXct("2021-07-20 19:00"),
                               by="min"),
                           # August 8
                           seq(from = as.POSIXct("2021-08-08 07:00"),
                               to = as.POSIXct("2021-08-08 19:00"),
                               by="min"),
                           # August 22
                           seq(from = as.POSIXct("2021-08-22 07:00"),
                               to = as.POSIXct("2021-08-22 19:00"),
                               by="min")
                           ))
```

Next, merge the weather data into the times dataframe and interpolate the temperature and humidity between measurements.

```
weather_every_minute <- all_times %>% # time only dataframe
  # add weather measurements based on matching date-time
  left_join(weather, by = 'capture_date_time') %>%
         # convert temperature units F->C
  mutate(temp_C = fahrenheit.to.celsius(temperature_F, round = 2),
         # interpolate temperatures
         temp_C_interpol = na.approx(temp_C),
         # also get temperature C-> K
         temp_K_interpol = temp_C_interpol + 273.15,
         # interpolate humidities
         RH_percent_interpol = na.approx(relative_humidity_percent),
         # interpolate Wind Speeds
         wind_mph_interpol = na.approx(wind_speed_mph),
         # interpolate solar radiation
         solar_rad_W_sqm_interpol = na.approx(solar_radiation_W_sqm),
         # compute vapor pressure deficit
         # find saturation level first
         e_s_kPa_int = 0.611*exp((2500000/461.5)*
                                ((1/273)-(1/temp_K_interpol))),
         # actual vapor pressure
         e_a_kPa_int = e_s_kPa_int * (RH_percent_interpol/100),
         # VPD
         VPD_kPa_int = e_s_kPa_int - e_a_kPa_int
         ) %>%
  # keep only the relevant variables
  dplyr::select(capture_date_time,
                temp_C_interpol,
                RH_percent_interpol,
                VPD_kPa_int,
                wind_mph_interpol,
                solar_rad_W_sqm_interpol)
summary(weather_every_minute)
```

```
##  capture_date_time              temp_C_interpol RH_percent_interpol
##  Min.   :2021-06-16 07:00:00   Min.   :12.50   Min.   : 16.50
##  1st Qu.:2021-06-26 10:00:00   1st Qu.:20.04   1st Qu.: 56.83
##  Median :2021-07-20 13:00:00   Median :22.35   Median : 67.10
##  Mean   :2021-07-19 08:12:00   Mean   :23.22   Mean   : 63.15
##  3rd Qu.:2021-08-08 16:00:00   3rd Qu.:25.17   3rd Qu.: 76.13
##  Max.   :2021-08-22 19:00:00   Max.   :38.33   Max.   :100.00
##   VPD_kPa_int     wind_mph_interpol solar_rad_W_sqm_interpol
##  Min.   :0.0000   Min.   : 0.100    Min.   :  13.6
##  1st Qu.:0.5724   1st Qu.: 2.800    1st Qu.: 370.0
##  Median :0.9074   Median : 4.700    Median : 699.6
##  Mean   :1.4591   Mean   : 4.820    Mean   : 624.2
##  3rd Qu.:1.4235   3rd Qu.: 5.833    3rd Qu.: 902.6
##  Max.   :5.8841   Max.   :13.600    Max.   :1011.7
```

I will add the weather data in when I add the scaled mass index (computed next) to the dataframe.

Compute Scaled Mass Index

This is also known as the body condition index, or log-log residuals.

I calculate as described by: Peig, J., & Green, A. J. (2009). New perspectives for estimating body condition from mass/length data: The scaled mass index as an alternative method. Oikos, 118(12), 1883–1891. https://doi.org/10.1111/j.1600-0706.2009.17643.x

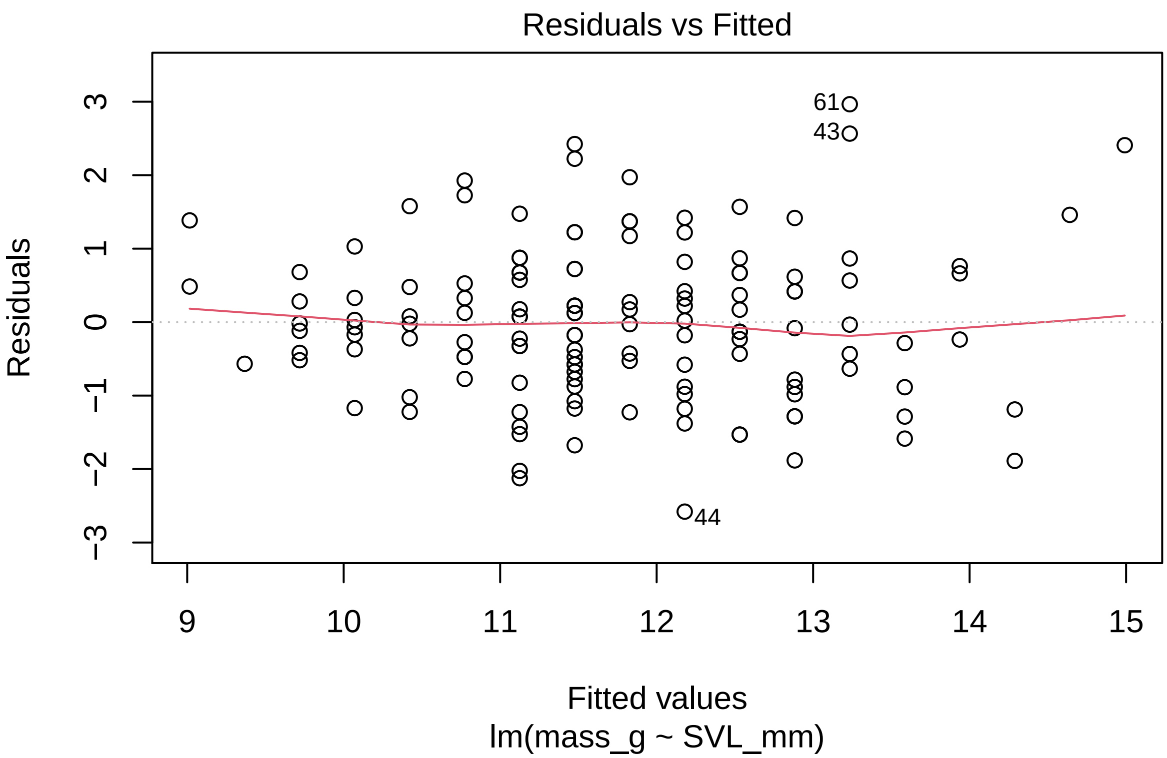
Step 1: Simple Linear Regression

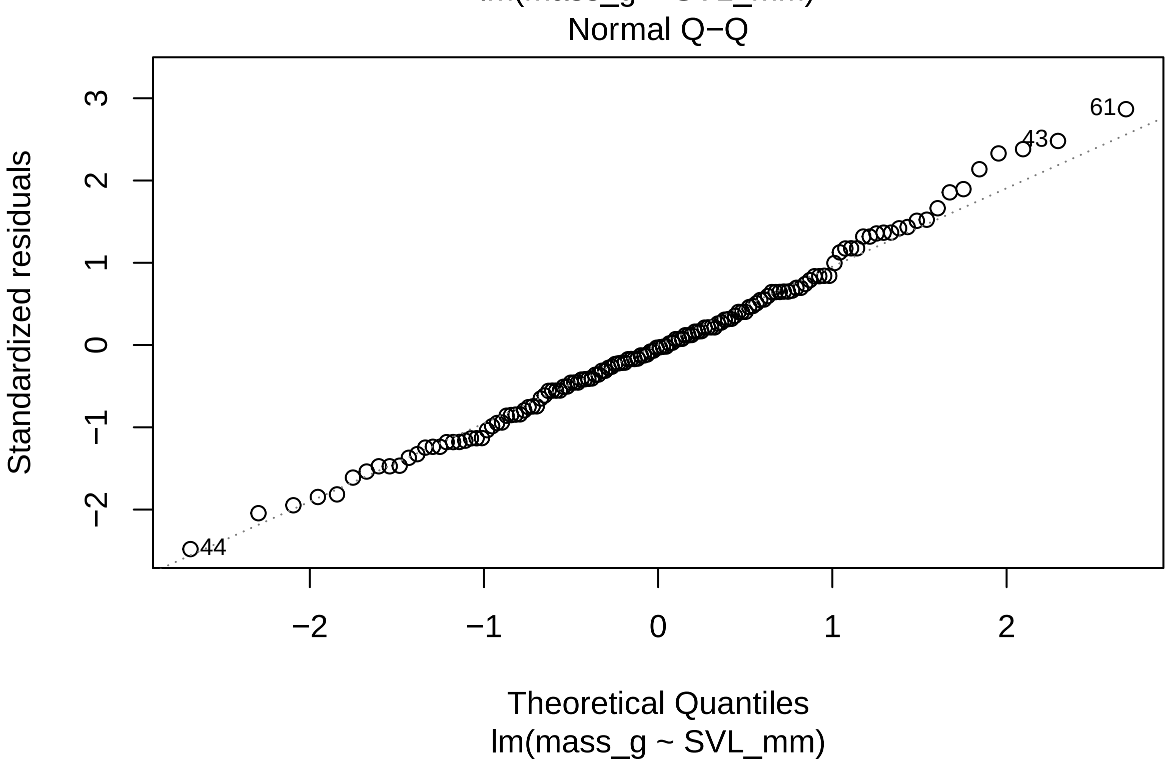
```
mass_SVL_SLR <- lm(data = capture_dat, mass_g ~ SVL_mm)
summary(mass_SVL_SLR)
```

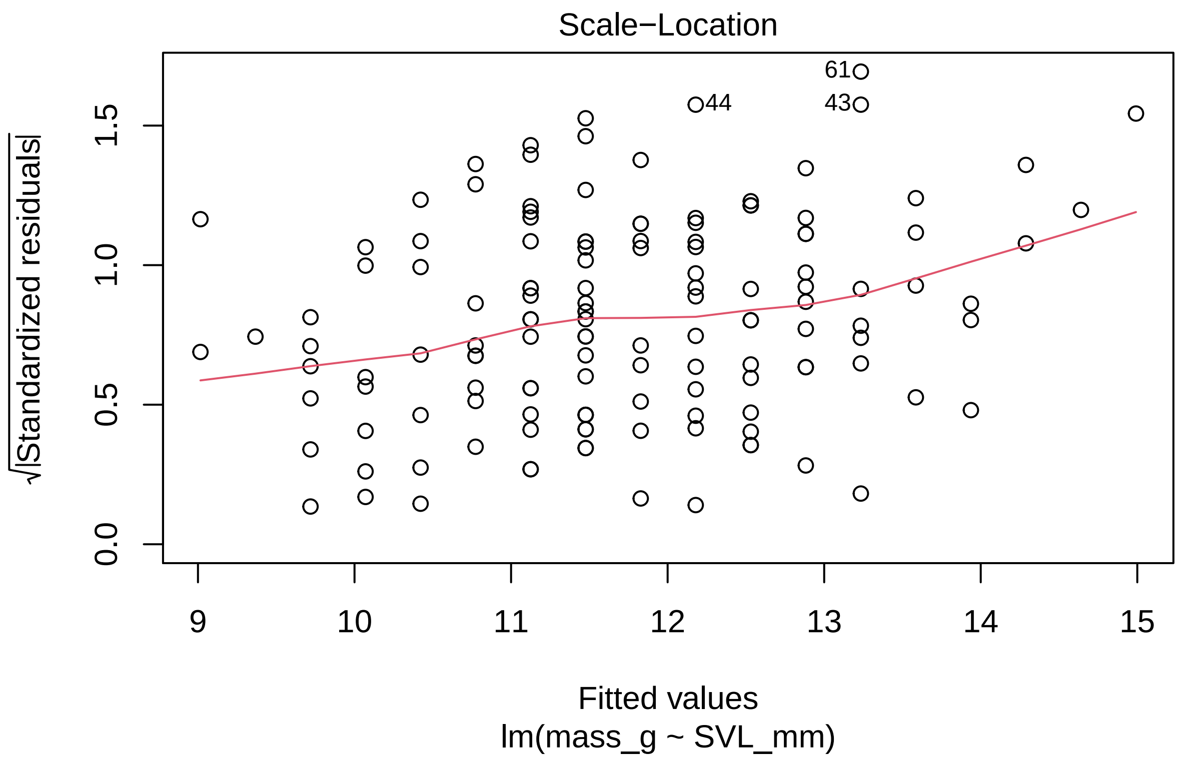
```
##
## Call:
## lm(formula = mass_g ~ SVL_mm, data = capture_dat)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -2.57951 -0.66586 -0.03104  0.66743  2.96590
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept) -12.07614    1.78776  -6.755 3.82e-10 ***
## SVL_mm        0.35153    0.02637  13.330  < 2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 1.044 on 136 degrees of freedom
## Multiple R-squared:  0.5665, Adjusted R-squared:  0.5633
## F-statistic: 177.7 on 1 and 136 DF,  p-value: < 2.2e-16
```

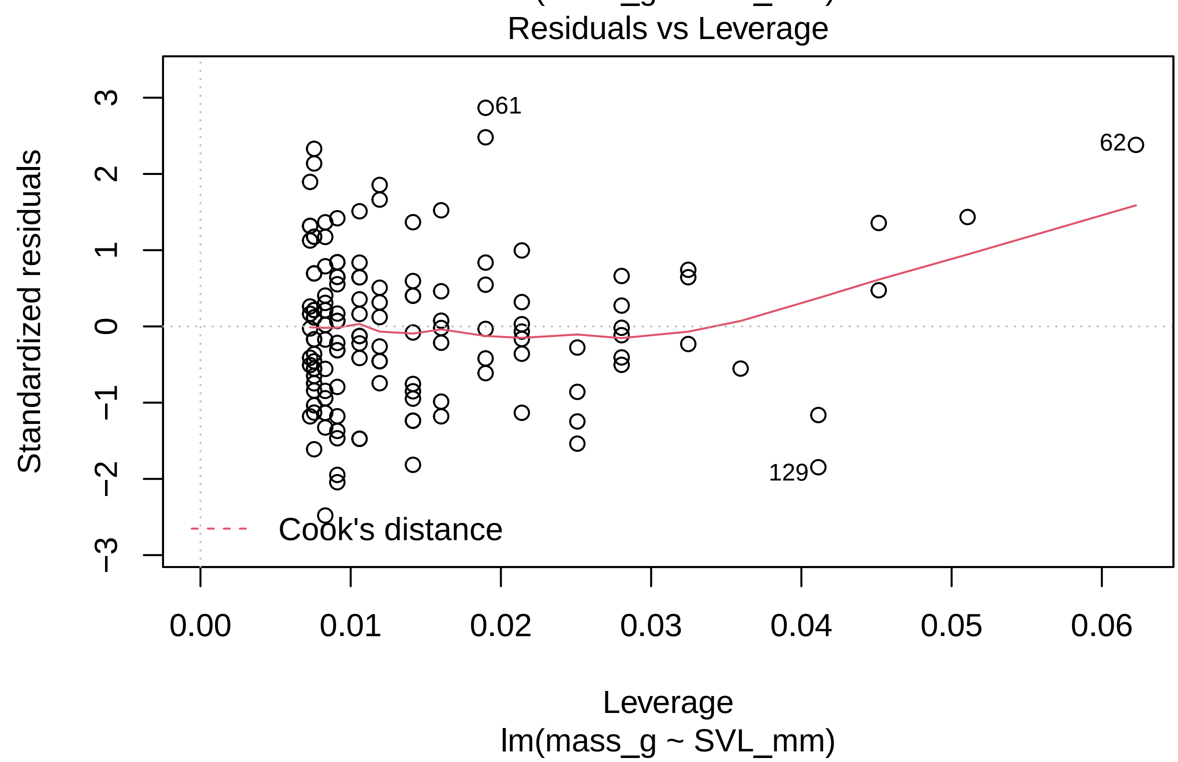
Step 2: Identify Outliers

```
plot(mass_SVL_SLR)
```


Residuals vs Fitted
Residuals
Fitted values
lm(mass_g ~ SVL_mm)
61
43
44

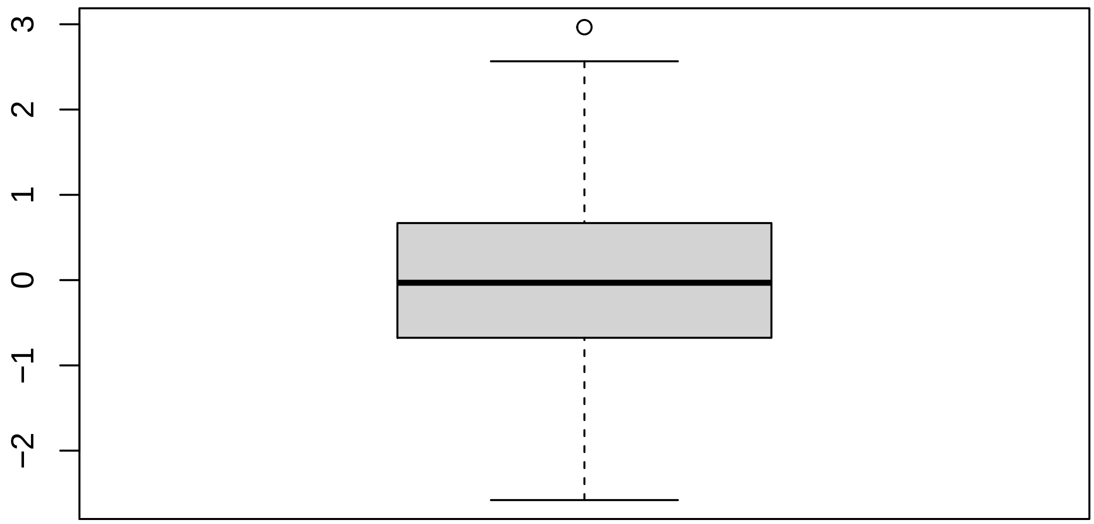

Normal Q−Q
Standardized residuals
Theoretical Quantiles
lm(mass_g ~ SVL_mm)
61
43
44



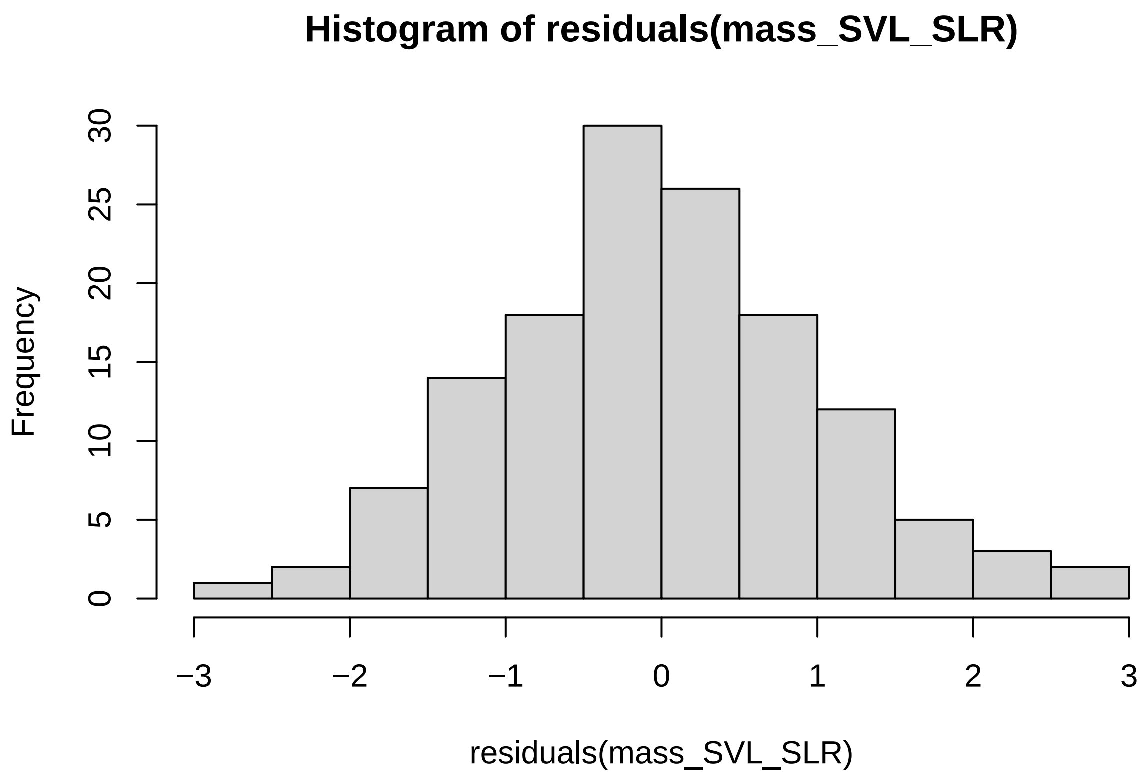


The conditions of linearity, equal error variance, and normality are all satisfied. It doesn't look like any residuals are >3 or <-3.

```
boxplot(residuals(mass_SVL_SLR))
```




```r
hist(residuals(mass_SVL_SLR))
```



From the boxplot, there is one individual with a much higher residual than the rest of the distribution. The histogram looks fine, and incredibly normally distributed.

Check average residual value:

```r
mean(residuals(mass_SVL_SLR))
```

```
## [1] -4.331781e-17
```

```r
median(residuals(mass_SVL_SLR))
```

```
## [1] -0.03104232
```

The mean is basically zero and the median is pretty close to zero, which is very good.

Check for high leverage points:

```
# compute values for observations
high_leverage <- data.frame(H = hatvalues(mass_SVL_SLR)) %>%
  mutate(row = row_number())

# compute cutoff value
h_bar <- (3*sum(high_leverage$H))/nrow(high_leverage)

# add to original dataframe
# see which observations have extremely high leverage (if any)
high_leverage_dat <- capture_dat %>%
  mutate(row = row_number()) %>%
  left_join(., high_leverage, by = "row") %>%
  dplyr::filter(H > h_bar)
high_leverage_dat
```

```
## # A tibble: 0 x 19
## # Groups:   individual_ID [0]
## # ... with 19 variables: measurement_date <date>, time_captured <dttm>,
## #   time_processed <dttm>, time_c_temp <dttm>, type <fct>, day <fct>,
## #   individual_ID <fct>, mass_g <dbl>, hemolyzed <fct>,
## #   hematocrit_percent <dbl>, osmolality_mmol_kg_mean <dbl>,
## #   CEWL_g_m2h_mean <dbl>, cloacal_temp_C <dbl>, capture_date <date>,
## #   day_n <dbl>, SVL_mm <int>, capture_date_time <dttm>, row <int>, H <dbl>
```

No points are considered high leverage, which is fantastic.

Check for influential points based on Cook's distance:

```
# get Cook's distance
cooks <- data.frame(c = cooks.distance(mass_SVL_SLR)) %>%
  mutate(row = row_number())

# add to original dataframe
influential <- capture_dat %>%
  mutate(row = row_number()) %>%
  left_join(., cooks, by = "row")

# see moderately influential points
cook_mod_inf <- influential %>%
  dplyr::filter(c>0.5)
cook_mod_inf
```

```
## # A tibble: 0 x 19
## # Groups:   individual_ID [0]
## # ... with 19 variables: measurement_date <date>, time_captured <dttm>,
## #   time_processed <dttm>, time_c_temp <dttm>, type <fct>, day <fct>,
## #   individual_ID <fct>, mass_g <dbl>, hemolyzed <fct>,
## #   hematocrit_percent <dbl>, osmolality_mmol_kg_mean <dbl>,
## #   CEWL_g_m2h_mean <dbl>, cloacal_temp_C <dbl>, capture_date <date>,
## #   day_n <dbl>, SVL_mm <int>, capture_date_time <dttm>, row <int>, c <dbl>
```

There are no infuential points based on Cook's distance, so there's nothing to potentially remove.

We could remove the one outlier found using the boxplot, but it's the only one, so we will leave it in the dataset. No points were indicated to be outliers based on residuals or a histogram, and there were no high leverage or influential points. Thus I can create a log-log model using the data as-is. Observation omissions are unlikely to increase generalizability.

Step 3: log-log Regression

```
log_mass_SVL_SLR <- lm(data = capture_dat,
                       log(mass_g) ~ log(SVL_mm))
summary(log_mass_SVL_SLR)
```

```
##
## Call:
## lm(formula = log(mass_g) ~ log(SVL_mm), data = capture_dat)
##
## Residuals:
##       Min        1Q    Median        3Q       Max
## -0.231524 -0.059318 -0.000981  0.055085  0.206551
##
## Coefficients:
##             Estimate Std. Error t value Pr(>|t|)
## (Intercept)  -5.9803     0.6283  -9.519   <2e-16 ***
## log(SVL_mm)   2.0013     0.1491  13.424   <2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.08708 on 136 degrees of freedom
## Multiple R-squared:  0.5699, Adjusted R-squared:  0.5667
## F-statistic: 180.2 on 1 and 136 DF,  p-value: < 2.2e-16
```

Step 4: Extract Values

compute standardized major axis using the log-log regression equation:

```
r <- sqrt(0.5699) # Pearson's correlection coefficient (sqrt of R-squared)
b_OLS <- 2.0013 # regression slope
b_SMA <- b_OLS/r
```

mean length in capture data:

```
L0 <- mean(capture_dat$SVL_mm)
```

Step 5: Calculate Scaled Mass Index

(And join weather data.)

```
capture_dat_plus <- capture_dat %>%
  # compute SMI
  mutate(SMI = mass_g * ((L0/SVL_mm) ^ b_SMA)) %>%
  # join weather data
  left_join(weather_every_minute, by = c("capture_date_time")) %>%
  # clean up the dataframe
  dplyr::select(capture_date, capture_date_time, individual_ID, # basics
                mass_g, SVL_mm, SMI, # lizard size
                hemolyzed, hematocrit_percent, osmolality_mmol_kg_mean, # blood
                CEWL_g_m2h_mean, cloacal_temp_C, # CEWL
                temp_C_interpol, VPD_kPa_int, wind_mph_interpol, solar_rad_W_sqm_interpol # weather
```

```r
                 )
summary(capture_dat_plus)
```

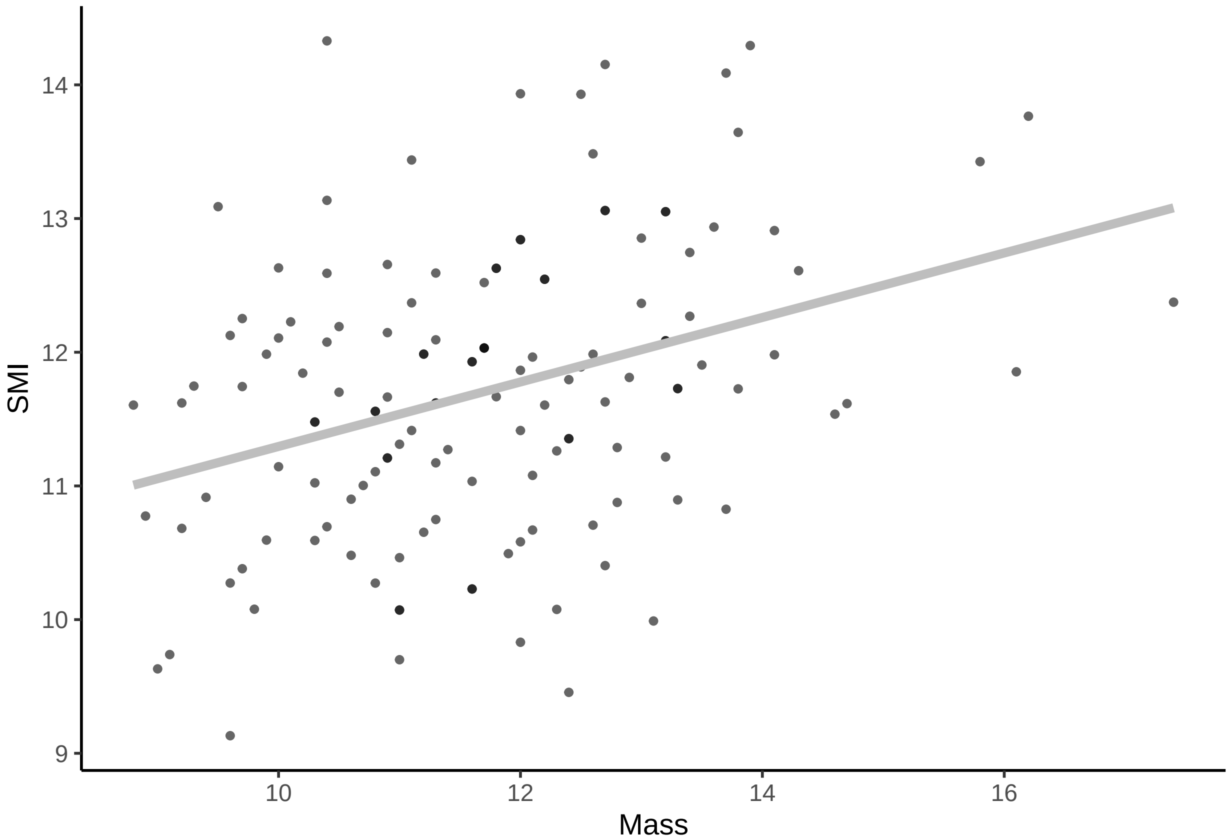
```
##   capture_date        capture_date_time              individual_ID
##  Min.   :2021-06-16   Min.   :2021-06-16 08:28:00   201    :  1
##  1st Qu.:2021-06-26   1st Qu.:2021-06-26 09:44:45   202    :  1
##  Median :2021-07-20   Median :2021-07-20 09:52:00   203    :  1
##  Mean   :2021-07-16   Mean   :2021-07-14 14:50:11   204    :  1
##  3rd Qu.:2021-08-08   3rd Qu.:2021-08-08 09:56:45   205    :  1
##  Max.   :2021-08-22   Max.   :2021-08-22 13:25:00   206    :  1
##                       NA's   :14                    (Other):132
##      mass_g          SVL_mm           SMI          hemolyzed hematocrit_percent
##  Min.   : 8.80   Min.   :60.00   Min.   : 9.132   N:127     Min.   :27.00
##  1st Qu.:10.60   1st Qu.:66.00   1st Qu.:10.937   Y: 11     1st Qu.:34.25
##  Median :11.65   Median :67.00   Median :11.727             Median :39.00
##  Mean   :11.73   Mean   :67.71   Mean   :11.712             Mean   :38.93
##  3rd Qu.:12.70   3rd Qu.:70.00   3rd Qu.:12.369             3rd Qu.:43.00
##  Max.   :17.40   Max.   :77.00   Max.   :14.329             Max.   :52.00
##
##  osmolality_mmol_kg_mean CEWL_g_m2h_mean  cloacal_temp_C  temp_C_interpol
##  Min.   :305.0           Min.   : 7.152   Min.   :25.00   Min.   :15.11
##  1st Qu.:334.3           1st Qu.:17.255   1st Qu.:26.00   1st Qu.:19.91
##  Median :344.6           Median :21.030   Median :26.00   Median :21.91
##  Mean   :348.3           Mean   :20.760   Mean   :26.45   Mean   :23.41
##  3rd Qu.:361.9           3rd Qu.:24.416   3rd Qu.:27.00   3rd Qu.:23.91
##  Max.   :395.0           Max.   :34.660   Max.   :30.00   Max.   :35.83
##                                                           NA's   :14
##   VPD_kPa_int     wind_mph_interpol solar_rad_W_sqm_interpol
##  Min.   :0.0000   Min.   : 0.100    Min.   : 294.7
##  1st Qu.:0.5420   1st Qu.: 2.025    1st Qu.: 682.9
##  Median :0.8284   Median : 3.100    Median : 759.9
##  Mean   :1.4295   Mean   : 4.406    Mean   : 762.9
##  3rd Qu.:1.2321   3rd Qu.: 5.880    3rd Qu.: 873.2
##  Max.   :4.9400   Max.   :12.720    Max.   :1007.0
##  NA's   :14       NA's   :14        NA's   :14
```

Check

Look at the difference between regular mass and SMI:

```r
capture_dat_plus %>%
  ggplot(data = .) +
  geom_point(aes(x = mass_g,
                 y = SMI,
                 ),
             size = 1,
             alpha = 0.6) +
  stat_smooth(aes(x = mass_g,
                  y = SMI,
                  ),
              formula = y ~ x,
              method = "lm",
              color = "gray",
              se = F,
```

```
             size = 1.6,
             alpha = 1 ) +
  theme_classic() +
  xlab("Mass") +
  ylab("SMI")
```

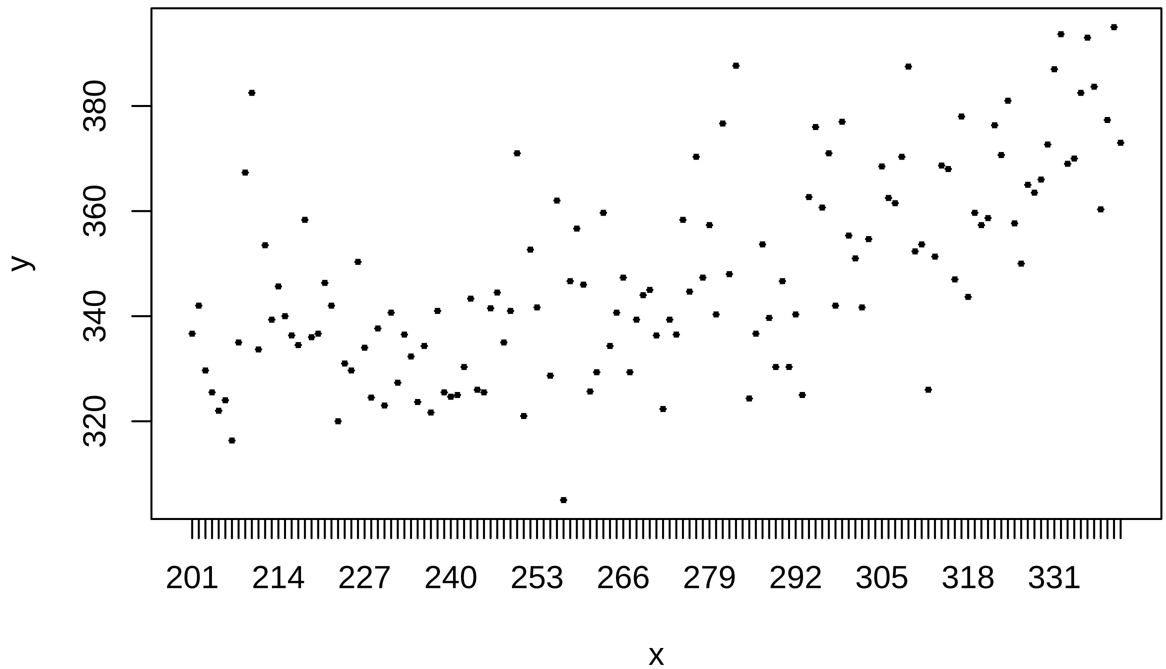


Quick Plots

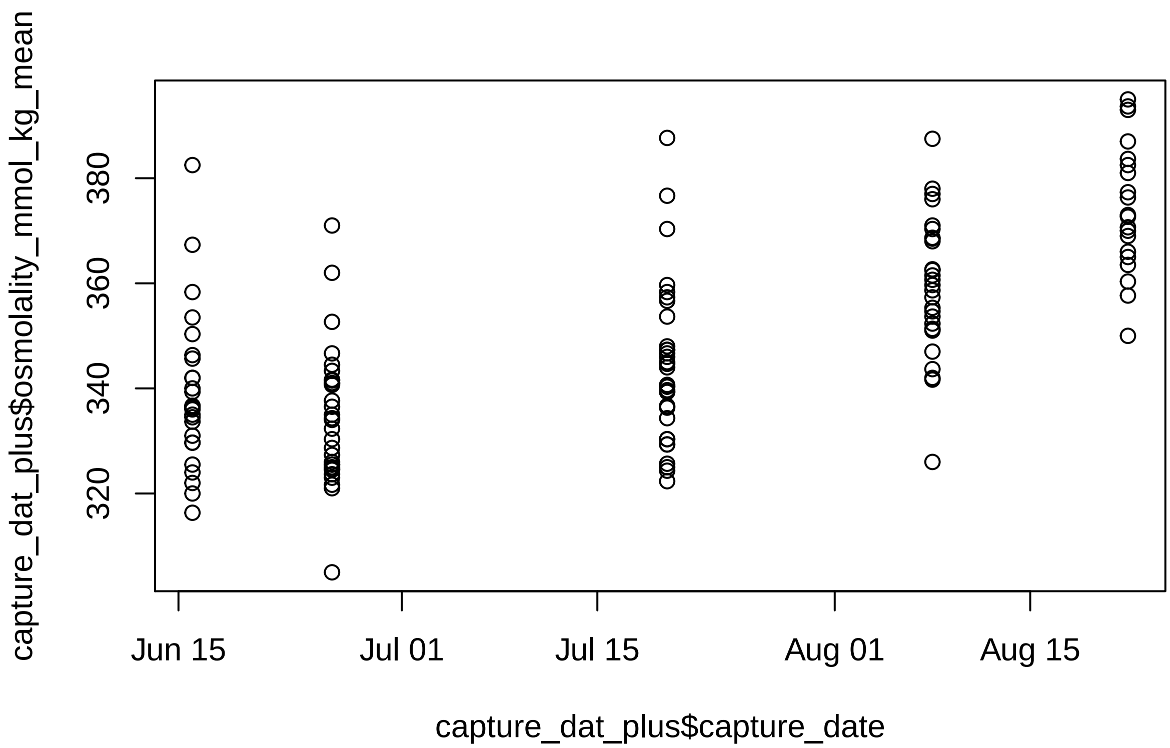
Plot very basic graphs to get an idea of what variables to incorporate into models and how.

Osmolality

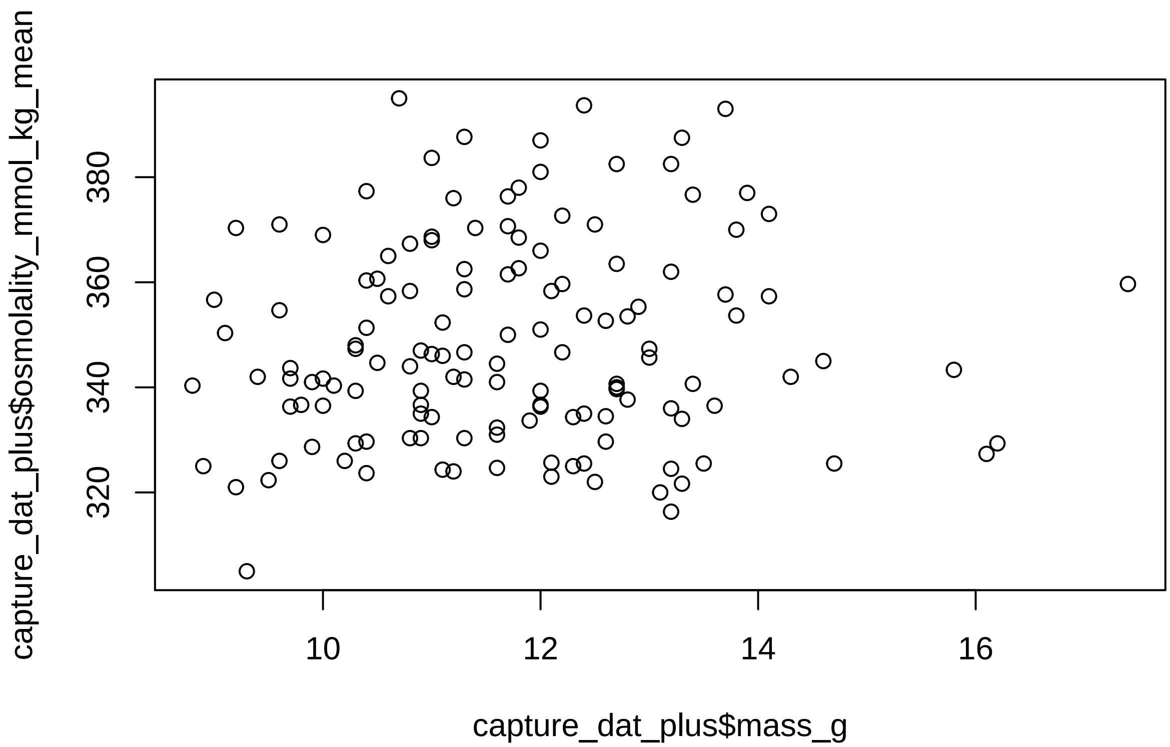
```
plot(capture_dat_plus$individual_ID,
     capture_dat_plus$osmolality_mmol_kg_mean)
```



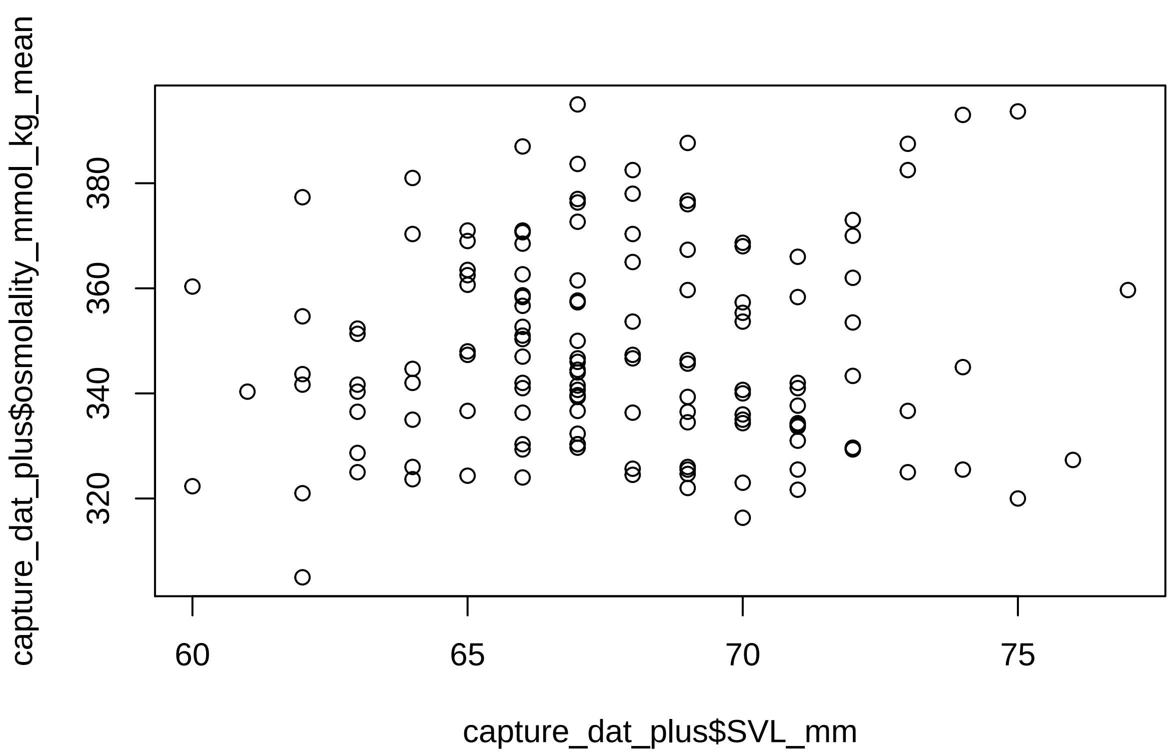

```
plot(capture_dat_plus$capture_date,
     capture_dat_plus$osmolality_mmol_kg_mean)
```



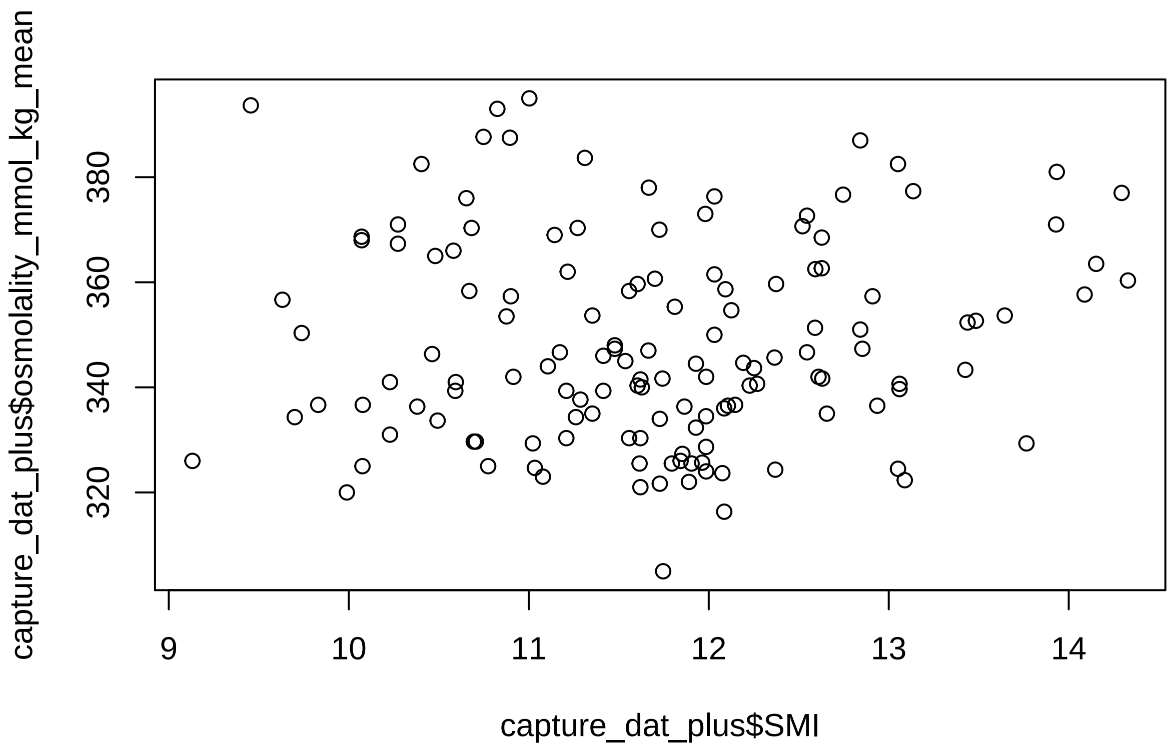

```
plot(capture_dat_plus$mass_g,
     capture_dat_plus$osmolality_mmol_kg_mean)
```



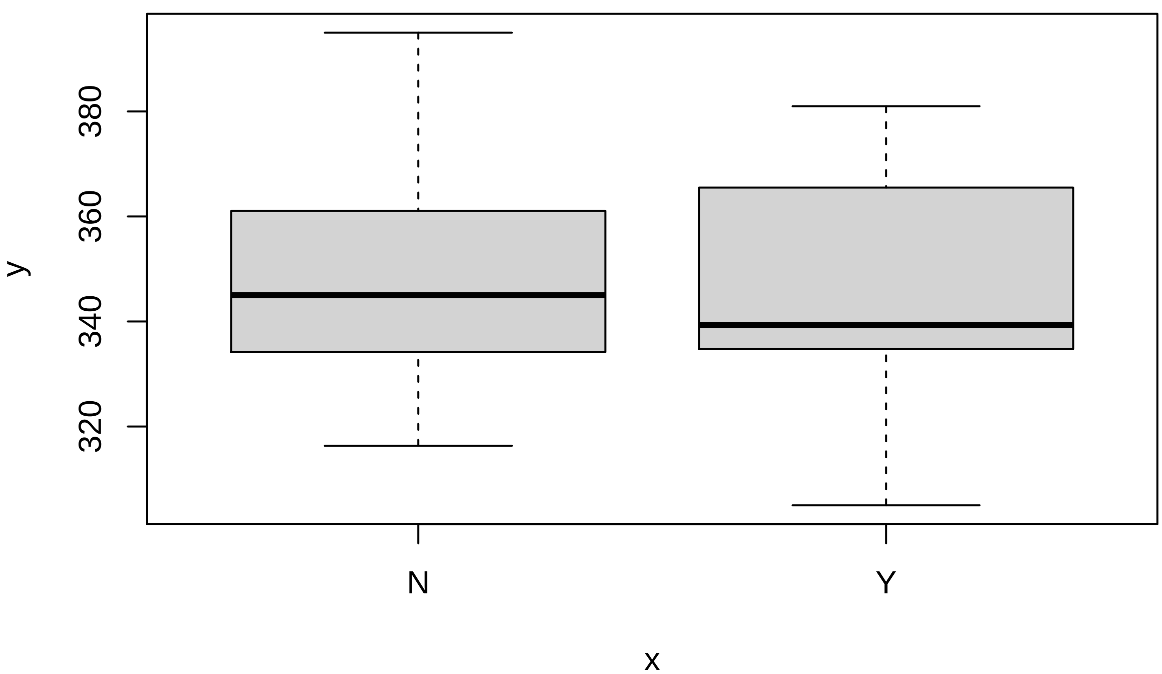

```
plot(capture_dat_plus$SVL_mm,
     capture_dat_plus$osmolality_mmol_kg_mean)
```



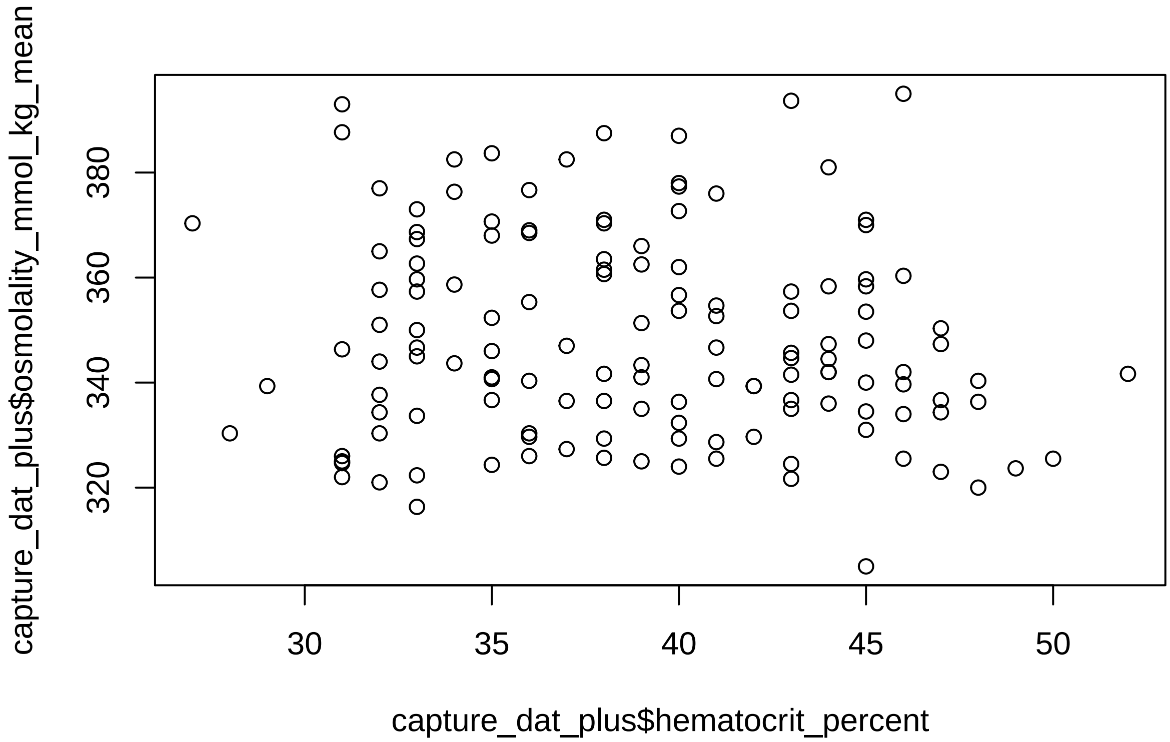

```
plot(capture_dat_plus$SMI,
     capture_dat_plus$osmolality_mmol_kg_mean)
```



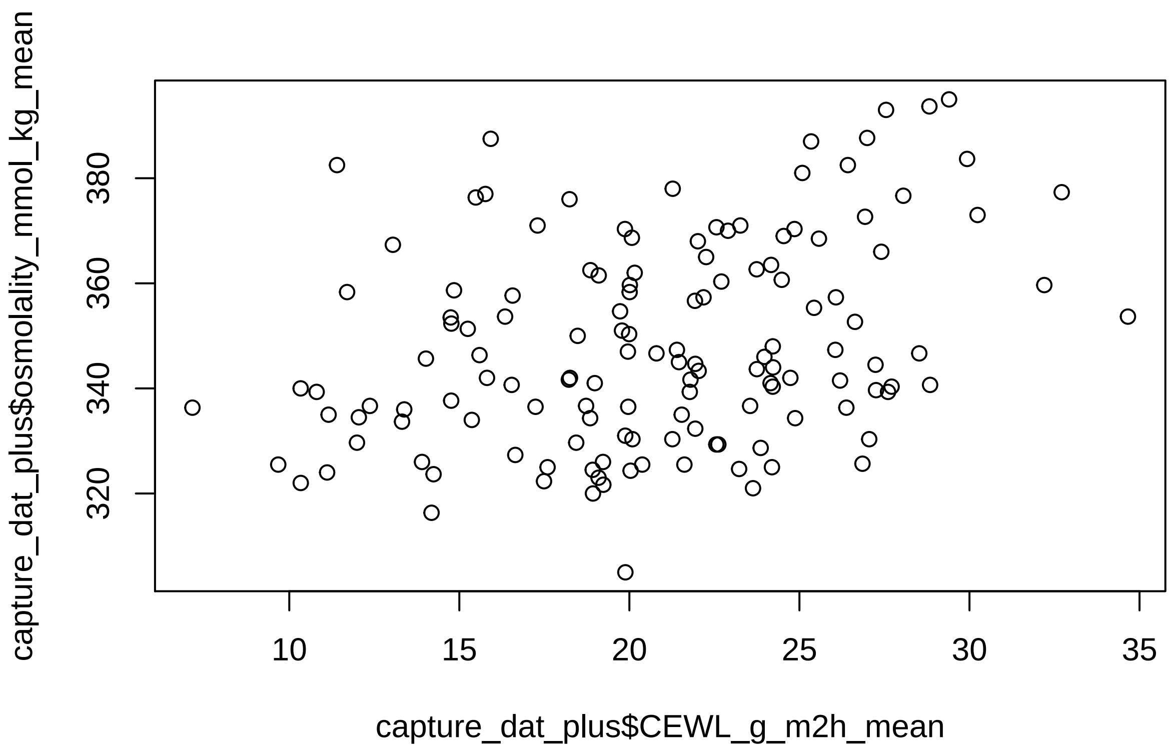

```
plot(capture_dat_plus$hemolyzed,
     capture_dat_plus$osmolality_mmol_kg_mean)
```



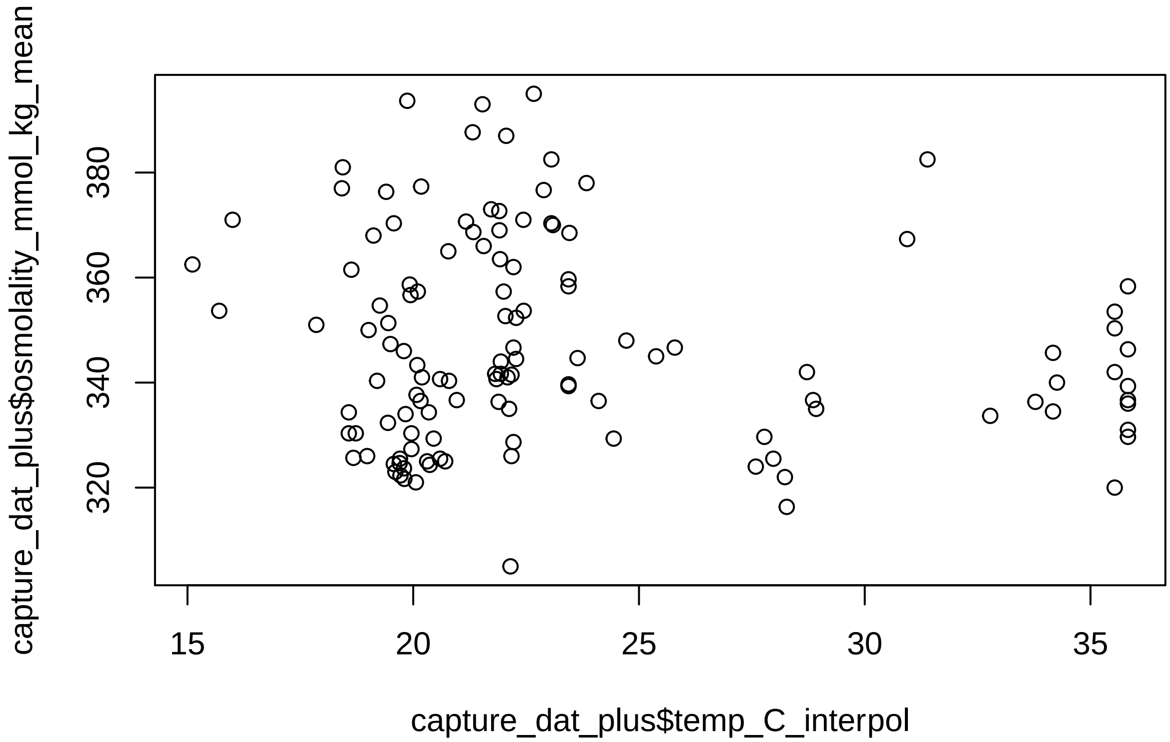

```
plot(capture_dat_plus$hematocrit_percent,
     capture_dat_plus$osmolality_mmol_kg_mean)
```



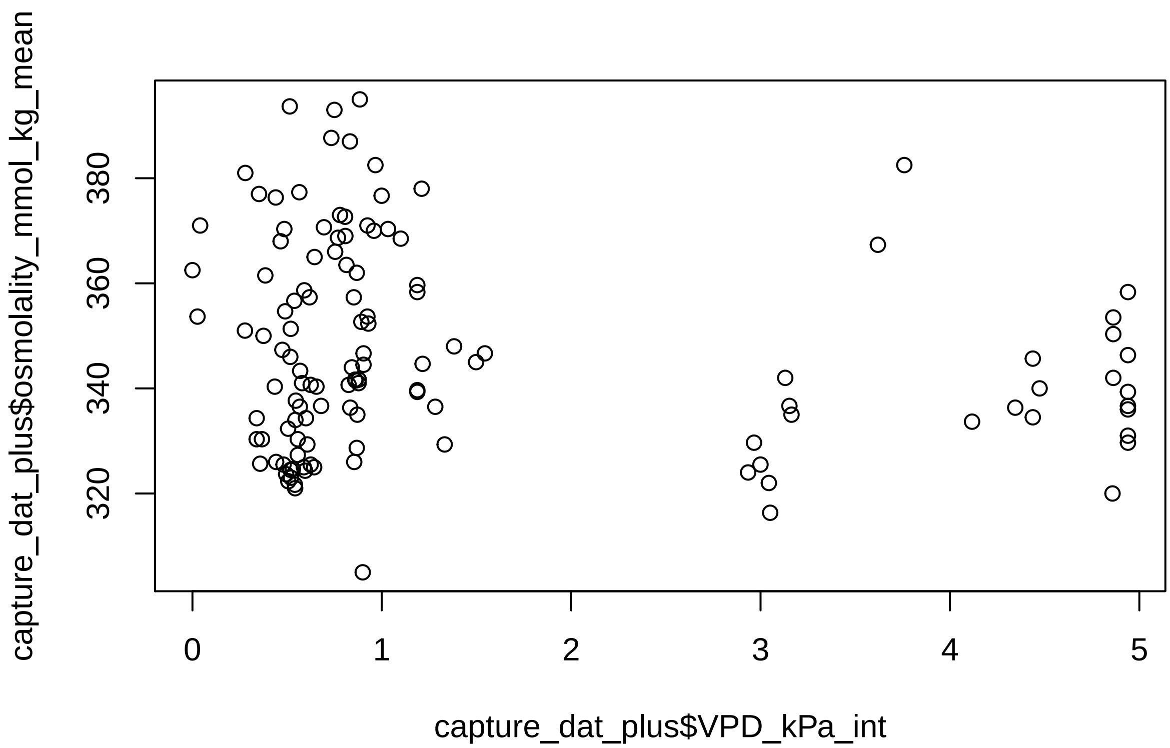

```r
plot(capture_dat_plus$CEWL_g_m2h_mean,
     capture_dat_plus$osmolality_mmol_kg_mean)
```



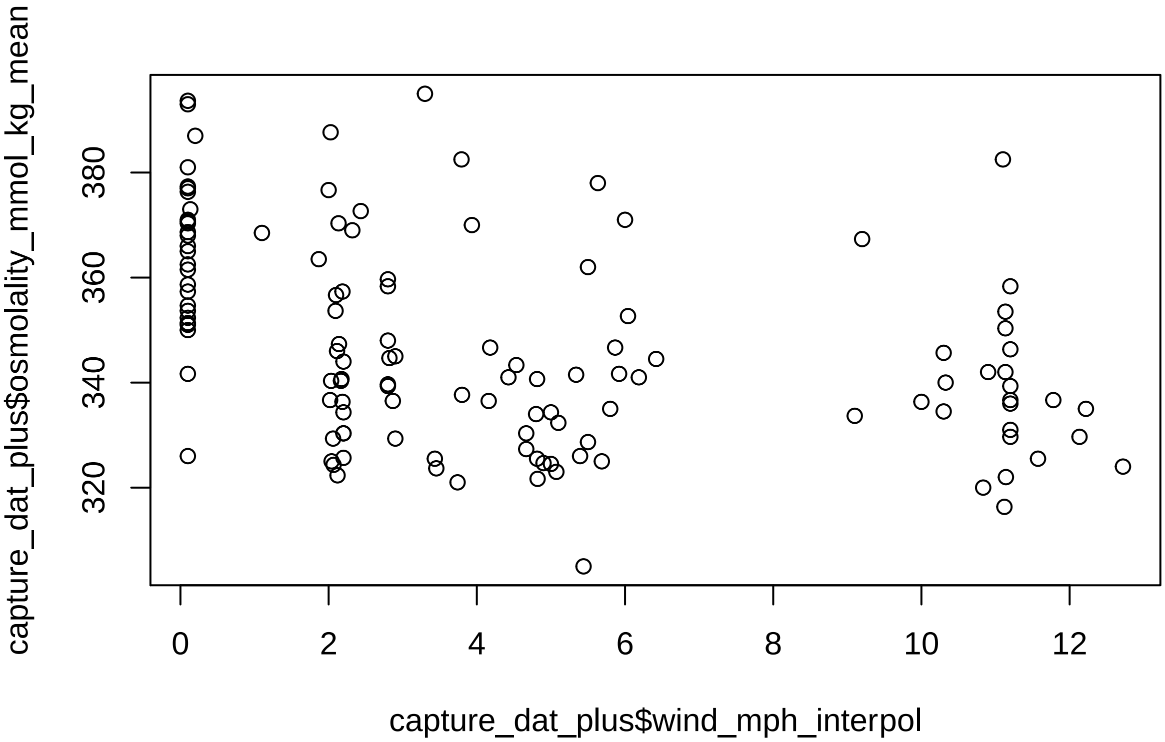

```r
plot(capture_dat_plus$temp_C_interpol,
     capture_dat_plus$osmolality_mmol_kg_mean)
```



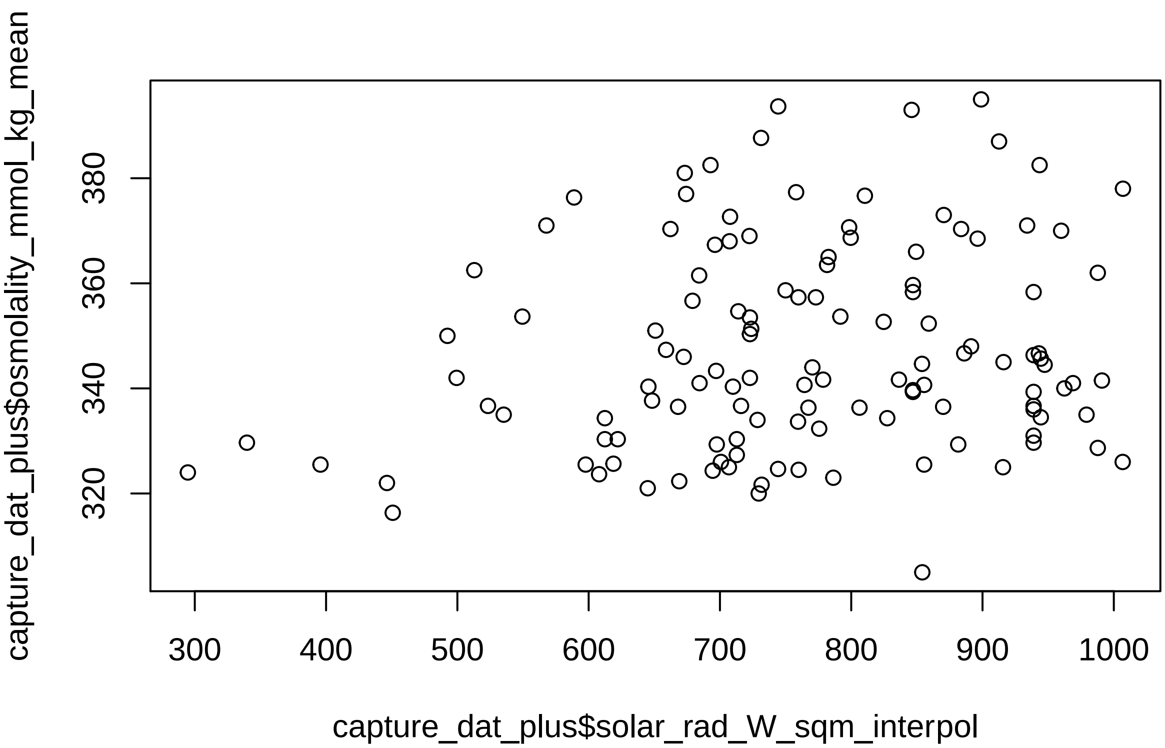

```r
plot(capture_dat_plus$VPD_kPa_int,
     capture_dat_plus$osmolality_mmol_kg_mean)
```




```r
plot(capture_dat_plus$wind_mph_interpol,
     capture_dat_plus$osmolality_mmol_kg_mean)
```



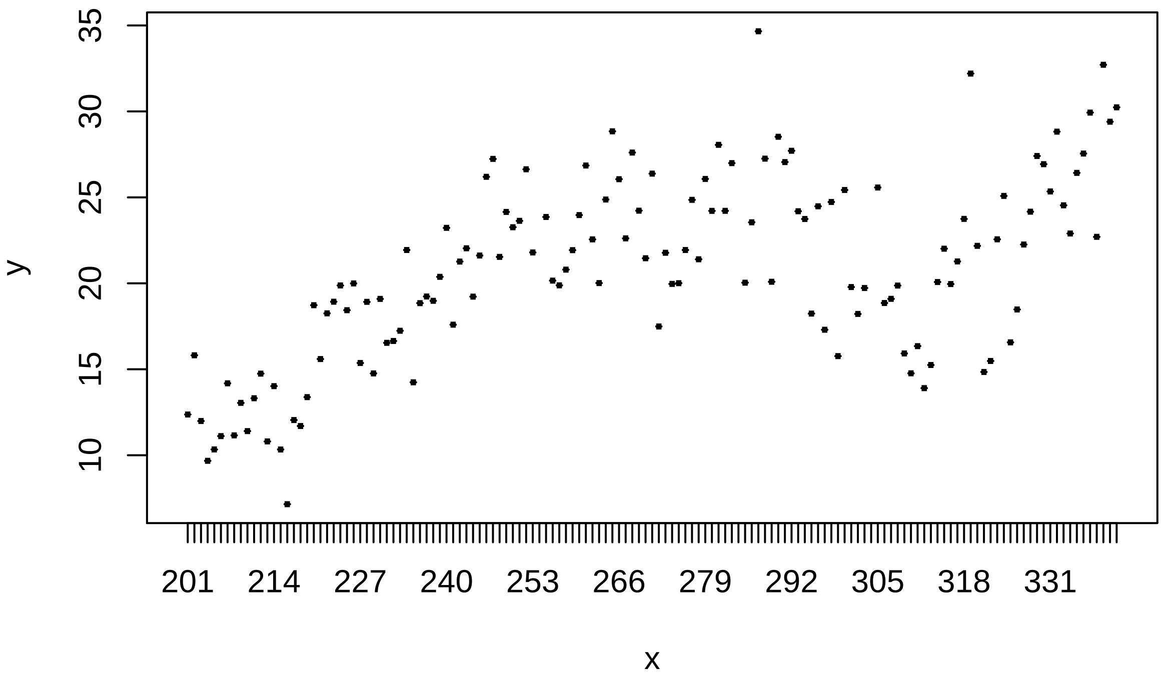

```
plot(capture_dat_plus$solar_rad_W_sqm_interpol,
     capture_dat_plus$osmolality_mmol_kg_mean)
```



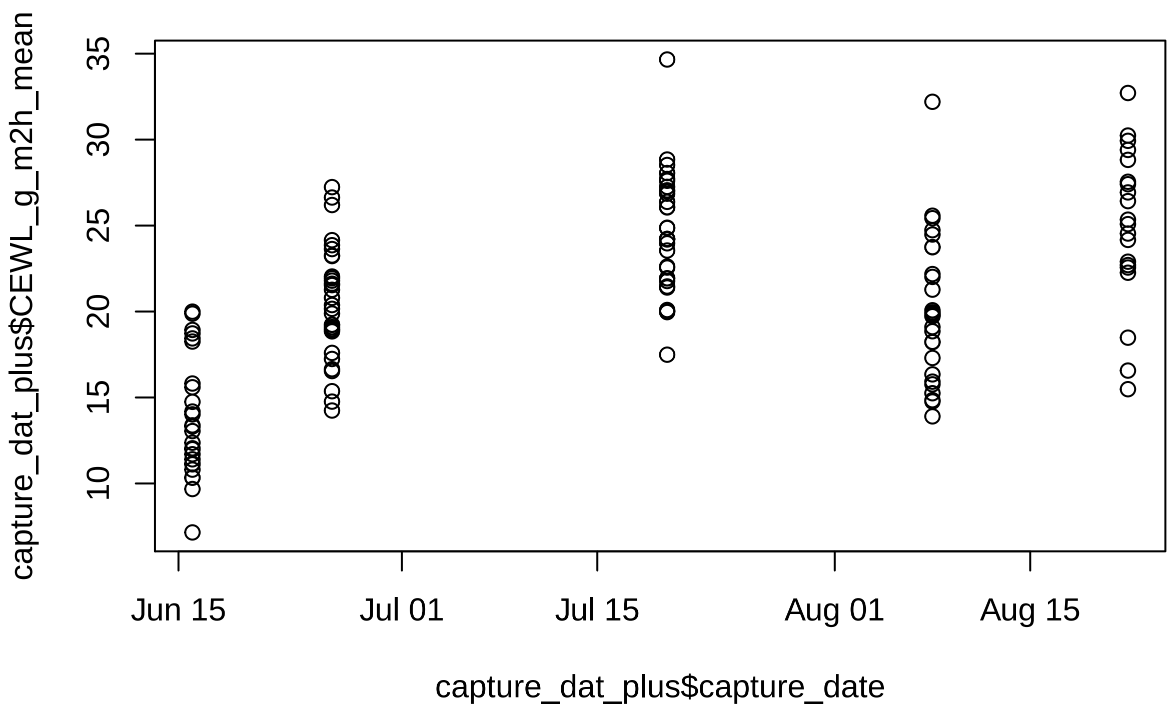
There does not appear to be a meaningful visual trend for plasma osmolality, so it will be interesting to see how the model selection process goes… There is definitely an increase in osmolality over the course of the season, though.

CEWL

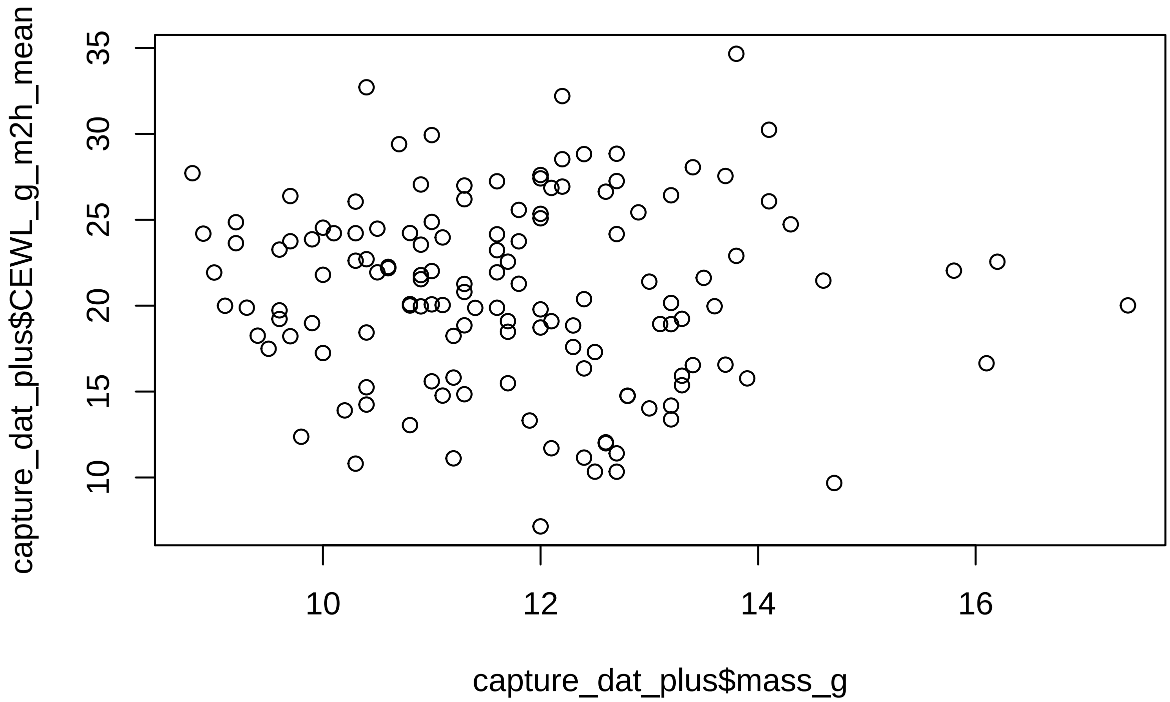
```r
plot(capture_dat_plus$individual_ID,
     capture_dat_plus$CEWL_g_m2h_mean)
```



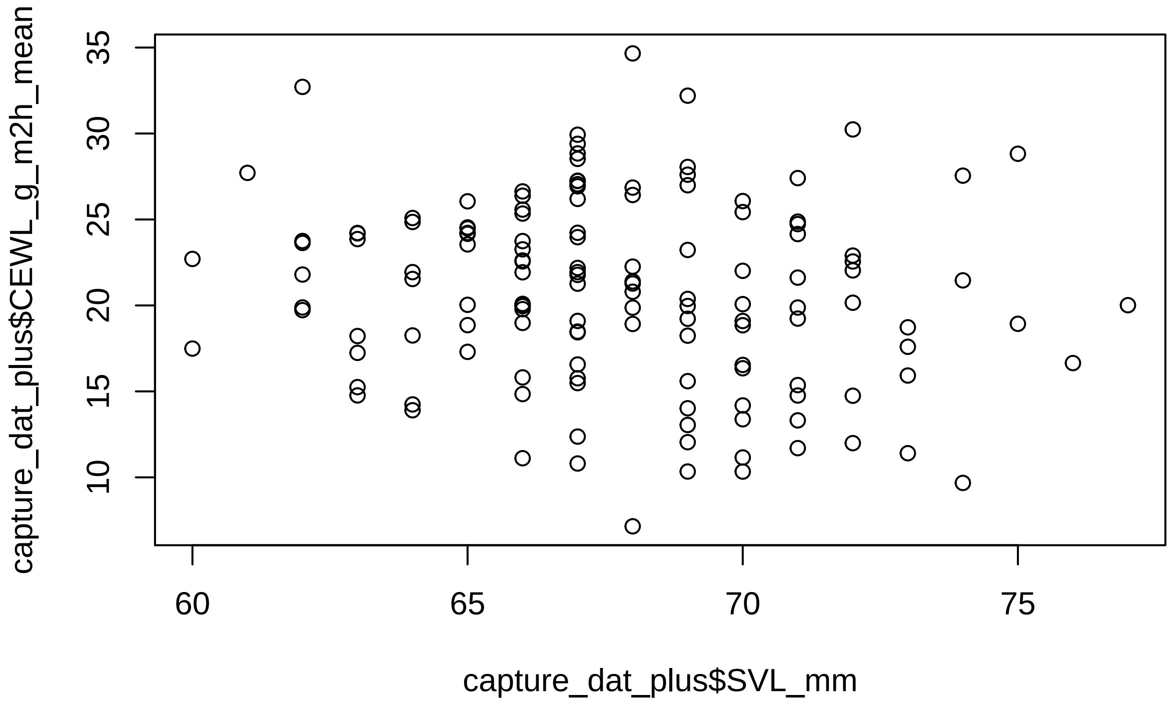

```r
plot(capture_dat_plus$capture_date,
     capture_dat_plus$CEWL_g_m2h_mean)
```



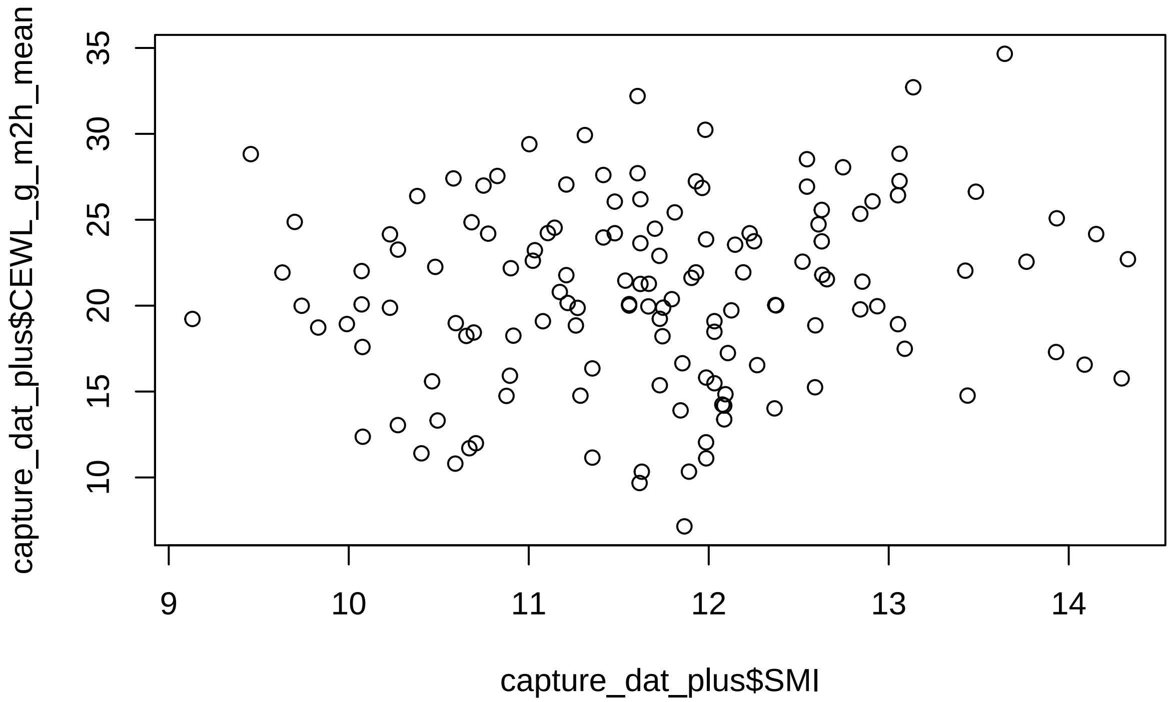

```r
plot(capture_dat_plus$mass_g,
     capture_dat_plus$CEWL_g_m2h_mean)
```



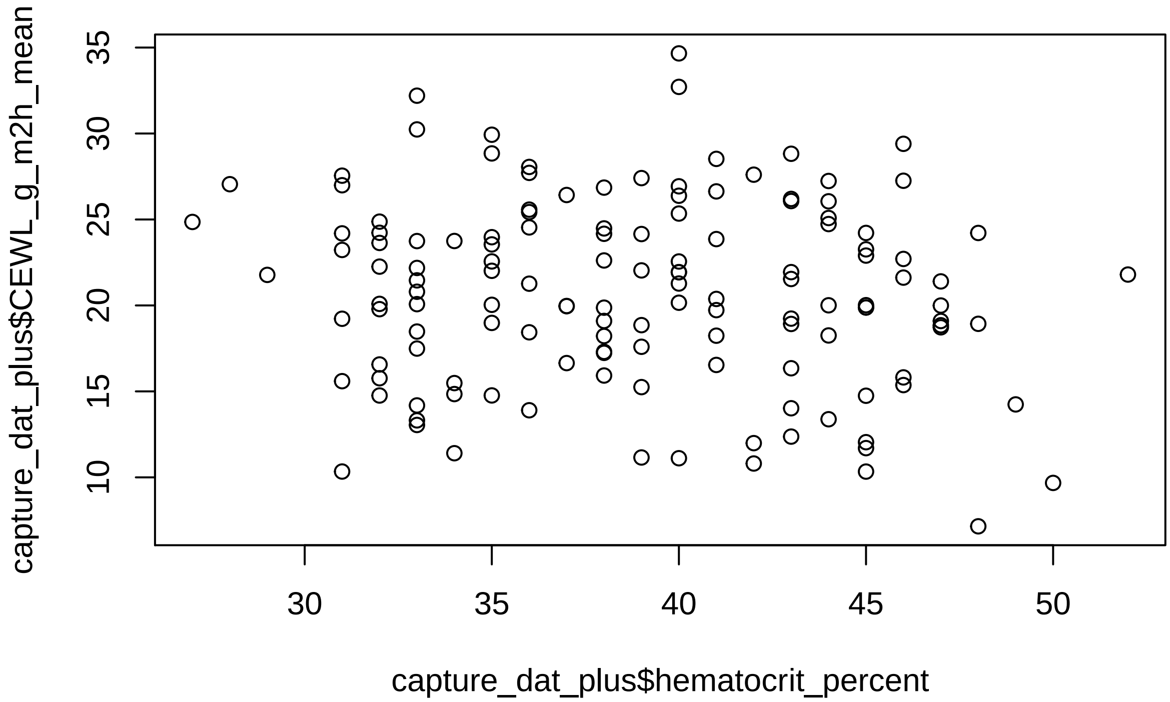

```r
plot(capture_dat_plus$SVL_mm,
     capture_dat_plus$CEWL_g_m2h_mean)
```



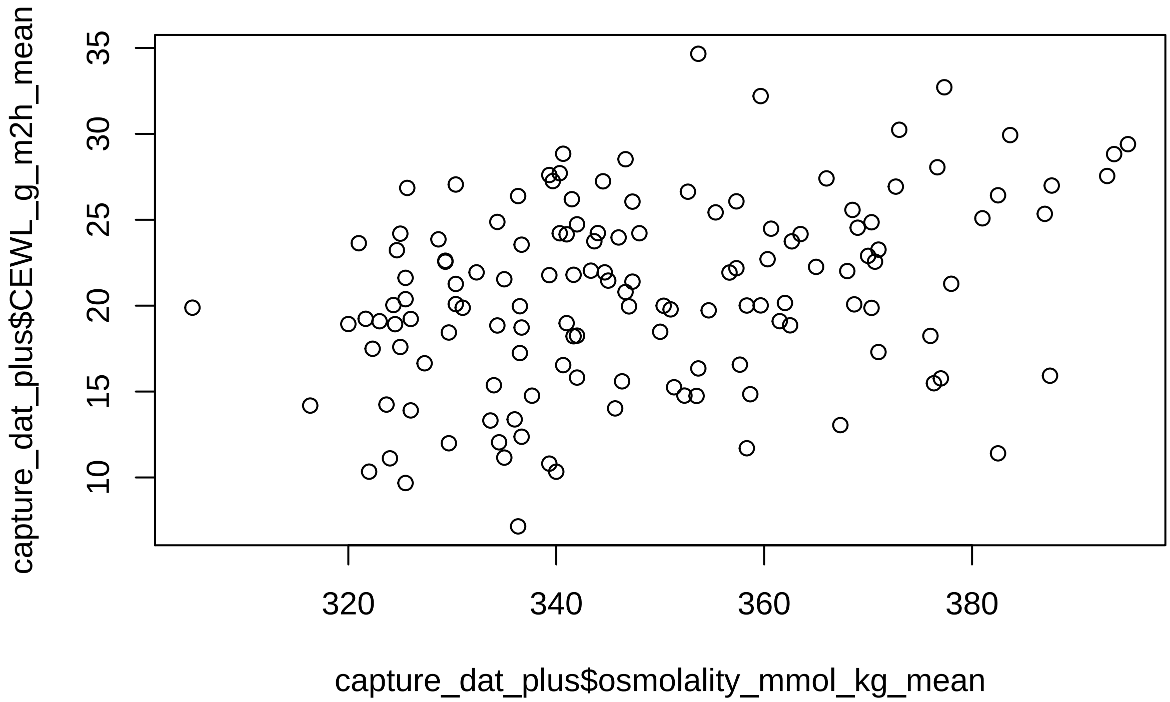

```r
plot(capture_dat_plus$SMI,
     capture_dat_plus$CEWL_g_m2h_mean)
```



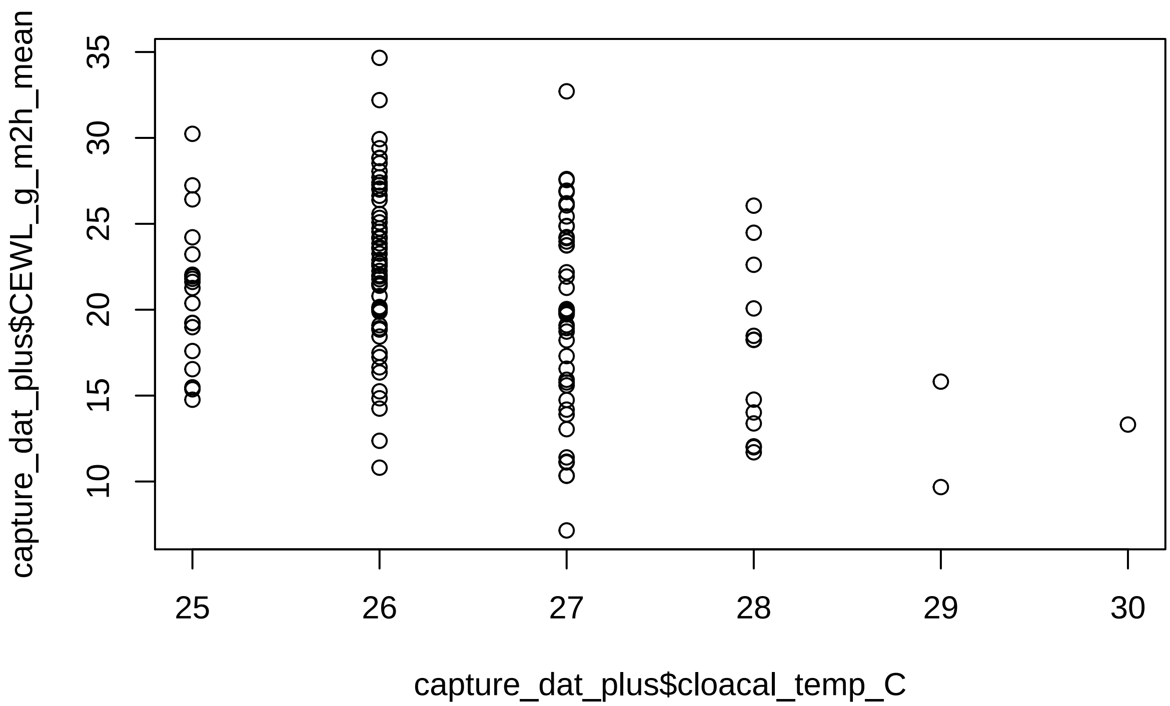

```r
plot(capture_dat_plus$hematocrit_percent,
     capture_dat_plus$CEWL_g_m2h_mean)
```



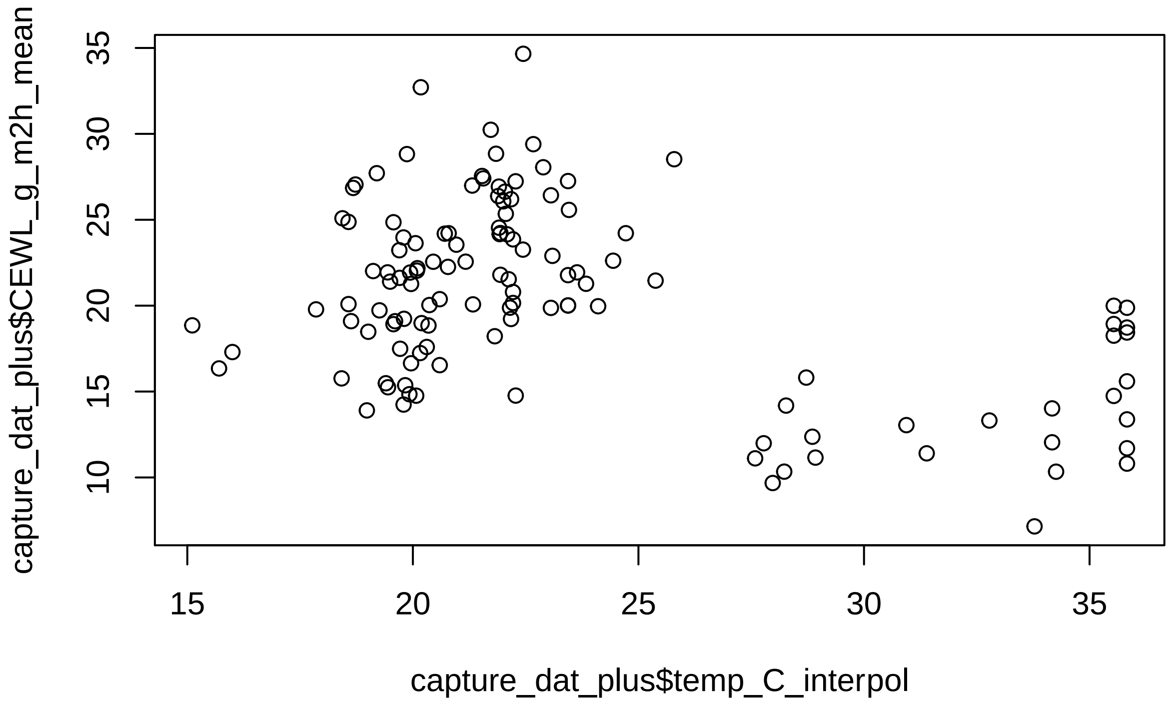

```r
plot(capture_dat_plus$osmolality_mmol_kg_mean,
     capture_dat_plus$CEWL_g_m2h_mean)
```



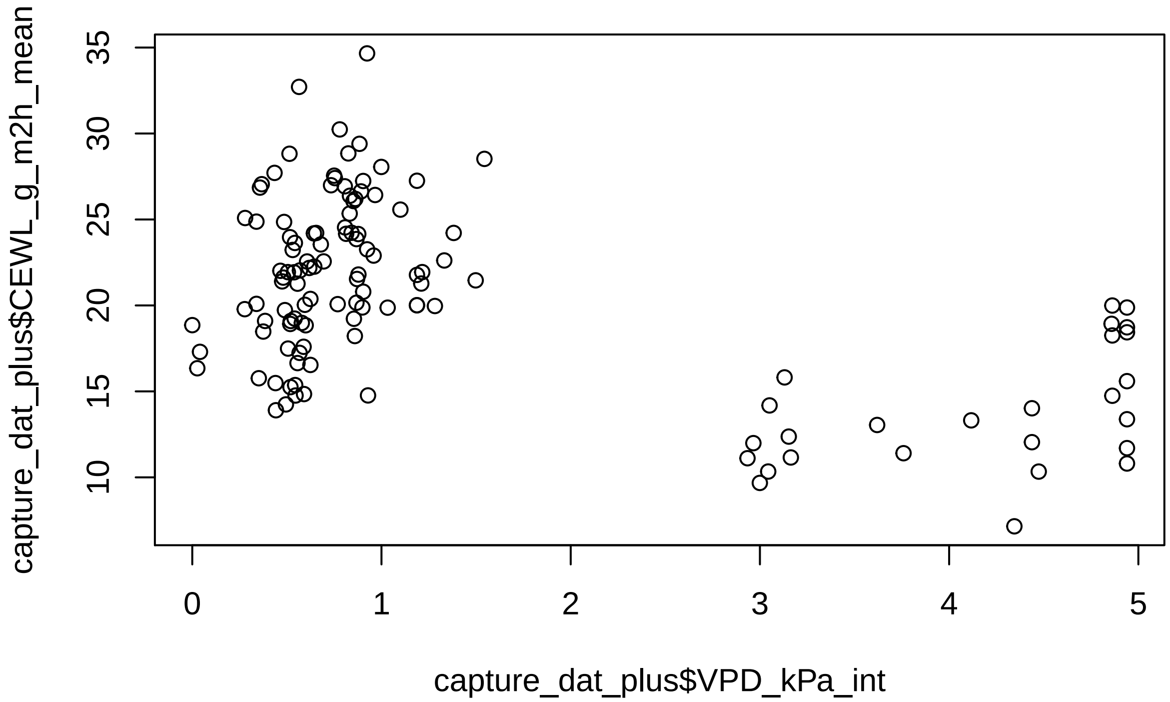

```r
plot(capture_dat_plus$cloacal_temp_C,
     capture_dat_plus$CEWL_g_m2h_mean)
```



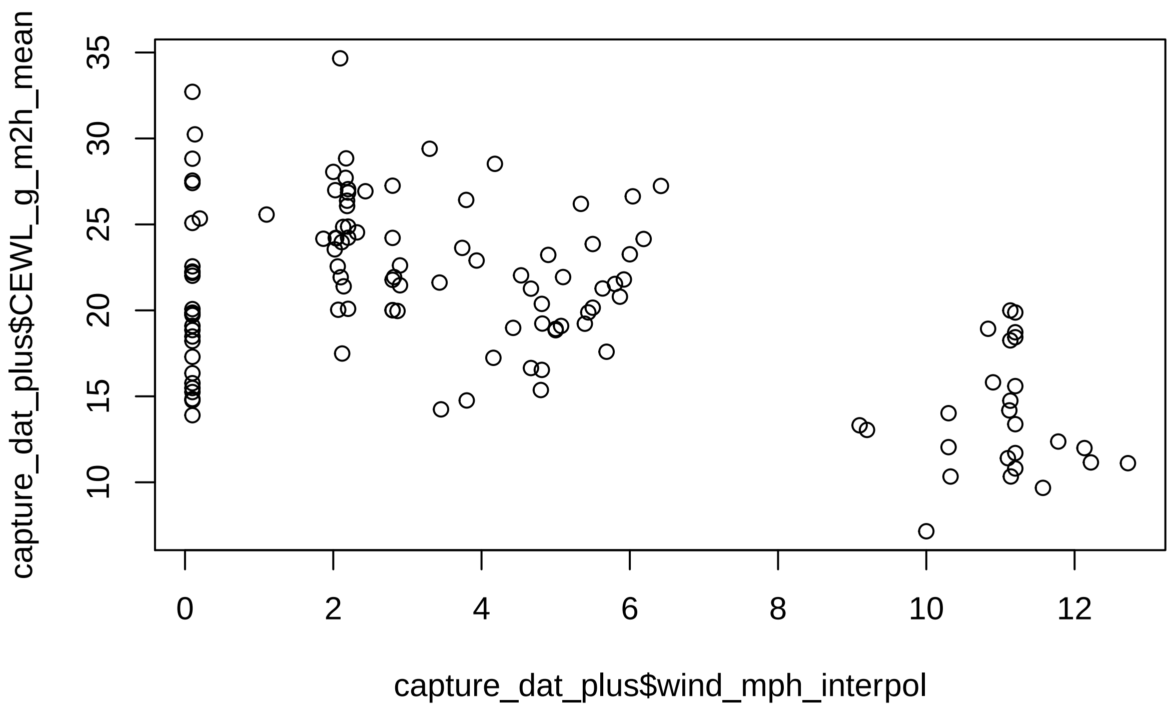

```r
plot(capture_dat_plus$temp_C_interpol,
     capture_dat_plus$CEWL_g_m2h_mean)
```



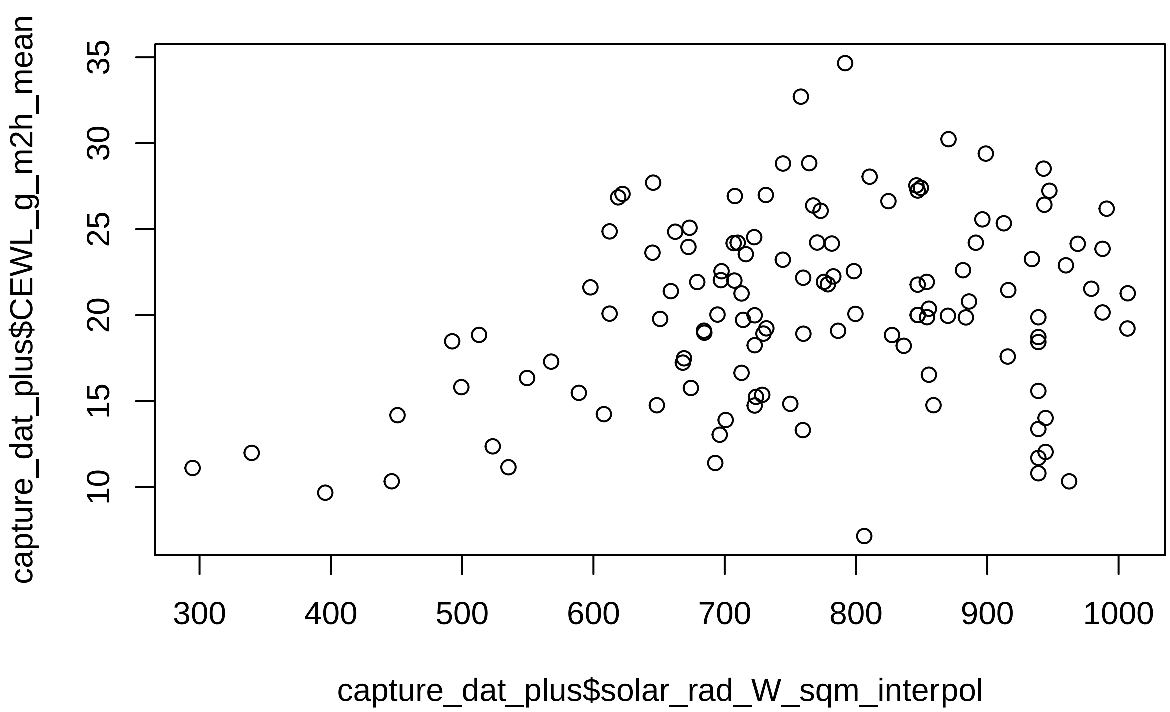

```r
plot(capture_dat_plus$VPD_kPa_int,
     capture_dat_plus$CEWL_g_m2h_mean)
```




```r
plot(capture_dat_plus$wind_mph_interpol,
     capture_dat_plus$CEWL_g_m2h_mean)
```




```
plot(capture_dat_plus$solar_rad_W_sqm_interpol,
     capture_dat_plus$CEWL_g_m2h_mean)
```



It looks like there are meaningful differences in CEWL across individuals/dates (probably confounded), and based on cloacal temp, capture temp, capture VPD, capture wind, and capture solar radiation.

LMMs

Osmolality

Model Selection

Since there are large differences in osmolality by date, but we are interested in what's different among dates, rather than the capture date itself, we will include that as a random effect in the model.

```r
osml_mod1 <- lm(data = capture_dat_plus,
                          # response variable
                          osmolality_mmol_kg_mean ~
                          # body size
                          mass_g + SVL_mm + SMI +
                          # blood sample traits
                          hemolyzed + hematocrit_percent +
                          # weather at the time of capture
                          temp_C_interpol * VPD_kPa_int +
                          wind_mph_interpol + solar_rad_W_sqm_interpol +
                          capture_date)
summary(osml_mod1)
```

```
##
## Call:
## lm(formula = osmolality_mmol_kg_mean ~ mass_g + SVL_mm + SMI +
##     hemolyzed + hematocrit_percent + temp_C_interpol * VPD_kPa_int +
##     wind_mph_interpol + solar_rad_W_sqm_interpol + capture_date,
##     data = capture_dat_plus)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -29.863  -9.653  -1.458   8.157  40.221
##
## Coefficients:
##                               Estimate Std. Error t value Pr(>|t|)
## (Intercept)                 -1.558e+04  2.226e+03  -6.997 2.03e-10 ***
## mass_g                      -8.314e+00  9.486e+00  -0.876    0.383
## SVL_mm                       4.533e+00  4.421e+00   1.025    0.307
## SMI                          7.979e+00  9.776e+00   0.816    0.416
## hemolyzedY                  -2.615e+00  4.792e+00  -0.546    0.586
## hematocrit_percent           5.548e-02  2.526e-01   0.220    0.827
## temp_C_interpol             -1.590e+00  3.166e+00  -0.502    0.617
## VPD_kPa_int                  1.474e+01  2.380e+01   0.619    0.537
## wind_mph_interpol            1.532e+00  1.277e+00   1.199    0.233
## solar_rad_W_sqm_interpol     2.822e-02  1.736e-02   1.625    0.107
## capture_date                 8.296e-01  1.212e-01   6.843 4.35e-10 ***
## temp_C_interpol:VPD_kPa_int -2.152e-01  3.821e-01  -0.563    0.574
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 13.61 on 112 degrees of freedom
##   (14 observations deleted due to missingness)
## Multiple R-squared:  0.5549, Adjusted R-squared:  0.5112
## F-statistic: 12.69 on 11 and 112 DF,  p-value: 2.711e-15
```

```r
drop1(osml_mod1)
```

```
## Single term deletions
##
## Model:
## osmolality_mmol_kg_mean ~ mass_g + SVL_mm + SMI + hemolyzed +
##     hematocrit_percent + temp_C_interpol * VPD_kPa_int + wind_mph_interpol +
##     solar_rad_W_sqm_interpol + capture_date
##                             Df Sum of Sq   RSS    AIC
## <none>                                   20747 658.86
## mass_g                       1     142.3 20889 657.71
## SVL_mm                       1     194.8 20941 658.02
## SMI                          1     123.4 20870 657.60
## hemolyzed                    1      55.2 20802 657.19
## hematocrit_percent           1       8.9 20756 656.92
## wind_mph_interpol            1     266.4 21013 658.44
## solar_rad_W_sqm_interpol     1     489.2 21236 659.75
## capture_date                 1    8673.3 29420 700.17
## temp_C_interpol:VPD_kPa_int  1      58.7 20805 657.21
```

The model would improve the most (based on lower AIC) if we drop hematocrit.

```r
osml_mod2 <- lm(data = capture_dat_plus,
                          # response variable
                          osmolality_mmol_kg_mean ~
                          # body size
                          mass_g + SVL_mm + SMI +
                          # blood sample traits
                          hemolyzed +
                          # weather at the time of capture
                          temp_C_interpol * VPD_kPa_int +
                          wind_mph_interpol + solar_rad_W_sqm_interpol +
                          capture_date)
summary(osml_mod2)
```

```
##
## Call:
## lm(formula = osmolality_mmol_kg_mean ~ mass_g + SVL_mm + SMI +
##     hemolyzed + temp_C_interpol * VPD_kPa_int + wind_mph_interpol +
##     solar_rad_W_sqm_interpol + capture_date, data = capture_dat_plus)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -29.820  -9.470  -1.231   8.266  39.923
##
## Coefficients:
##                               Estimate Std. Error t value Pr(>|t|)
## (Intercept)                 -1.560e+04  2.213e+03  -7.050 1.51e-10 ***
## mass_g                      -8.294e+00  9.445e+00  -0.878    0.382
## SVL_mm                       4.529e+00  4.402e+00   1.029    0.306
## SMI                          8.027e+00  9.732e+00   0.825    0.411
## hemolyzedY                  -2.534e+00  4.758e+00  -0.533    0.595
## temp_C_interpol             -1.527e+00  3.140e+00  -0.486    0.628
## VPD_kPa_int                  1.397e+01  2.344e+01   0.596    0.552
## wind_mph_interpol            1.596e+00  1.238e+00   1.289    0.200
```

```
## solar_rad_W_sqm_interpol     2.826e-02  1.729e-02   1.634    0.105
## capture_date                 8.311e-01  1.205e-01   6.895 3.26e-10 ***
## temp_C_interpol:VPD_kPa_int -2.018e-01  3.756e-01  -0.537    0.592
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 13.55 on 113 degrees of freedom
##   (14 observations deleted due to missingness)
## Multiple R-squared:  0.5547, Adjusted R-squared:  0.5153
## F-statistic: 14.08 on 10 and 113 DF,  p-value: 7.137e-16
```

```
drop1(osml_mod2)
```

```
## Single term deletions
##
## Model:
## osmolality_mmol_kg_mean ~ mass_g + SVL_mm + SMI + hemolyzed +
##     temp_C_interpol * VPD_kPa_int + wind_mph_interpol + solar_rad_W_sqm_interpol +
##     capture_date
##                             Df Sum of Sq   RSS    AIC
## <none>                                   20756 656.92
## mass_g                       1     141.6 20897 655.76
## SVL_mm                       1     194.4 20950 656.07
## SMI                          1     124.9 20880 655.66
## hemolyzed                    1      52.1 20808 655.23
## wind_mph_interpol            1     305.3 21061 656.73
## solar_rad_W_sqm_interpol     1     490.5 21246 657.81
## capture_date                 1    8732.2 29488 698.46
## temp_C_interpol:VPD_kPa_int  1      53.0 20808 655.23
```

```
# compare to full model
anova(osml_mod1, osml_mod2)
```

```
## Analysis of Variance Table
##
## Model 1: osmolality_mmol_kg_mean ~ mass_g + SVL_mm + SMI + hemolyzed +
##     hematocrit_percent + temp_C_interpol * VPD_kPa_int + wind_mph_interpol +
##     solar_rad_W_sqm_interpol + capture_date
## Model 2: osmolality_mmol_kg_mean ~ mass_g + SVL_mm + SMI + hemolyzed +
##     temp_C_interpol * VPD_kPa_int + wind_mph_interpol + solar_rad_W_sqm_interpol +
##     capture_date
##   Res.Df   RSS Df Sum of Sq      F Pr(>F)
## 1    112 20747
## 2    113 20756 -1   -8.9318 0.0482 0.8266
```

Next we can drop the interaction between temperature and VPD.

```
osml_mod3 <- lm(data = capture_dat_plus,
                          # response variable
                          osmolality_mmol_kg_mean ~
                          # body size
                          mass_g + SVL_mm + SMI +
                          # blood
                          hemolyzed +
                          # weather at the time of capture
                          temp_C_interpol + VPD_kPa_int +
```

```r
                          wind_mph_interpol + solar_rad_W_sqm_interpol +
                          capture_date)
summary(osml_mod3)
```

```
##
## Call:
## lm(formula = osmolality_mmol_kg_mean ~ mass_g + SVL_mm + SMI +
##     hemolyzed + temp_C_interpol + VPD_kPa_int + wind_mph_interpol +
##     solar_rad_W_sqm_interpol + capture_date, data = capture_dat_plus)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -29.209  -9.413  -0.920   8.282  40.584
##
## Coefficients:
##                            Estimate Std. Error t value Pr(>|t|)
## (Intercept)              -1.589e+04  2.143e+03  -7.413 2.34e-11 ***
## mass_g                   -8.640e+00  9.394e+00  -0.920   0.3597
## SVL_mm                    4.706e+00  4.376e+00   1.075   0.2845
## SMI                       8.427e+00  9.673e+00   0.871   0.3855
## hemolyzedY               -2.543e+00  4.743e+00  -0.536   0.5928
## temp_C_interpol          -3.932e-01  2.317e+00  -0.170   0.8656
## VPD_kPa_int               2.168e+00  8.133e+00   0.267   0.7903
## wind_mph_interpol         1.884e+00  1.113e+00   1.693   0.0931 .
## solar_rad_W_sqm_interpol  2.273e-02  1.385e-02   1.641   0.1035
## capture_date              8.447e-01  1.175e-01   7.189 7.30e-11 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 13.51 on 114 degrees of freedom
##   (14 observations deleted due to missingness)
## Multiple R-squared:  0.5535, Adjusted R-squared:  0.5183
## F-statistic:  15.7 on 9 and 114 DF,  p-value: < 2.2e-16
```

```r
drop1(osml_mod3)
```

```
## Single term deletions
##
## Model:
## osmolality_mmol_kg_mean ~ mass_g + SVL_mm + SMI + hemolyzed +
##     temp_C_interpol + VPD_kPa_int + wind_mph_interpol + solar_rad_W_sqm_interpol +
##     capture_date
##                          Df Sum of Sq   RSS    AIC
## <none>                                20808 655.23
## mass_g                    1     154.4 20963 654.15
## SVL_mm                    1     211.0 21020 654.48
## SMI                       1     138.5 20947 654.05
## hemolyzed                 1      52.5 20861 653.54
## temp_C_interpol           1       5.3 20814 653.26
## VPD_kPa_int               1      13.0 20822 653.31
## wind_mph_interpol         1     523.3 21332 656.31
## solar_rad_W_sqm_interpol  1     491.6 21300 656.13
## capture_date              1    9432.6 30241 699.59
```

```r
# compare to previous model
anova(osml_mod2, osml_mod3)
```

```
## Analysis of Variance Table
##
## Model 1: osmolality_mmol_kg_mean ~ mass_g + SVL_mm + SMI + hemolyzed +
##     temp_C_interpol * VPD_kPa_int + wind_mph_interpol + solar_rad_W_sqm_interpol +
##     capture_date
## Model 2: osmolality_mmol_kg_mean ~ mass_g + SVL_mm + SMI + hemolyzed +
##     temp_C_interpol + VPD_kPa_int + wind_mph_interpol + solar_rad_W_sqm_interpol +
##     capture_date
##   Res.Df   RSS Df Sum of Sq      F Pr(>F)
## 1    113 20756
## 2    114 20808 -1   -53.014 0.2886 0.5922
```

Drop temperature.

```r
osml_mod4 <- lm(data = capture_dat_plus,
                          # response variable
                          osmolality_mmol_kg_mean ~
                          # body size
                          mass_g + SVL_mm + SMI +
                          # blood
                          hemolyzed +
                          # weather at the time of capture
                          VPD_kPa_int +
                          solar_rad_W_sqm_interpol + wind_mph_interpol +
                          capture_date)
summary(osml_mod4)
```

```
##
## Call:
## lm(formula = osmolality_mmol_kg_mean ~ mass_g + SVL_mm + SMI +
##     hemolyzed + VPD_kPa_int + solar_rad_W_sqm_interpol + wind_mph_interpol +
##     capture_date, data = capture_dat_plus)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -28.909  -9.551  -0.958   8.338  40.518
##
## Coefficients:
##                            Estimate Std. Error t value Pr(>|t|)
## (Intercept)              -1.580e+04  2.072e+03  -7.625 7.64e-12 ***
## mass_g                   -9.096e+00  8.963e+00  -1.015   0.3124
## SVL_mm                    4.921e+00  4.169e+00   1.180   0.2403
## SMI                       8.875e+00  9.266e+00   0.958   0.3402
## hemolyzedY               -2.345e+00  4.578e+00  -0.512   0.6094
## VPD_kPa_int               8.259e-01  1.885e+00   0.438   0.6621
## solar_rad_W_sqm_interpol  2.092e-02  8.829e-03   2.369   0.0195 *
## wind_mph_interpol         1.835e+00  1.070e+00   1.715   0.0891 .
## capture_date              8.390e-01  1.121e-01   7.482 1.59e-11 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 13.45 on 115 degrees of freedom
```

```
##   (14 observations deleted due to missingness)
## Multiple R-squared:  0.5534, Adjusted R-squared:  0.5224
## F-statistic: 17.81 on 8 and 115 DF,  p-value: < 2.2e-16
```

```r
drop1(osml_mod4)
```

```
## Single term deletions
##
## Model:
## osmolality_mmol_kg_mean ~ mass_g + SVL_mm + SMI + hemolyzed +
##     VPD_kPa_int + solar_rad_W_sqm_interpol + wind_mph_interpol +
##     capture_date
##                          Df Sum of Sq   RSS    AIC
## <none>                                20814 653.26
## mass_g                    1     186.4 21000 652.37
## SVL_mm                    1     252.2 21066 652.76
## SMI                       1     166.0 20980 652.25
## hemolyzed                 1      47.5 20861 651.55
## VPD_kPa_int               1      34.8 20849 651.47
## solar_rad_W_sqm_interpol  1    1016.2 21830 657.17
## wind_mph_interpol         1     532.1 21346 654.39
## capture_date              1   10132.2 30946 700.44
```

```r
# compare to previous model
anova(osml_mod3, osml_mod4)
```

```
## Analysis of Variance Table
##
## Model 1: osmolality_mmol_kg_mean ~ mass_g + SVL_mm + SMI + hemolyzed +
##     temp_C_interpol + VPD_kPa_int + wind_mph_interpol + solar_rad_W_sqm_interpol +
##     capture_date
## Model 2: osmolality_mmol_kg_mean ~ mass_g + SVL_mm + SMI + hemolyzed +
##     VPD_kPa_int + solar_rad_W_sqm_interpol + wind_mph_interpol +
##     capture_date
##   Res.Df   RSS Df Sum of Sq      F Pr(>F)
## 1    114 20808
## 2    115 20814 -1   -5.2546 0.0288 0.8656
```

Drop VPD:

```r
osml_mod5 <- lm(data = capture_dat_plus,
                          # response variable
                          osmolality_mmol_kg_mean ~
                          # body size
                          mass_g + SVL_mm + SMI +
                          # blood
                          hemolyzed +
                          # weather at the time of capture
                          solar_rad_W_sqm_interpol + wind_mph_interpol +
                          capture_date)
summary(osml_mod5)
```

```
##
## Call:
## lm(formula = osmolality_mmol_kg_mean ~ mass_g + SVL_mm + SMI +
##     hemolyzed + solar_rad_W_sqm_interpol + wind_mph_interpol +
##     capture_date, data = capture_dat_plus)
```

```
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -28.586  -9.562  -0.677   8.683  40.539
##
## Coefficients:
##                             Estimate Std. Error t value Pr(>|t|)
## (Intercept)               -1.623e+04  1.815e+03  -8.943 7.07e-15 ***
## mass_g                    -9.151e+00  8.931e+00  -1.025 0.307700
## SVL_mm                     4.943e+00  4.155e+00   1.190 0.236566
## SMI                        8.867e+00  9.234e+00   0.960 0.338888
## hemolyzedY                -2.239e+00  4.555e+00  -0.491 0.624048
## solar_rad_W_sqm_interpol   2.184e-02  8.549e-03   2.554 0.011941 *
## wind_mph_interpol          2.217e+00  6.211e-01   3.569 0.000523 ***
## capture_date               8.619e-01  9.887e-02   8.717 2.36e-14 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 13.41 on 116 degrees of freedom
##   (14 observations deleted due to missingness)
## Multiple R-squared:  0.5527, Adjusted R-squared:  0.5257
## F-statistic: 20.48 on 7 and 116 DF,  p-value: < 2.2e-16
```

```r
drop1(osml_mod5)
```

```
## Single term deletions
##
## Model:
## osmolality_mmol_kg_mean ~ mass_g + SVL_mm + SMI + hemolyzed +
##     solar_rad_W_sqm_interpol + wind_mph_interpol + capture_date
##                          Df Sum of Sq   RSS    AIC
## <none>                                20849 651.47
## mass_g                    1     188.7 21037 650.59
## SVL_mm                    1     254.4 21103 650.97
## SMI                       1     165.8 21014 650.45
## hemolyzed                 1      43.4 20892 649.73
## solar_rad_W_sqm_interpol  1    1172.5 22021 656.25
## wind_mph_interpol         1    2289.1 23138 662.39
## capture_date              1   13658.1 34507 711.95
```

```r
# compare to previous model
anova(osml_mod4, osml_mod5)
```

```
## Analysis of Variance Table
##
## Model 1: osmolality_mmol_kg_mean ~ mass_g + SVL_mm + SMI + hemolyzed +
##     VPD_kPa_int + solar_rad_W_sqm_interpol + wind_mph_interpol +
##     capture_date
## Model 2: osmolality_mmol_kg_mean ~ mass_g + SVL_mm + SMI + hemolyzed +
##     solar_rad_W_sqm_interpol + wind_mph_interpol + capture_date
##   Res.Df   RSS Df Sum of Sq     F Pr(>F)
## 1    115 20814
## 2    116 20849 -1   -34.753 0.192 0.6621
```

Drop whether a sample is hemolyzed:

```r
osml_mod6 <- lm(data = capture_dat_plus,
                          # response variable
                          osmolality_mmol_kg_mean ~
                          # body size
                          mass_g + SVL_mm + SMI +
                          # weather at the time of capture
                          solar_rad_W_sqm_interpol + wind_mph_interpol +
                          capture_date)
summary(osml_mod6)
```

```
##
## Call:
## lm(formula = osmolality_mmol_kg_mean ~ mass_g + SVL_mm + SMI +
##     solar_rad_W_sqm_interpol + wind_mph_interpol + capture_date,
##     data = capture_dat_plus)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -28.454  -9.524  -1.428   8.887  40.637
##
## Coefficients:
##                            Estimate Std. Error t value Pr(>|t|)
## (Intercept)              -1.615e+04  1.802e+03  -8.964 5.94e-15 ***
## mass_g                   -9.037e+00  8.899e+00  -1.015 0.311967
## SVL_mm                    4.925e+00  4.141e+00   1.189 0.236667
## SMI                       8.640e+00  9.192e+00   0.940 0.349198
## solar_rad_W_sqm_interpol  2.085e-02  8.285e-03   2.517 0.013191 *
## wind_mph_interpol         2.158e+00  6.075e-01   3.552 0.000552 ***
## capture_date              8.577e-01  9.819e-02   8.735 2.03e-14 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 13.36 on 117 degrees of freedom
##   (14 observations deleted due to missingness)
## Multiple R-squared:  0.5518, Adjusted R-squared:  0.5288
## F-statistic:    24 on 6 and 117 DF,  p-value: < 2.2e-16
```

```r
drop1(osml_mod6)
```

```
## Single term deletions
##
## Model:
## osmolality_mmol_kg_mean ~ mass_g + SVL_mm + SMI + solar_rad_W_sqm_interpol +
##     wind_mph_interpol + capture_date
##                          Df Sum of Sq   RSS    AIC
## <none>                                20892 649.73
## mass_g                    1     184.1 21076 648.82
## SVL_mm                    1     252.6 21145 649.22
## SMI                       1     157.8 21050 648.66
## solar_rad_W_sqm_interpol  1    1131.2 22023 654.27
## wind_mph_interpol         1    2252.9 23145 660.43
## capture_date              1   13625.9 34518 709.99
```

```r
# compare to previous model
anova(osml_mod5, osml_mod6)
```

```
## Analysis of Variance Table
##
## Model 1: osmolality_mmol_kg_mean ~ mass_g + SVL_mm + SMI + hemolyzed +
##     solar_rad_W_sqm_interpol + wind_mph_interpol + capture_date
## Model 2: osmolality_mmol_kg_mean ~ mass_g + SVL_mm + SMI + solar_rad_W_sqm_interpol +
##     wind_mph_interpol + capture_date
##   Res.Df   RSS Df Sum of Sq      F Pr(>F)
## 1    116 20849
## 2    117 20892 -1   -43.406 0.2415  0.624
```

Drop body condition (SMI):

```
osml_mod7 <- lm(data = capture_dat_plus,
                          # response variable
                          osmolality_mmol_kg_mean ~
                          # body size
                          mass_g + SVL_mm +
                          # weather at the time of capture
                          solar_rad_W_sqm_interpol + wind_mph_interpol +
                          capture_date)
summary(osml_mod7)
```

```
##
## Call:
## lm(formula = osmolality_mmol_kg_mean ~ mass_g + SVL_mm + solar_rad_W_sqm_interpol +
##     wind_mph_interpol + capture_date, data = capture_dat_plus)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -29.024  -9.218  -1.560   7.764  41.652
##
## Coefficients:
##                            Estimate Std. Error t value Pr(>|t|)
## (Intercept)              -1.631e+04  1.793e+03  -9.096 2.75e-15 ***
## mass_g                   -7.468e-01  1.183e+00  -0.631 0.528962
## SVL_mm                    1.073e+00  5.883e-01   1.824 0.070713 .
## solar_rad_W_sqm_interpol  2.117e-02  8.274e-03   2.559 0.011767 *
## wind_mph_interpol         2.259e+00  5.975e-01   3.781 0.000247 ***
## capture_date              8.802e-01  9.521e-02   9.245 1.23e-15 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 13.36 on 118 degrees of freedom
##   (14 observations deleted due to missingness)
## Multiple R-squared:  0.5484, Adjusted R-squared:  0.5292
## F-statistic: 28.66 on 5 and 118 DF,  p-value: < 2.2e-16
```

```
drop1(osml_mod7)
```

```
## Single term deletions
##
## Model:
## osmolality_mmol_kg_mean ~ mass_g + SVL_mm + solar_rad_W_sqm_interpol +
##     wind_mph_interpol + capture_date
##                          Df Sum of Sq   RSS    AIC
## <none>                                21050 648.66
```

```
## mass_g                      1      71.1 21121 647.08
## SVL_mm                      1     593.4 21643 650.11
## solar_rad_W_sqm_interpol    1    1168.0 22218 653.36
## wind_mph_interpol           1    2550.1 23600 660.84
## capture_date                1   15245.6 36295 714.22
```

Drop mass:

```r
osml_mod8 <- lm(data = capture_dat_plus,
                          # response variable
                          osmolality_mmol_kg_mean ~
                          # body size
                          SVL_mm +
                          # weather at the time of capture
                          solar_rad_W_sqm_interpol + wind_mph_interpol +
                          capture_date)
summary(osml_mod8)
```

```
##
## Call:
## lm(formula = osmolality_mmol_kg_mean ~ SVL_mm + solar_rad_W_sqm_interpol +
##     wind_mph_interpol + capture_date, data = capture_dat_plus)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -28.707  -9.595  -1.384   8.286  42.088
##
## Coefficients:
##                            Estimate Std. Error t value Pr(>|t|)
## (Intercept)              -1.629e+04  1.788e+03  -9.109 2.41e-15 ***
## SVL_mm                    7.864e-01  3.736e-01   2.105 0.037395 *
## solar_rad_W_sqm_interpol  2.159e-02  8.227e-03   2.624 0.009842 **
## wind_mph_interpol         2.311e+00  5.904e-01   3.914 0.000152 ***
## capture_date              8.796e-01  9.496e-02   9.263 1.04e-15 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 13.32 on 119 degrees of freedom
##   (14 observations deleted due to missingness)
## Multiple R-squared:  0.5468, Adjusted R-squared:  0.5316
## F-statistic:  35.9 on 4 and 119 DF,  p-value: < 2.2e-16
```

```r
drop1(osml_mod8)
```

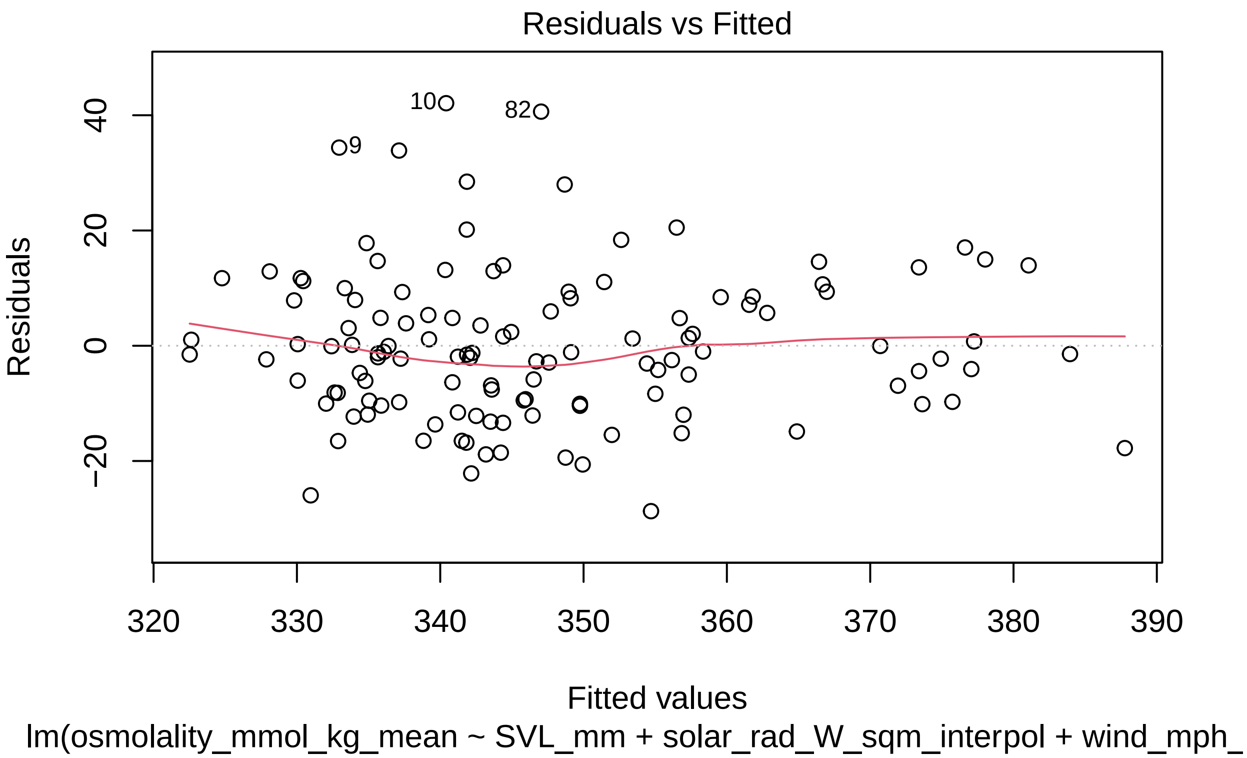
```
## Single term deletions
##
## Model:
## osmolality_mmol_kg_mean ~ SVL_mm + solar_rad_W_sqm_interpol +
##     wind_mph_interpol + capture_date
##                          Df Sum of Sq   RSS    AIC
## <none>                                21121 647.08
## SVL_mm                    1     786.4 21907 649.61
## solar_rad_W_sqm_interpol  1    1221.6 22342 652.05
## wind_mph_interpol         1    2718.4 23839 660.09
## capture_date              1   15228.5 36349 712.40
```

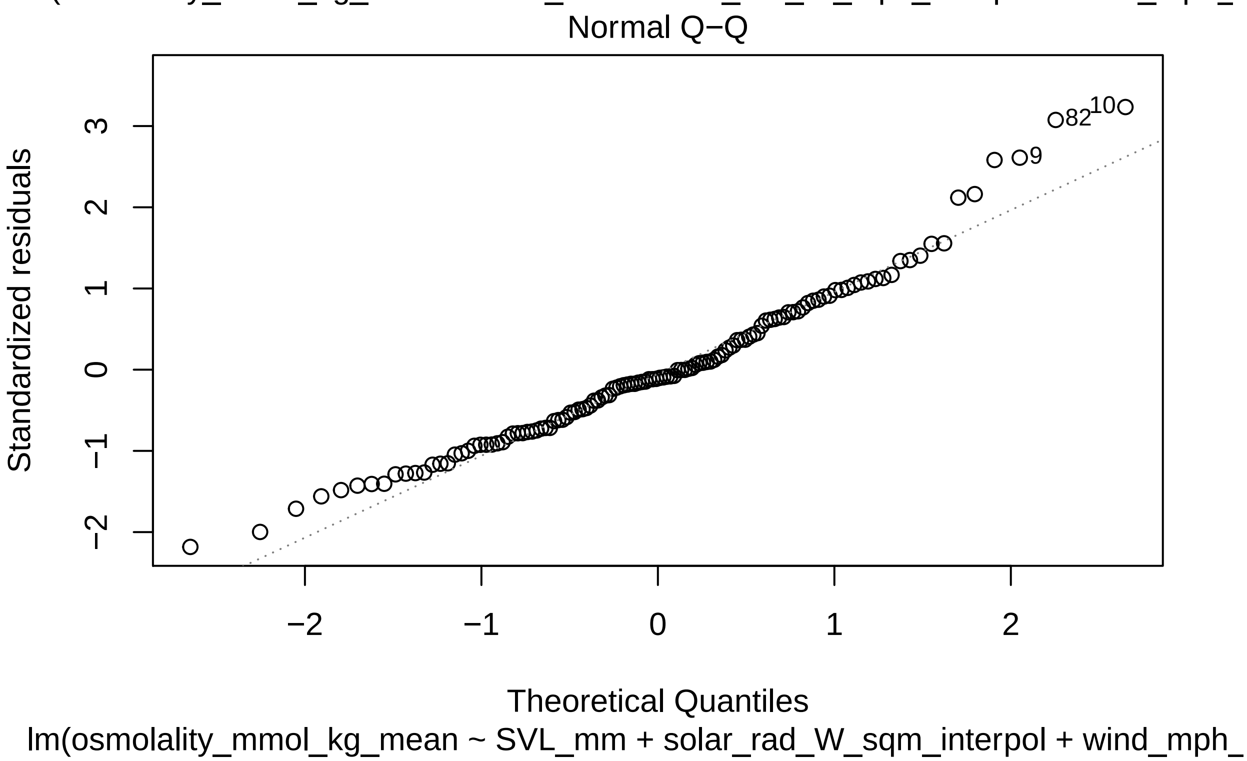
Model 8 is the best model!

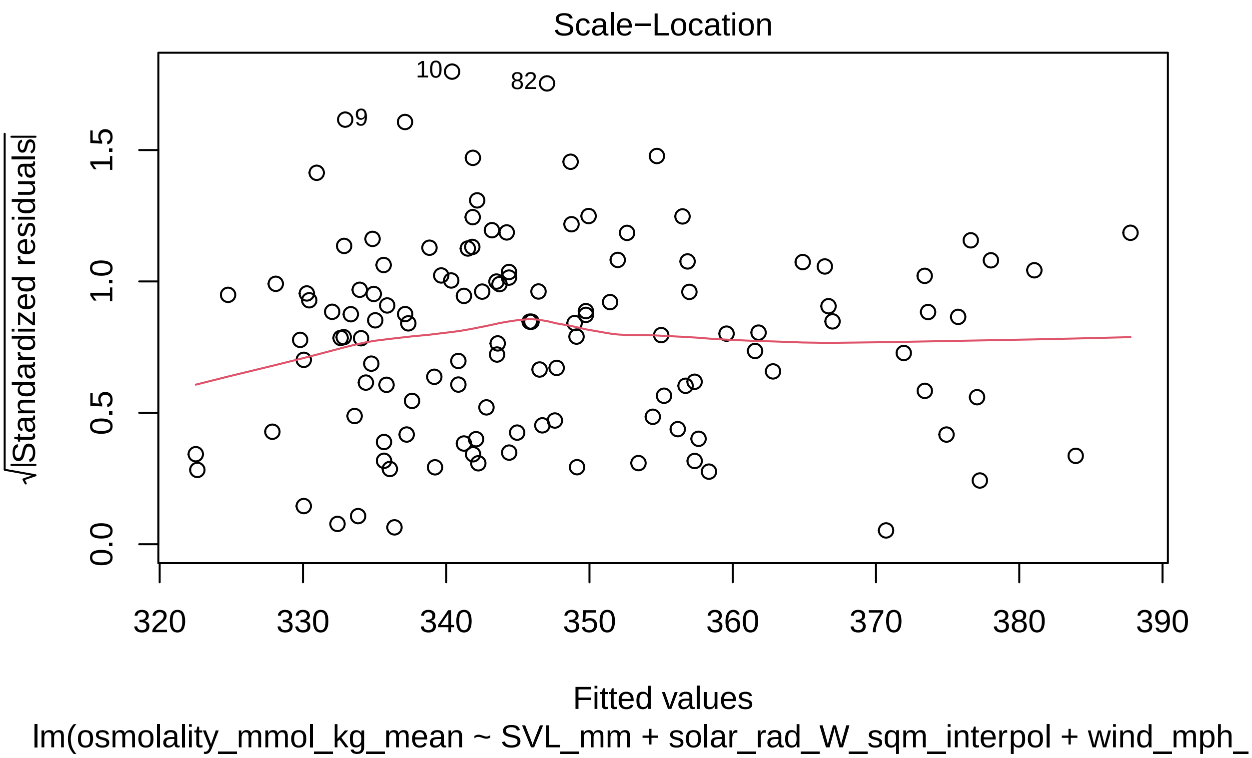
LM Conditions

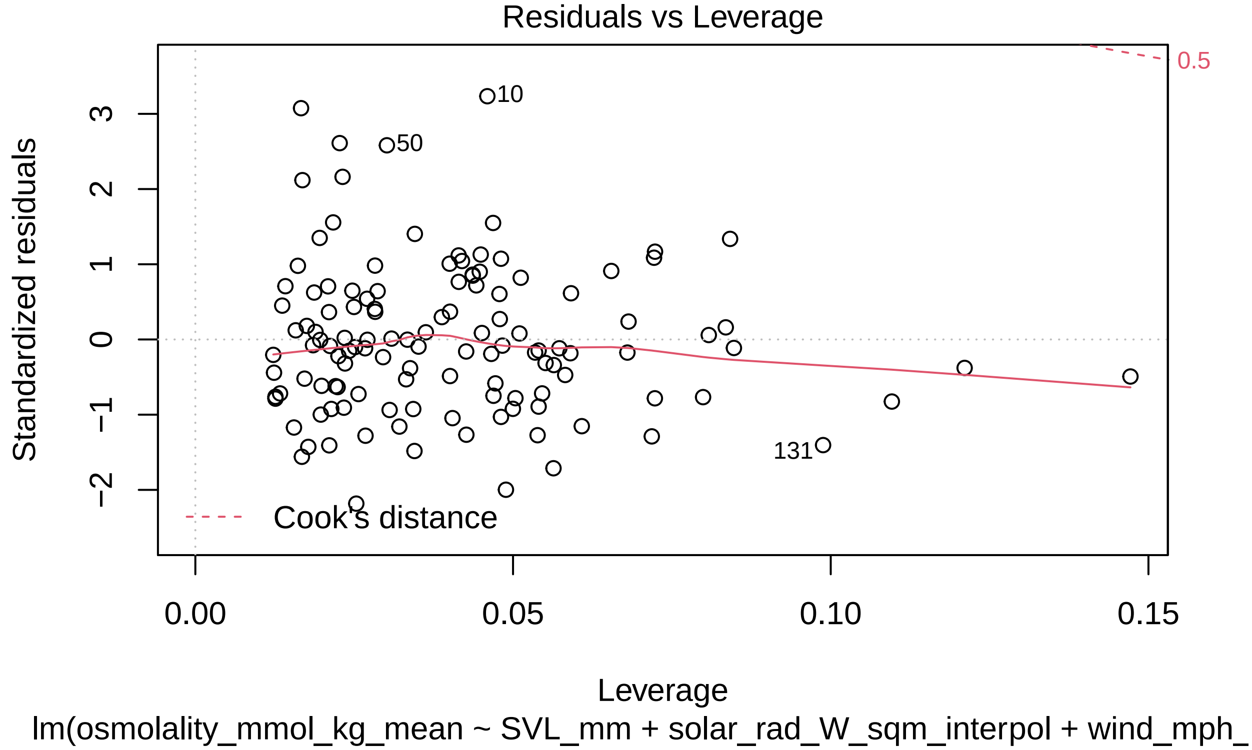
Check residual plots:

```
plot(osml_mod8)
```

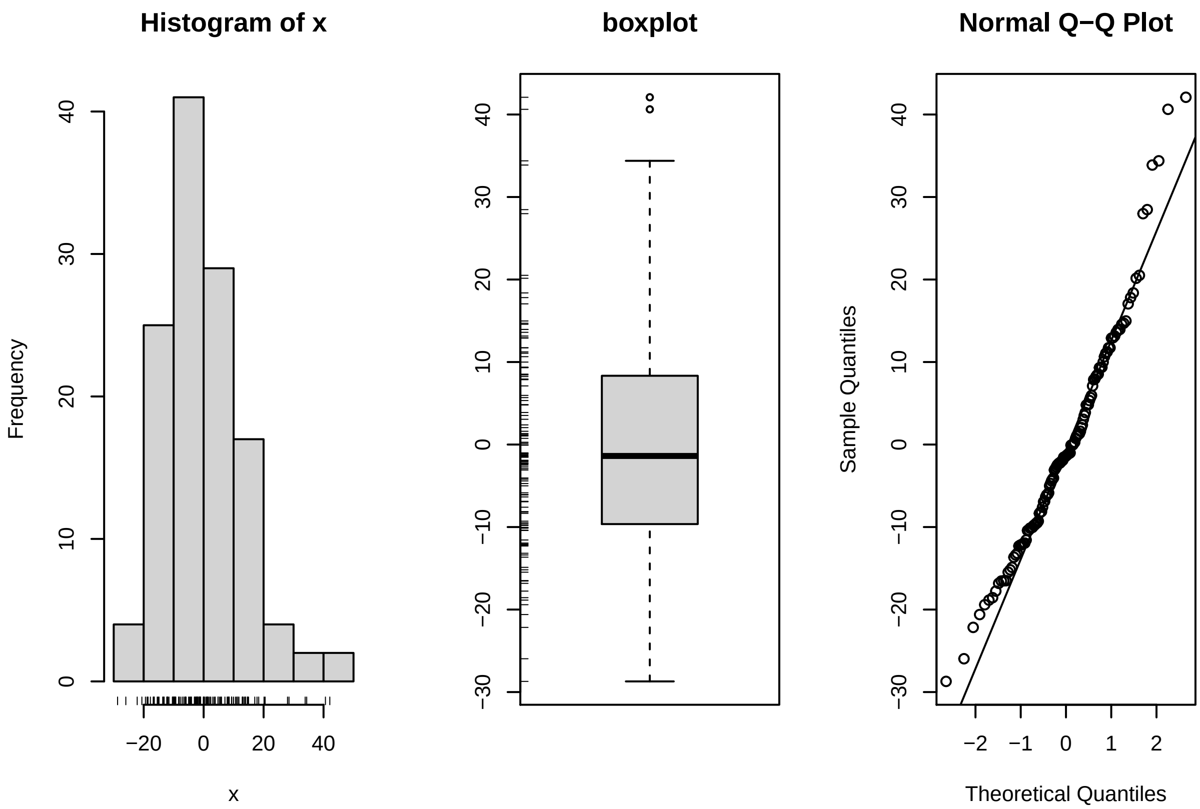









```
simple.eda(residuals(osml_mod8))
```




```
shapiro.test(residuals(osml_mod8))
```

```
##
##  Shapiro-Wilk normality test
##
## data:  residuals(osml_mod8)
## W = 0.96834, p-value = 0.005199
```

There is no clear pattern in the residuals ~ fitted plot, so linearity seems satisfied. Equal error variance seems fine. Normality seems fine, even though the Shapiro-Wilk normality test is significant.

Conclusion

Save the model output.

```
osml_best_mod_results <- broom.mixed::tidy(osml_mod8)
write.csv(osml_best_mod_results,
          "./results_statistics/capture_osml_best_model.csv")
```

To report in paper:

The best model to predict the variation in baseline plasma osmolality included SVL, solar radiation and wind speed at the time of capture, and date as fixed effects. The final model had acceptable LM conditions. During model selection, each reduced model was only 1-2-delta-AIC better than the previous model. The full model included mass, SVL, SMI, whether the blood sample was hemolyzed, percent hematocrit, and temperature, VPD, wind speed, and solar radiation at the time of capture, with date as a random effect.

CEWL

It looks like there are meaningful differences in CEWL across individuals/dates (probably confounded), and based on cloacal temp, capture temp, capture VPD, capture wind, and capture solar radiation.

Model Selection

Start with the full model of all potential predictor variables. We will again include date as a random effect.

```
CEWL_mod1 <- lm(data = capture_dat_plus,
                          # response variable
                          CEWL_g_m2h_mean ~
                          # essential covariate
                          cloacal_temp_C +
                          # body size
                          mass_g + SVL_mm + SMI +
                          # blood
                          osmolality_mmol_kg_mean + hematocrit_percent +
                          # weather at the time of capture
                          temp_C_interpol * VPD_kPa_int +
                          wind_mph_interpol + solar_rad_W_sqm_interpol +
                          capture_date)
summary(CEWL_mod1)
```

```
##
## Call:
## lm(formula = CEWL_g_m2h_mean ~ cloacal_temp_C + mass_g + SVL_mm +
##     SMI + osmolality_mmol_kg_mean + hematocrit_percent + temp_C_interpol *
##     VPD_kPa_int + wind_mph_interpol + solar_rad_W_sqm_interpol +
##     capture_date, data = capture_dat_plus)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -9.1278 -2.3108 -0.1368  2.3330 10.9099
##
## Coefficients:
##                               Estimate Std. Error t value Pr(>|t|)
## (Intercept)                 -7.825e+02  7.113e+02  -1.100 0.273659
## cloacal_temp_C              -6.655e-02  4.698e-01  -0.142 0.887609
## mass_g                      -2.344e+00  2.555e+00  -0.917 0.360983
## SVL_mm                       1.044e+00  1.191e+00   0.877 0.382643
## SMI                          2.182e+00  2.634e+00   0.828 0.409224
## osmolality_mmol_kg_mean      3.726e-02  2.535e-02   1.470 0.144438
## hematocrit_percent          -6.867e-03  6.757e-02  -0.102 0.919235
## temp_C_interpol              4.911e+00  8.506e-01   5.773 7.19e-08 ***
## VPD_kPa_int                 -3.470e+01  6.728e+00  -5.157 1.10e-06 ***
## wind_mph_interpol            3.689e-01  3.542e-01   1.041 0.299958
## solar_rad_W_sqm_interpol    -1.157e-02  4.550e-03  -2.542 0.012396 *
## capture_date                 3.444e-02  3.847e-02   0.895 0.372675
## temp_C_interpol:VPD_kPa_int  4.128e-01  1.082e-01   3.816 0.000223 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 3.65 on 111 degrees of freedom
##   (14 observations deleted due to missingness)
## Multiple R-squared:  0.5827, Adjusted R-squared:  0.5376
## F-statistic: 12.92 on 12 and 111 DF,  p-value: 3.511e-16
```

```
drop1(CEWL_mod1)
```

```
## Single term deletions
```

```
##
## Model:
## CEWL_g_m2h_mean ~ cloacal_temp_C + mass_g + SVL_mm + SMI + osmolality_mmol_kg_mean +
##     hematocrit_percent + temp_C_interpol * VPD_kPa_int + wind_mph_interpol +
##     solar_rad_W_sqm_interpol + capture_date
##                             Df Sum of Sq    RSS    AIC
## <none>                                   1478.8 333.36
## cloacal_temp_C               1     0.267 1479.1 331.38
## mass_g                       1    11.210 1490.0 332.30
## SVL_mm                       1    10.236 1489.0 332.22
## SMI                          1     9.143 1488.0 332.12
## osmolality_mmol_kg_mean      1    28.782 1507.6 333.75
## hematocrit_percent           1     0.138 1479.0 331.37
## wind_mph_interpol            1    14.448 1493.3 332.57
## solar_rad_W_sqm_interpol     1    86.098 1564.9 338.38
## capture_date                 1    10.674 1489.5 332.25
## temp_C_interpol:VPD_kPa_int  1   194.013 1672.8 346.65
```

We will start with dropping hematocrit.

```
CEWL_mod2 <- lm(data = capture_dat_plus,
                          # response variable
                          CEWL_g_m2h_mean ~
                          # essential covariate
                          cloacal_temp_C +
                          # body size
                          mass_g + SVL_mm + SMI +
                          # blood
                          osmolality_mmol_kg_mean +
                          # weather at the time of capture
                          temp_C_interpol * VPD_kPa_int +
                          wind_mph_interpol + solar_rad_W_sqm_interpol +
                          capture_date)
summary(CEWL_mod2)
```

```
##
## Call:
## lm(formula = CEWL_g_m2h_mean ~ cloacal_temp_C + mass_g + SVL_mm +
##     SMI + osmolality_mmol_kg_mean + temp_C_interpol * VPD_kPa_int +
##     wind_mph_interpol + solar_rad_W_sqm_interpol + capture_date,
##     data = capture_dat_plus)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -9.1097 -2.2967 -0.1641  2.3094 10.9095
##
## Coefficients:
##                               Estimate Std. Error t value Pr(>|t|)
## (Intercept)                 -7.793e+02  7.075e+02  -1.102 0.273030
## cloacal_temp_C              -6.637e-02  4.677e-01  -0.142 0.887419
## mass_g                      -2.348e+00  2.544e+00  -0.923 0.358048
## SVL_mm                       1.045e+00  1.186e+00   0.882 0.379911
## SMI                          2.177e+00  2.622e+00   0.830 0.408167
## osmolality_mmol_kg_mean      3.722e-02  2.524e-02   1.475 0.143052
## temp_C_interpol              4.904e+00  8.445e-01   5.807 6.03e-08 ***
```

```
## VPD_kPa_int                 -3.461e+01  6.639e+00  -5.213 8.58e-07 ***
## wind_mph_interpol            3.607e-01  3.435e-01   1.050 0.295863
## solar_rad_W_sqm_interpol    -1.158e-02  4.528e-03  -2.557 0.011887 *
## capture_date                 3.426e-02  3.826e-02   0.895 0.372529
## temp_C_interpol:VPD_kPa_int  4.112e-01  1.065e-01   3.862 0.000189 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 3.634 on 112 degrees of freedom
##   (14 observations deleted due to missingness)
## Multiple R-squared:  0.5827, Adjusted R-squared:  0.5417
## F-statistic: 14.22 on 11 and 112 DF,  p-value: < 2.2e-16
```

```
drop1(CEWL_mod2)
```

```
## Single term deletions
##
## Model:
## CEWL_g_m2h_mean ~ cloacal_temp_C + mass_g + SVL_mm + SMI + osmolality_mmol_kg_mean +
##     temp_C_interpol * VPD_kPa_int + wind_mph_interpol + solar_rad_W_sqm_interpol +
##     capture_date
##                             Df Sum of Sq    RSS    AIC
## <none>                                   1479.0 331.37
## cloacal_temp_C               1     0.266 1479.2 329.39
## mass_g                       1    11.247 1490.2 330.31
## SVL_mm                       1    10.262 1489.2 330.23
## SMI                          1     9.102 1488.0 330.13
## osmolality_mmol_kg_mean      1    28.724 1507.7 331.76
## wind_mph_interpol            1    14.565 1493.5 330.59
## solar_rad_W_sqm_interpol     1    86.355 1565.3 336.41
## capture_date                 1    10.585 1489.5 330.26
## temp_C_interpol:VPD_kPa_int  1   196.910 1675.9 344.87
```

```
anova(CEWL_mod1, CEWL_mod2)
```

```
## Analysis of Variance Table
##
## Model 1: CEWL_g_m2h_mean ~ cloacal_temp_C + mass_g + SVL_mm + SMI + osmolality_mmol_kg_mean +
##     hematocrit_percent + temp_C_interpol * VPD_kPa_int + wind_mph_interpol +
##     solar_rad_W_sqm_interpol + capture_date
## Model 2: CEWL_g_m2h_mean ~ cloacal_temp_C + mass_g + SVL_mm + SMI + osmolality_mmol_kg_mean +
##     temp_C_interpol * VPD_kPa_int + wind_mph_interpol + solar_rad_W_sqm_interpol +
##     capture_date
##   Res.Df    RSS Df Sum of Sq      F Pr(>F)
## 1    111 1478.8
## 2    112 1479.0 -1   -0.1376 0.0103 0.9192
```

I'm shocked that AIC suggests dropping cloacal temperature. We know it's important, so I will retain it despite the supposed benefits to model fit.

Instead, we will try dropping body condition because it's slightly less helpful than its collinear variables SVL and mass.

```
CEWL_mod3 <- lm(data = capture_dat_plus,
                          # response variable
                          CEWL_g_m2h_mean ~
                          # essential covariate
```

```r
                          cloacal_temp_C +
                          # body size
                          mass_g + SVL_mm +
                          # blood
                          osmolality_mmol_kg_mean +
                          # weather at the time of capture
                          temp_C_interpol * VPD_kPa_int +
                          wind_mph_interpol + solar_rad_W_sqm_interpol +
                          capture_date)
summary(CEWL_mod3)
```

```
##
## Call:
## lm(formula = CEWL_g_m2h_mean ~ cloacal_temp_C + mass_g + SVL_mm +
##     osmolality_mmol_kg_mean + temp_C_interpol * VPD_kPa_int +
##     wind_mph_interpol + solar_rad_W_sqm_interpol + capture_date,
##     data = capture_dat_plus)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -9.0744 -2.3221 -0.1409  2.1106 11.1963
##
## Coefficients:
##                              Estimate Std. Error t value Pr(>|t|)
## (Intercept)                -8.087e+02  7.056e+02  -1.146  0.25415
## cloacal_temp_C             -4.220e-02  4.662e-01  -0.091  0.92803
## mass_g                     -2.530e-01  3.252e-01  -0.778  0.43812
## SVL_mm                      7.021e-02  1.631e-01   0.431  0.66762
## osmolality_mmol_kg_mean     3.893e-02  2.512e-02   1.550  0.12393
## temp_C_interpol             4.741e+00  8.202e-01   5.781 6.71e-08 ***
## VPD_kPa_int                -3.390e+01  6.575e+00  -5.156 1.09e-06 ***
## wind_mph_interpol           3.928e-01  3.408e-01   1.153  0.25155
## solar_rad_W_sqm_interpol   -1.077e-02  4.416e-03  -2.439  0.01628 *
## capture_date                3.943e-02  3.770e-02   1.046  0.29781
## temp_C_interpol:VPD_kPa_int  4.069e-01  1.062e-01   3.831  0.00021 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 3.629 on 113 degrees of freedom
##   (14 observations deleted due to missingness)
## Multiple R-squared:  0.5801, Adjusted R-squared:  0.5429
## F-statistic: 15.61 on 10 and 113 DF,  p-value: < 2.2e-16
```

```r
drop1(CEWL_mod3)
```

```
## Single term deletions
##
## Model:
## CEWL_g_m2h_mean ~ cloacal_temp_C + mass_g + SVL_mm + osmolality_mmol_kg_mean +
##     temp_C_interpol * VPD_kPa_int + wind_mph_interpol + solar_rad_W_sqm_interpol +
##     capture_date
##                             Df Sum of Sq    RSS    AIC
## <none>                                   1488.0 330.13
## cloacal_temp_C               1     0.108 1488.2 328.14
```

```
## mass_g                          1     7.973 1496.0 328.80
## SVL_mm                          1     2.441 1490.5 328.34
## osmolality_mmol_kg_mean         1    31.639 1519.7 330.74
## wind_mph_interpol               1    17.491 1505.5 329.58
## solar_rad_W_sqm_interpol        1    78.336 1566.4 334.49
## capture_date                    1    14.407 1502.5 329.33
## temp_C_interpol:VPD_kPa_int     1   193.291 1681.3 343.28
```

```r
anova(CEWL_mod2, CEWL_mod3)
```

```
## Analysis of Variance Table
##
## Model 1: CEWL_g_m2h_mean ~ cloacal_temp_C + mass_g + SVL_mm + SMI + osmolality_mmol_kg_mean +
##     temp_C_interpol * VPD_kPa_int + wind_mph_interpol + solar_rad_W_sqm_interpol +
##     capture_date
## Model 2: CEWL_g_m2h_mean ~ cloacal_temp_C + mass_g + SVL_mm + osmolality_mmol_kg_mean +
##     temp_C_interpol * VPD_kPa_int + wind_mph_interpol + solar_rad_W_sqm_interpol +
##     capture_date
##   Res.Df  RSS Df Sum of Sq      F Pr(>F)
## 1    112 1479
## 2    113 1488 -1   -9.1022 0.6893 0.4082
```

Drop SVL next:

```r
CEWL_mod4 <- lm(data = capture_dat_plus,
                          # response variable
                          CEWL_g_m2h_mean ~
                          # essential covariate
                          cloacal_temp_C +
                          # body size
                          mass_g +
                          # blood
                          osmolality_mmol_kg_mean +
                          # weather at the time of capture
                          temp_C_interpol * VPD_kPa_int +
                          wind_mph_interpol + solar_rad_W_sqm_interpol +
                          capture_date)
summary(CEWL_mod4)
```

```
##
## Call:
## lm(formula = CEWL_g_m2h_mean ~ cloacal_temp_C + mass_g + osmolality_mmol_kg_mean +
##     temp_C_interpol * VPD_kPa_int + wind_mph_interpol + solar_rad_W_sqm_interpol +
##     capture_date, data = capture_dat_plus)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -9.0783 -2.2145 -0.1144  2.0660 11.0163
##
## Coefficients:
##                            Estimate Std. Error t value Pr(>|t|)
## (Intercept)              -7.795e+02  6.998e+02  -1.114 0.267668
## cloacal_temp_C           -5.002e-02  4.642e-01  -0.108 0.914374
## mass_g                   -1.452e-01  2.068e-01  -0.702 0.483810
## osmolality_mmol_kg_mean   4.064e-02  2.471e-02   1.644 0.102841
## temp_C_interpol           4.724e+00  8.163e-01   5.787 6.40e-08 ***
```

```
## VPD_kPa_int                 -3.383e+01  6.549e+00  -5.165 1.03e-06 ***
## wind_mph_interpol             3.990e-01  3.393e-01   1.176 0.242020
## solar_rad_W_sqm_interpol    -1.066e-02  4.392e-03  -2.426 0.016819 *
## capture_date                  3.805e-02  3.743e-02   1.017 0.311450
## temp_C_interpol:VPD_kPa_int  4.070e-01  1.058e-01   3.846 0.000198 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 3.616 on 114 degrees of freedom
##   (14 observations deleted due to missingness)
## Multiple R-squared:  0.5794, Adjusted R-squared:  0.5462
## F-statistic: 17.45 on 9 and 114 DF,  p-value: < 2.2e-16
```

```r
drop1(CEWL_mod4)
```

```
## Single term deletions
##
## Model:
## CEWL_g_m2h_mean ~ cloacal_temp_C + mass_g + osmolality_mmol_kg_mean +
##     temp_C_interpol * VPD_kPa_int + wind_mph_interpol + solar_rad_W_sqm_interpol +
##     capture_date
##                             Df Sum of Sq    RSS    AIC
## <none>                                   1490.5 328.34
## cloacal_temp_C               1     0.152 1490.7 326.35
## mass_g                       1     6.452 1497.0 326.87
## osmolality_mmol_kg_mean      1    35.356 1525.8 329.24
## wind_mph_interpol            1    18.084 1508.6 327.83
## solar_rad_W_sqm_interpol     1    76.972 1567.5 332.58
## capture_date                 1    13.515 1504.0 327.46
## temp_C_interpol:VPD_kPa_int  1   193.394 1683.9 341.46
```

```r
anova(CEWL_mod3, CEWL_mod4)
```

```
## Analysis of Variance Table
##
## Model 1: CEWL_g_m2h_mean ~ cloacal_temp_C + mass_g + SVL_mm + osmolality_mmol_kg_mean +
##     temp_C_interpol * VPD_kPa_int + wind_mph_interpol + solar_rad_W_sqm_interpol +
##     capture_date
## Model 2: CEWL_g_m2h_mean ~ cloacal_temp_C + mass_g + osmolality_mmol_kg_mean +
##     temp_C_interpol * VPD_kPa_int + wind_mph_interpol + solar_rad_W_sqm_interpol +
##     capture_date
##   Res.Df    RSS Df Sum of Sq      F Pr(>F)
## 1    113 1488.0
## 2    114 1490.5 -1    -2.441 0.1854 0.6676
```

Drop mass:

```r
CEWL_mod5 <- lm(data = capture_dat_plus,
                          # response variable
                          CEWL_g_m2h_mean ~
                          # essential covariate
                          cloacal_temp_C +
                          # blood
                          osmolality_mmol_kg_mean +
                          # weather at the time of capture
                          temp_C_interpol * VPD_kPa_int +
```

```r
                          wind_mph_interpol + solar_rad_W_sqm_interpol +
                          capture_date)
summary(CEWL_mod5)
```

```
##
## Call:
## lm(formula = CEWL_g_m2h_mean ~ cloacal_temp_C + osmolality_mmol_kg_mean +
##     temp_C_interpol * VPD_kPa_int + wind_mph_interpol + solar_rad_W_sqm_interpol +
##     capture_date, data = capture_dat_plus)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -9.0618 -2.3162 -0.1145  2.2306 10.7172
##
## Coefficients:
##                               Estimate Std. Error t value Pr(>|t|)
## (Intercept)                 -7.898e+02  6.981e+02  -1.131 0.260239
## cloacal_temp_C              -3.269e-02  4.625e-01  -0.071 0.943773
## osmolality_mmol_kg_mean      3.880e-02  2.452e-02   1.582 0.116289
## temp_C_interpol              4.750e+00  8.136e-01   5.839 4.97e-08 ***
## VPD_kPa_int                 -3.416e+01  6.517e+00  -5.242 7.29e-07 ***
## wind_mph_interpol            3.948e-01  3.385e-01   1.166 0.245918
## solar_rad_W_sqm_interpol    -1.077e-02  4.379e-03  -2.460 0.015369 *
## capture_date                 3.850e-02  3.734e-02   1.031 0.304611
## temp_C_interpol:VPD_kPa_int  4.138e-01  1.052e-01   3.935 0.000143 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 3.608 on 115 degrees of freedom
##   (14 observations deleted due to missingness)
## Multiple R-squared:  0.5776, Adjusted R-squared:  0.5482
## F-statistic: 19.66 on 8 and 115 DF,  p-value: < 2.2e-16
```

```r
anova(CEWL_mod4, CEWL_mod5)
```

```
## Analysis of Variance Table
##
## Model 1: CEWL_g_m2h_mean ~ cloacal_temp_C + mass_g + osmolality_mmol_kg_mean +
##     temp_C_interpol * VPD_kPa_int + wind_mph_interpol + solar_rad_W_sqm_interpol +
##     capture_date
## Model 2: CEWL_g_m2h_mean ~ cloacal_temp_C + osmolality_mmol_kg_mean +
##     temp_C_interpol * VPD_kPa_int + wind_mph_interpol + solar_rad_W_sqm_interpol +
##     capture_date
##   Res.Df    RSS Df Sum of Sq      F Pr(>F)
## 1    114 1490.5
## 2    115 1497.0 -1    -6.452 0.4935 0.4838
```

```r
drop1(CEWL_mod5)
```

```
## Single term deletions
##
## Model:
## CEWL_g_m2h_mean ~ cloacal_temp_C + osmolality_mmol_kg_mean +
##     temp_C_interpol * VPD_kPa_int + wind_mph_interpol + solar_rad_W_sqm_interpol +
##     capture_date
```

```
##                            Df Sum of Sq    RSS    AIC
## <none>                                  1497.0 326.87
## cloacal_temp_C              1     0.065 1497.0 324.88
## osmolality_mmol_kg_mean     1    32.597 1529.5 327.54
## wind_mph_interpol           1    17.705 1514.7 326.33
## solar_rad_W_sqm_interpol    1    78.793 1575.7 331.23
## capture_date                1    13.842 1510.8 326.01
## temp_C_interpol:VPD_kPa_int  1   201.540 1698.5 340.53
```

Try dropping capture date:

```
CEWL_mod6 <- lm(data = capture_dat_plus,
                          # response variable
                          CEWL_g_m2h_mean ~
                          # essential covariate
                          cloacal_temp_C +
                          # blood
                          osmolality_mmol_kg_mean +
                          # weather at the time of capture
                          temp_C_interpol * VPD_kPa_int +
                          wind_mph_interpol + solar_rad_W_sqm_interpol
                )
summary(CEWL_mod6)
```

```
##
## Call:
## lm(formula = CEWL_g_m2h_mean ~ cloacal_temp_C + osmolality_mmol_kg_mean +
##     temp_C_interpol * VPD_kPa_int + wind_mph_interpol + solar_rad_W_sqm_interpol,
##     data = capture_dat_plus)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -8.8250 -2.1472 -0.0583  2.1181 10.3609
##
## Coefficients:
##                              Estimate Std. Error t value Pr(>|t|)
## (Intercept)                -70.259024  20.381006  -3.447 0.000790 ***
## cloacal_temp_C              -0.005170   0.461838  -0.011 0.991088
## osmolality_mmol_kg_mean      0.053060   0.020259   2.619 0.009996 **
## temp_C_interpol              4.779234   0.813349   5.876 4.11e-08 ***
## VPD_kPa_int                -33.512017   6.488172  -5.165 1.01e-06 ***
## wind_mph_interpol            0.148380   0.239825   0.619 0.537325
## solar_rad_W_sqm_interpol    -0.011335   0.004347  -2.608 0.010315 *
## temp_C_interpol:VPD_kPa_int   0.398941   0.104199   3.829 0.000209 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 3.609 on 116 degrees of freedom
##   (14 observations deleted due to missingness)
## Multiple R-squared:  0.5737, Adjusted R-squared:  0.548
## F-statistic:  22.3 on 7 and 116 DF,  p-value: < 2.2e-16
```

```
anova(CEWL_mod5, CEWL_mod6)
```

```
## Analysis of Variance Table
##
```

```
## Model 1: CEWL_g_m2h_mean ~ cloacal_temp_C + osmolality_mmol_kg_mean +
##     temp_C_interpol * VPD_kPa_int + wind_mph_interpol + solar_rad_W_sqm_interpol +
##     capture_date
## Model 2: CEWL_g_m2h_mean ~ cloacal_temp_C + osmolality_mmol_kg_mean +
##     temp_C_interpol * VPD_kPa_int + wind_mph_interpol + solar_rad_W_sqm_interpol
##   Res.Df    RSS Df Sum of Sq      F Pr(>F)
## 1    115 1497.0
## 2    116 1510.8 -1   -13.842 1.0634 0.3046
```

```r
drop1(CEWL_mod6)
```

```
## Single term deletions
##
## Model:
## CEWL_g_m2h_mean ~ cloacal_temp_C + osmolality_mmol_kg_mean +
##     temp_C_interpol * VPD_kPa_int + wind_mph_interpol + solar_rad_W_sqm_interpol
##                             Df Sum of Sq    RSS    AIC
## <none>                                   1510.8 326.01
## cloacal_temp_C               1     0.002 1510.8 324.01
## osmolality_mmol_kg_mean      1    89.335 1600.1 331.14
## wind_mph_interpol            1     4.986 1515.8 324.42
## solar_rad_W_sqm_interpol     1    88.562 1599.3 331.08
## temp_C_interpol:VPD_kPa_int  1   190.914 1701.7 338.77
```

Drop wind:

```r
CEWL_mod7 <- lm(data = capture_dat_plus,
                          # response variable
                          CEWL_g_m2h_mean ~
                          # essential covariate
                          cloacal_temp_C +
                          # blood
                          osmolality_mmol_kg_mean +
                          # weather at the time of capture
                          temp_C_interpol * VPD_kPa_int +
                          solar_rad_W_sqm_interpol)
summary(CEWL_mod7)
```

```
##
## Call:
## lm(formula = CEWL_g_m2h_mean ~ cloacal_temp_C + osmolality_mmol_kg_mean +
##     temp_C_interpol * VPD_kPa_int + solar_rad_W_sqm_interpol,
##     data = capture_dat_plus)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -8.9817 -2.0411 -0.0844  2.1366 10.2409
##
## Coefficients:
##                              Estimate Std. Error t value Pr(>|t|)
## (Intercept)                -62.505056  16.029848  -3.899 0.000161 ***
## cloacal_temp_C              -0.124926   0.418212  -0.299 0.765689
## osmolality_mmol_kg_mean      0.047036   0.017720   2.654 0.009050 **
## temp_C_interpol              4.608085   0.762843   6.041 1.87e-08 ***
## VPD_kPa_int                -31.255123   5.351464  -5.840 4.77e-08 ***
## solar_rad_W_sqm_interpol    -0.010807   0.004251  -2.542 0.012321 *
```

```
## temp_C_interpol:VPD_kPa_int   0.363209   0.086500   4.199 5.26e-05 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 3.599 on 117 degrees of freedom
##   (14 observations deleted due to missingness)
## Multiple R-squared:  0.5723, Adjusted R-squared:  0.5503
## F-statistic: 26.09 on 6 and 117 DF,  p-value: < 2.2e-16
```

```r
anova(CEWL_mod6, CEWL_mod7)
```

```
## Analysis of Variance Table
##
## Model 1: CEWL_g_m2h_mean ~ cloacal_temp_C + osmolality_mmol_kg_mean +
##     temp_C_interpol * VPD_kPa_int + wind_mph_interpol + solar_rad_W_sqm_interpol
## Model 2: CEWL_g_m2h_mean ~ cloacal_temp_C + osmolality_mmol_kg_mean +
##     temp_C_interpol * VPD_kPa_int + solar_rad_W_sqm_interpol
##   Res.Df    RSS Df Sum of Sq      F Pr(>F)
## 1    116 1510.8
## 2    117 1515.8 -1   -4.9855 0.3828 0.5373
```

```r
drop1(CEWL_mod7)
```

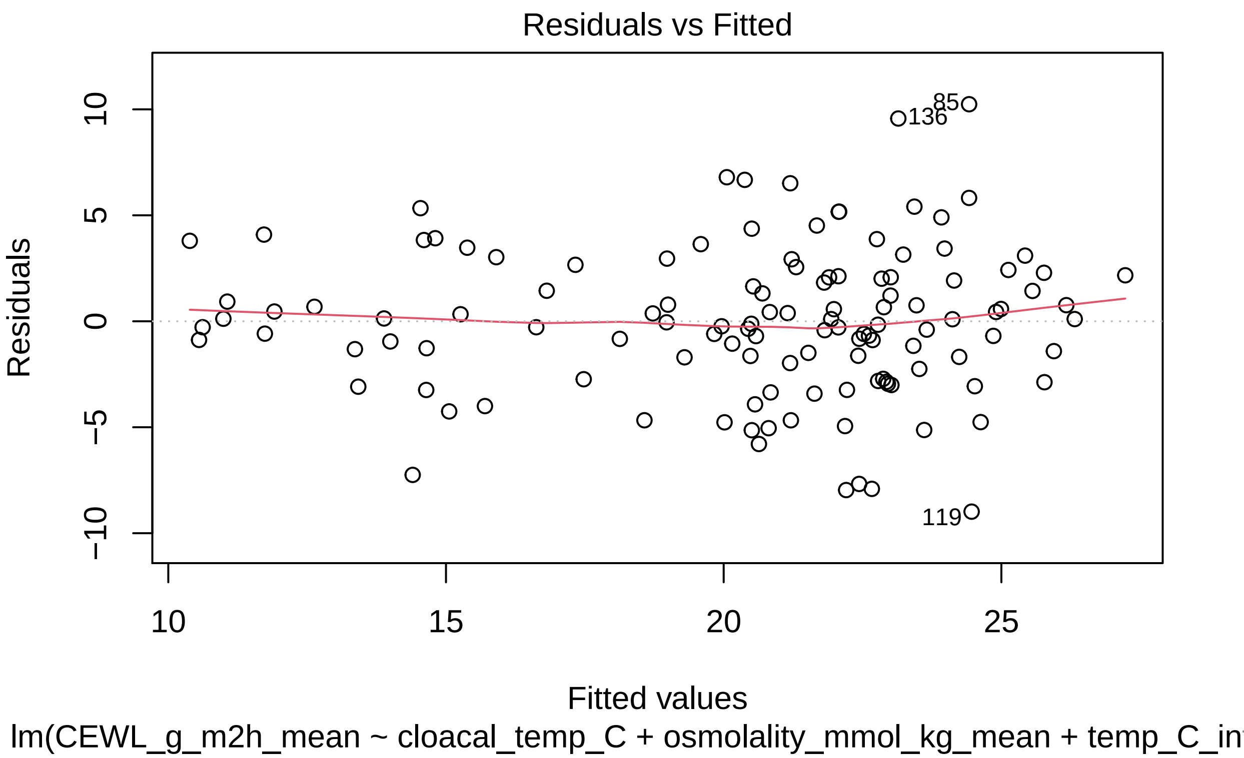
```
## Single term deletions
##
## Model:
## CEWL_g_m2h_mean ~ cloacal_temp_C + osmolality_mmol_kg_mean +
##     temp_C_interpol * VPD_kPa_int + solar_rad_W_sqm_interpol
##                              Df Sum of Sq    RSS    AIC
## <none>                                    1515.8 324.42
## cloacal_temp_C                1     1.156 1516.9 322.52
## osmolality_mmol_kg_mean       1    91.282 1607.1 329.67
## solar_rad_W_sqm_interpol      1    83.730 1599.5 329.09
## temp_C_interpol:VPD_kPa_int   1   228.418 1744.2 339.83
```

This is the best model! Technically, the best model would not have cloacal temperature included, but it's an essential covariate to CEWL.

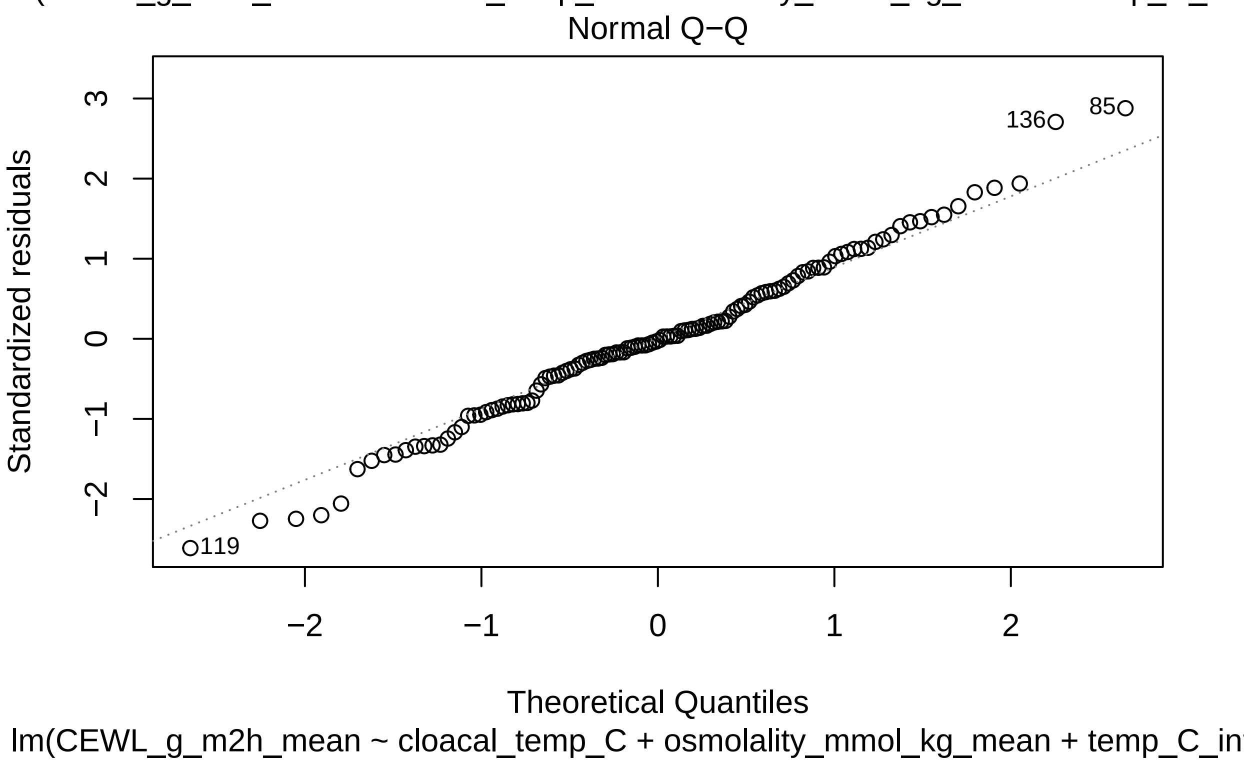
LM Conditions

Check that the best model meets the criteria for linear regression.

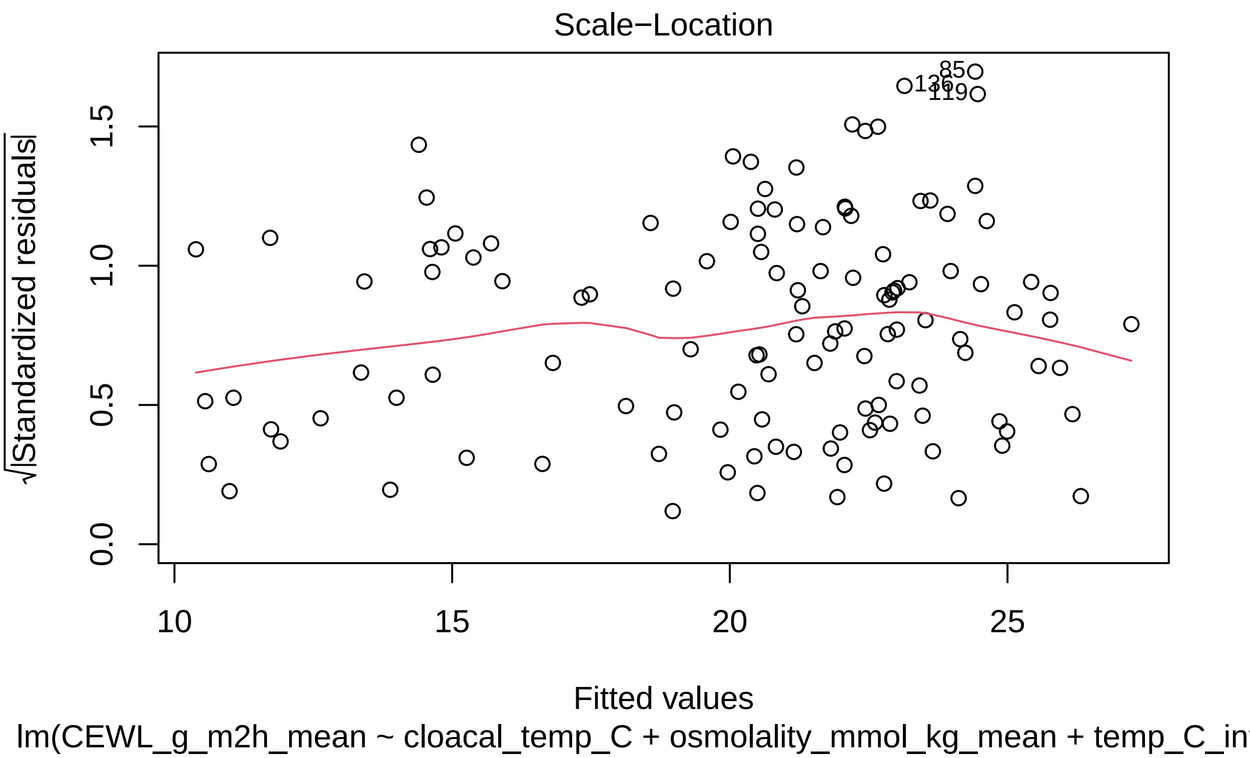
```r
plot(CEWL_mod7)
```

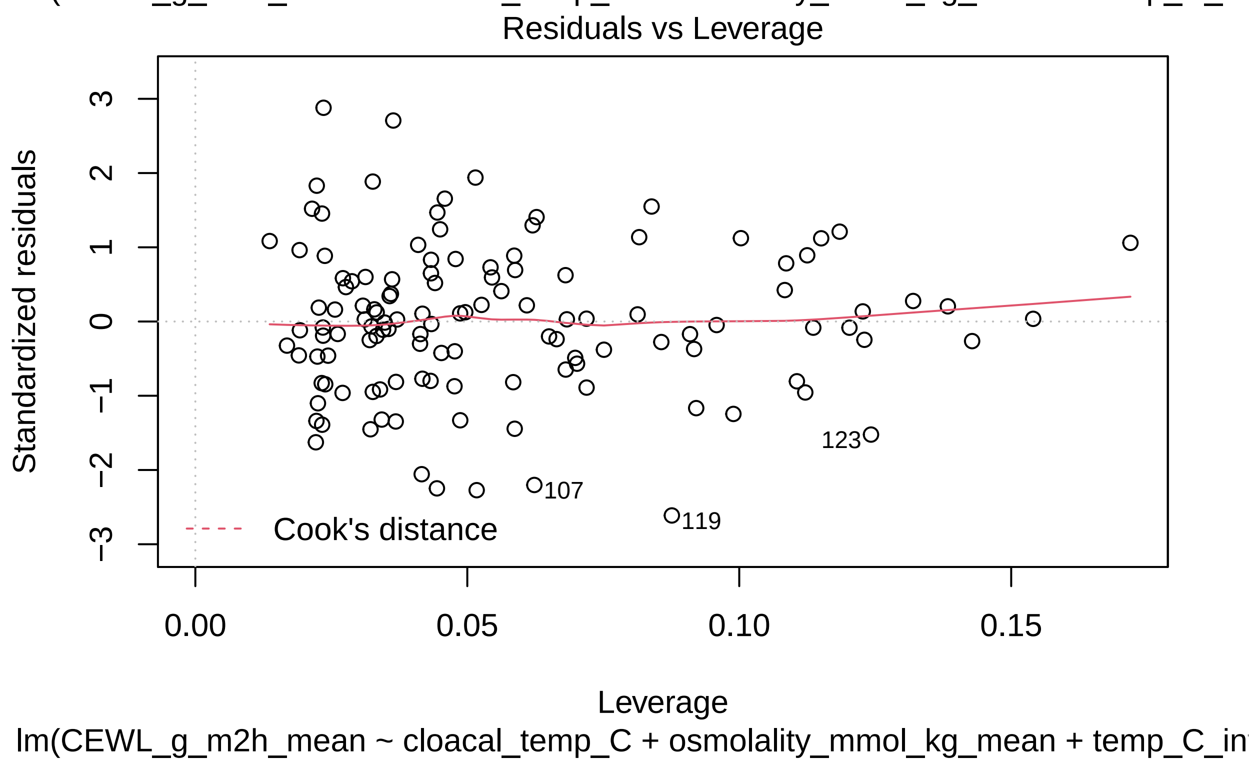


Residuals vs Fitted
Residuals
Fitted values
lm(CEWL_g_m2h_mean ~ cloacal_temp_C + osmolality_mmol_kg_mean + temp_C_in
85
136
119
10
5
0
−5
−10
10
15
20
25

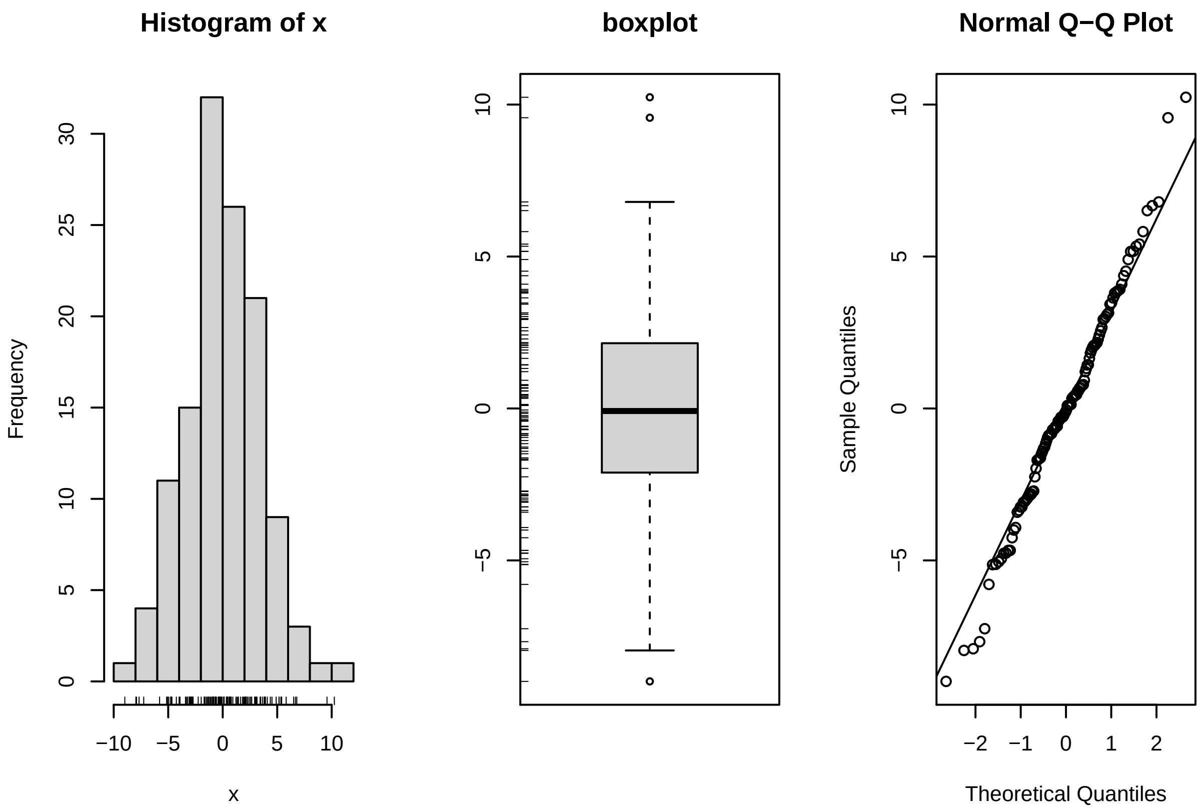


Normal Q−Q
Standardized residuals
Theoretical Quantiles
lm(CEWL_g_m2h_mean ~ cloacal_temp_C + osmolality_mmol_kg_mean + temp_C_in
136
85
119
3
2
1
0
−1
−2
−2
−1
0
1
2






```
simple.eda(residuals(CEWL_mod7))
```




```r
shapiro.test(residuals(CEWL_mod7))
```

```
##
##  Shapiro-Wilk normality test
##
## data:  residuals(CEWL_mod7)
## W = 0.99105, p-value = 0.608
```

There is some slight fanning in the residuals ~ fitted plot, suggesting equal error variance is not perfect, but overall, all LNE conditions appear to be met.

Conclusion

Save the model output.

```r
CEWL_best_mod_results <- broom.mixed::tidy(CEWL_mod7)
write.csv(CEWL_best_mod_results,
          "./results_statistics/capture_CEWL_best_model.csv")
```

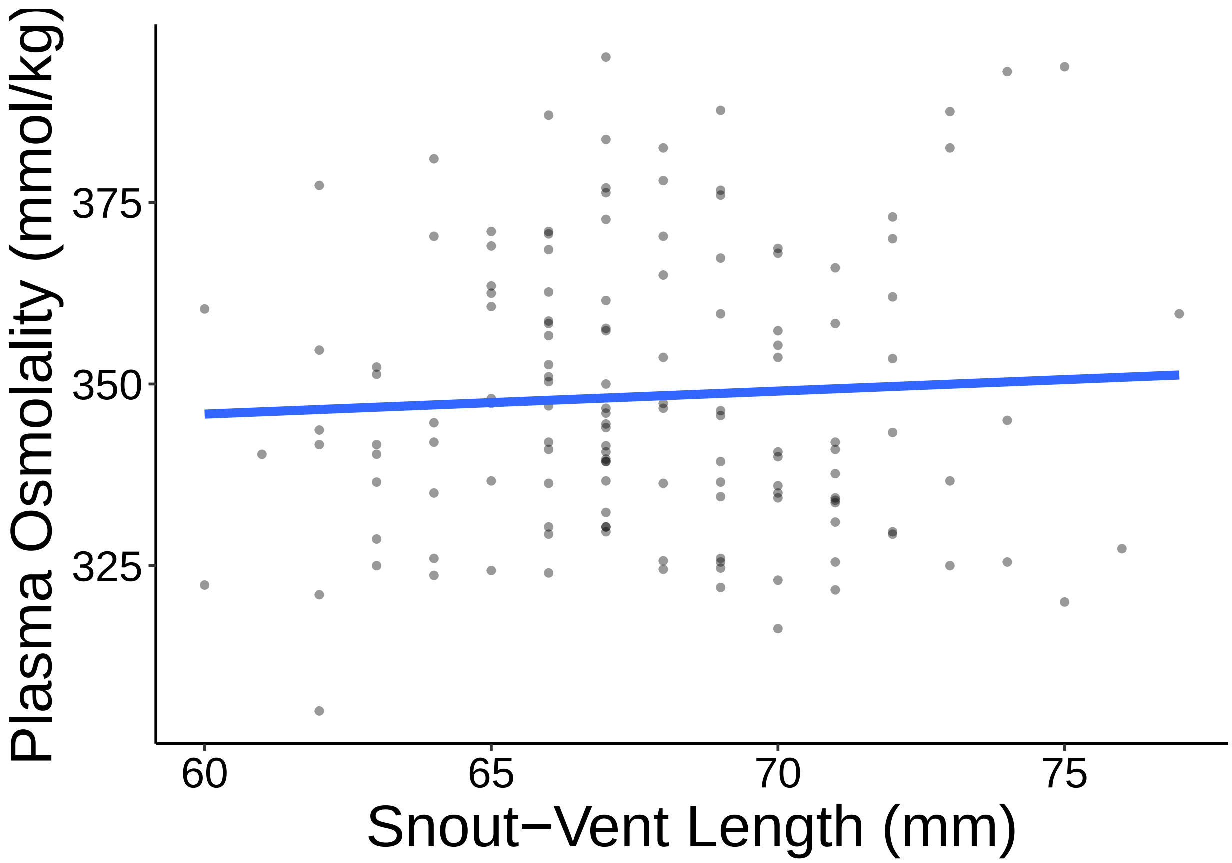
To report in paper:

The best model to predict CEWL included cloacal temperature, plasma osmolality, temperature, VPD, and solar radiation at the time of capture, and the interaction between temp*VPD. The final model met all linear regression conditions for linearity, normality, and equal error variance. During model selection, each reduced model was only 1-2-delta-AIC better than the previous model. The full model included cloacal temperature, mass, SVL, SMI, plasma osmolality, percent hematocrit, and temperature, VPD, wind speed, and solar radiation at the time of capture, with date as a random effect. The effect of cloacal temperature was not significant and should have been dropped from the model based on AIC, but the literature and our previous study suggest that cloacal temperature is an strong covariate of CEWL, so we retained it in the reduced model despite nonsignificance.

Model Figures

Osmolality ~ SVL

```
capture_dat_plus %>%
  ggplot() +
  geom_point(aes(x = SVL_mm,
                 y = osmolality_mmol_kg_mean),
             size = 1,
             alpha = 0.4) +
  stat_smooth(aes(x = SVL_mm,
                  y = osmolality_mmol_kg_mean),
              formula = y ~ x,
              method = "lm",
              se = F,
              size = 1.6,
              alpha = 1 ) +
  theme_classic() +
  xlab("Snout-Vent Length (mm)") +
  ylab("Plasma Osmolality (mmol/kg)") +
  #ylab("") +
  #xlim() +
  #ylim() +
  #annotate("text", x = , y = ,
   #        label = "paste(italic(R) ^ 2, \" = 0.\")",
    #       parse = TRUE,
     #      size = 6) +
  #annotate("text", x = , y = ,
   #        label = "paste(italic(p), \" < 0.0001\")",
    #       parse = TRUE,
     #      size = 6) +
  theme(text = element_text(color = "black",
                            family = "sans",
                            size = 22),
        axis.text = element_text(color = "black",
                                 family = "sans",
                                 size = 16),
        #axis.text.y = element_blank(),
        #plot.margin = unit(c(0.1,0,0.1,0.45), "cm")
        ) -> cap_osml_SVL_fig
cap_osml_SVL_fig
```




```
# export figure
#ggsave(filename = "cap_osml_mass_fig.jpeg",
 #      plot = cap_osml_mass_fig,
  #     path = "./results_figures",
   #    device = "jpeg",
    #   dpi = 1200,
     #  width = 6, height = 4)
```

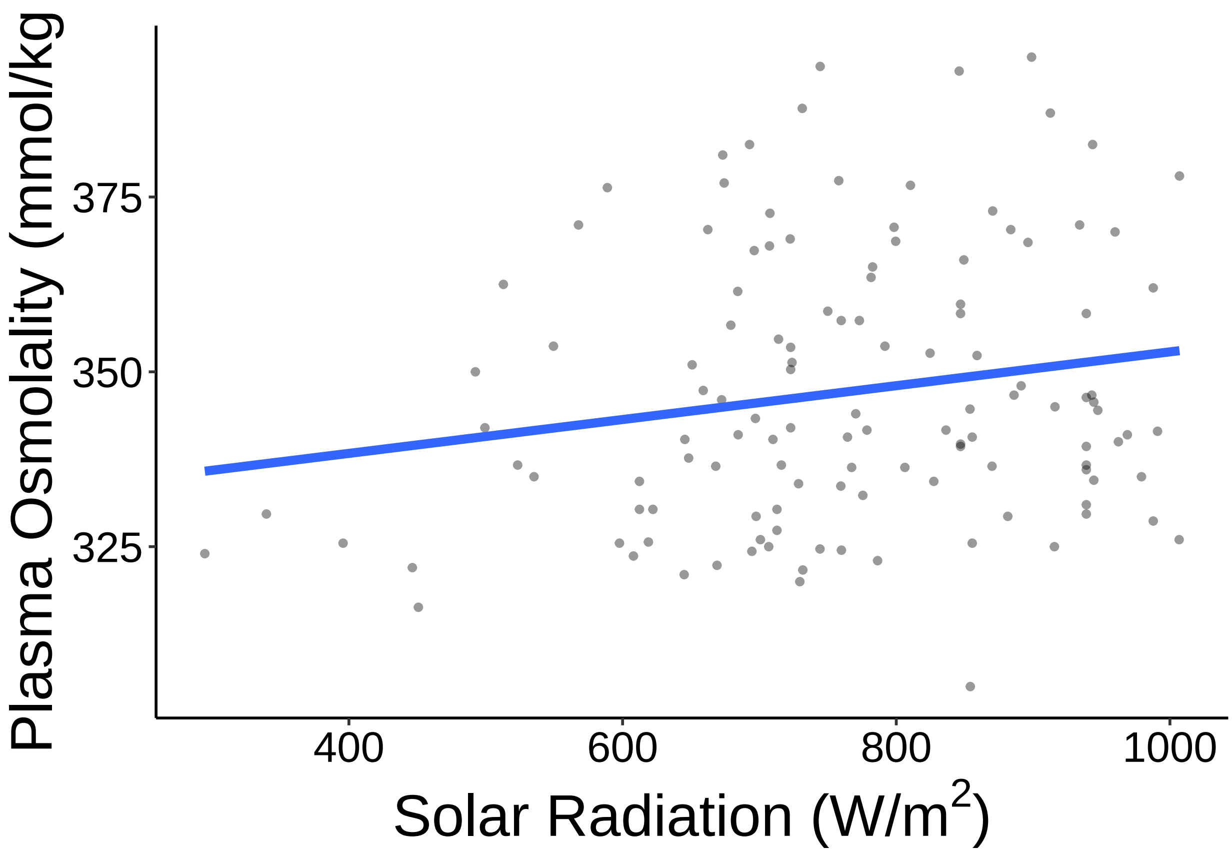
Osmolality ~ Solar Radiation

```
capture_dat_plus %>%
  ggplot() +
  geom_point(aes(x = solar_rad_W_sqm_interpol,
                 y = osmolality_mmol_kg_mean),
             size = 1,
             alpha = 0.4) +
  stat_smooth(aes(x = solar_rad_W_sqm_interpol,
                  y = osmolality_mmol_kg_mean),
              formula = y ~ x,
              method = "lm",
              se = F,
              size = 1.6,
              alpha = 1 ) +
  theme_classic() +
  xlab(bquote('Solar Radiation (W/'*m^2*')')) +
  ylab("Plasma Osmolality (mmol/kg)") +
```

```
  #ylab("") +
  #xlim() +
  #ylim() +
  #annotate("text", x = , y = ,
   #         label = "paste(italic(R) ^ 2, \" = 0.\")",
    #       parse = TRUE,
     #      size = 6) +
  #annotate("text", x = , y = ,
   #         label = "paste(italic(p), \" < 0.0001\")",
    #       parse = TRUE,
     #      size = 6) +
  theme(text = element_text(color = "black",
                            family = "sans",
                            size = 22),
        axis.text = element_text(color = "black",
                                 family = "sans",
                                 size = 16),
        #axis.text.y = element_blank(),
        #plot.margin = unit(c(0.1,0,0.1,0.45), "cm")
        ) -> cap_osml_sorad_fig
cap_osml_sorad_fig
```

```
## Warning: Removed 14 rows containing non-finite values (stat_smooth).
```

```
## Warning: Removed 14 rows containing missing values (geom_point).
```

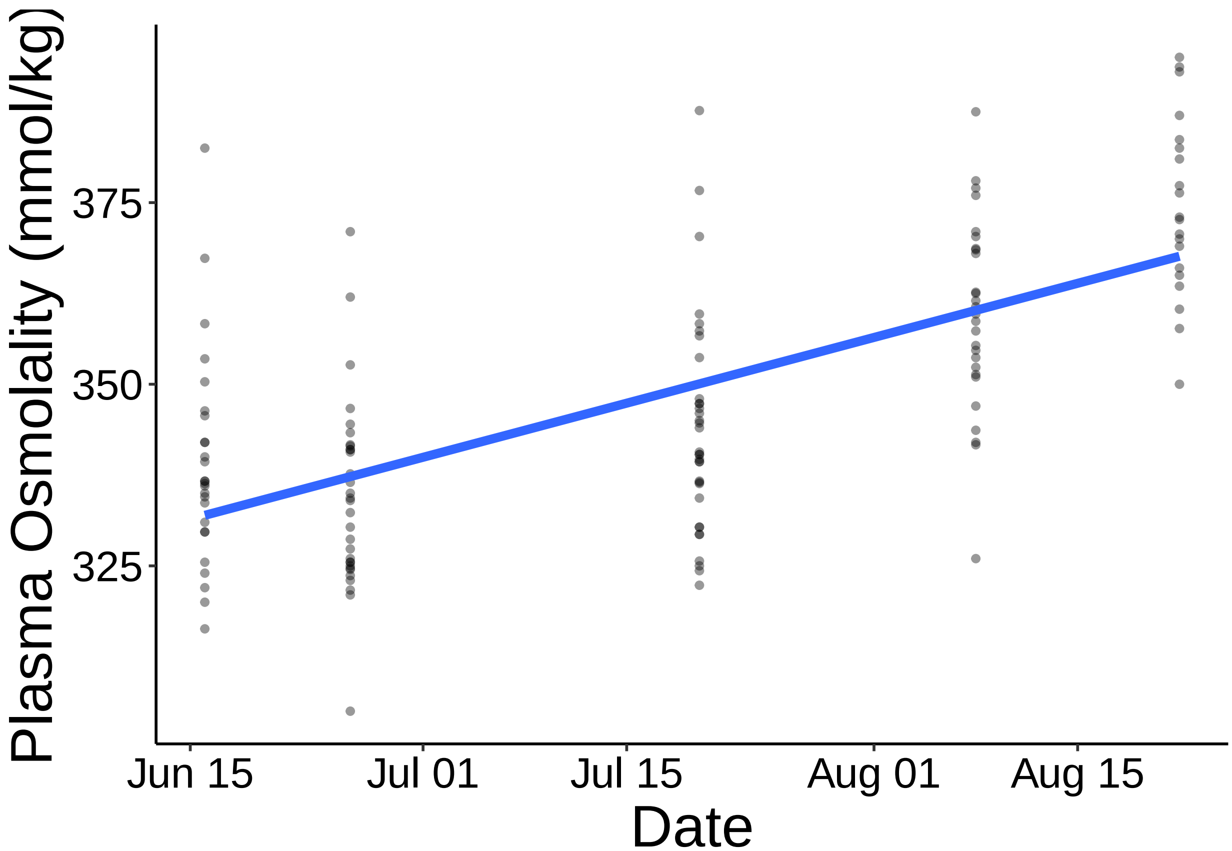



```
# export figure
#ggsave(filename = "cap_osml_mass_fig.jpeg",
```

```
#      plot = cap_osml_mass_fig,
 #     path = "./results_figures",
  #    device = "jpeg",
   #   dpi = 1200,
    #  width = 6, height = 4)
```

Osmolality ~ Date

```
capture_dat_plus %>%
  ggplot() +
  geom_point(aes(x = capture_date,
                 y = osmolality_mmol_kg_mean),
             size = 1,
             alpha = 0.4) +
  stat_smooth(aes(x = capture_date,
                  y = osmolality_mmol_kg_mean),
              formula = y ~ x,
              method = "lm",
              se = F,
              size = 1.6,
              alpha = 1 ) +
  theme_classic() +
  xlab("Date") +
  ylab("Plasma Osmolality (mmol/kg)") +
  #ylab("") +
  #xlim() +
  #ylim() +
  #annotate("text", x = , y = ,
   #        label = "paste(italic(R) ^ 2, \" = 0.\")",
    #       parse = TRUE,
     #      size = 6) +
  #annotate("text", x = , y = ,
   #        label = "paste(italic(p), \" < 0.0001\")",
    #       parse = TRUE,
     #      size = 6) +
  theme(text = element_text(color = "black",
                            family = "sans",
                            size = 22),
        axis.text = element_text(color = "black",
                                 family = "sans",
                                 size = 16),
        #axis.text.y = element_blank(),
        #plot.margin = unit(c(0.1,0,0.1,0.45), "cm")
        ) -> cap_osml_date_fig
cap_osml_date_fig
```

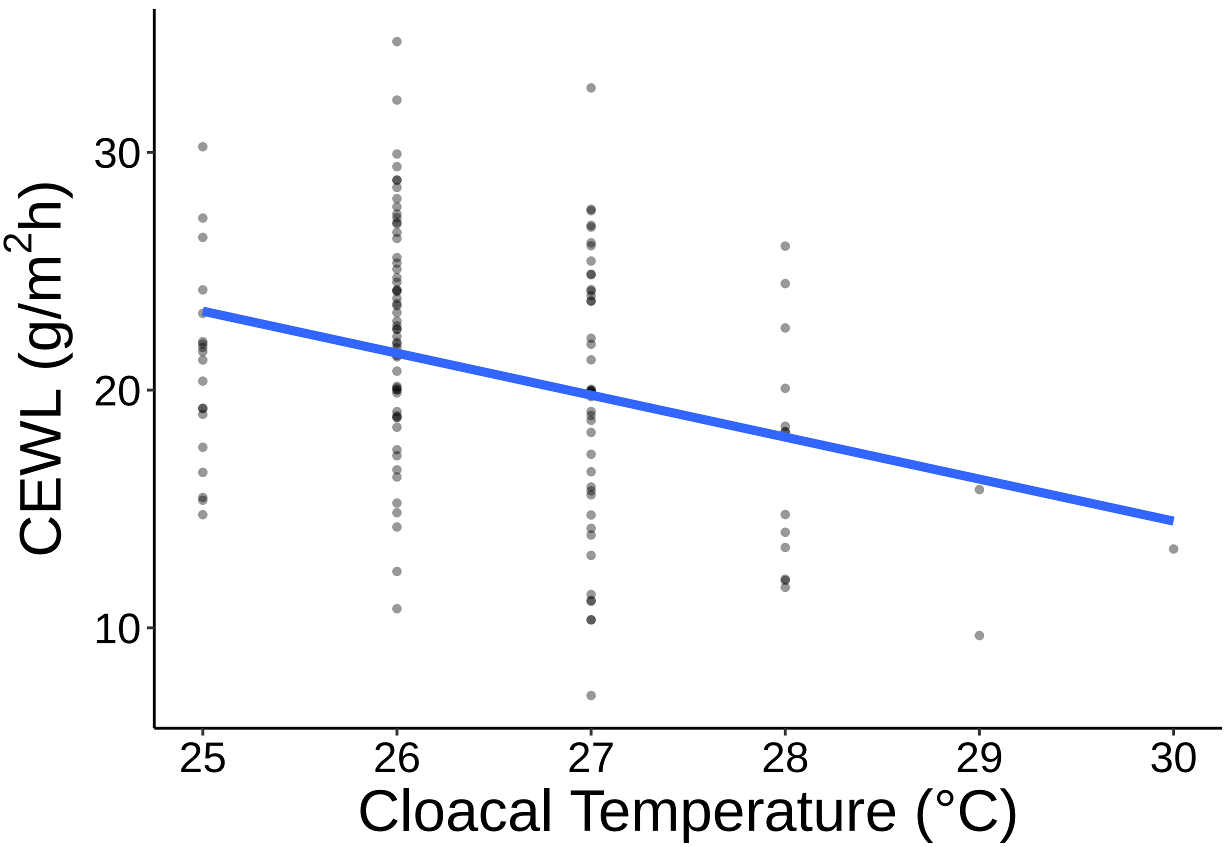



```
# export figure
#ggsave(filename = "cap_osml_mass_fig.jpeg",
 #      plot = cap_osml_mass_fig,
  #     path = "./results_figures",
   #    device = "jpeg",
    #   dpi = 1200,
     #  width = 6, height = 4)
```

CEWL ~ Cloacal Temperature

```
capture_dat_plus %>%
  ggplot() +
  geom_point(aes(x = cloacal_temp_C,
                 y = CEWL_g_m2h_mean),
             size = 1,
             alpha = 0.4) +
  stat_smooth(aes(x = cloacal_temp_C,
                  y = CEWL_g_m2h_mean),
              formula = y ~ x,
              method = "lm",
              se = F,
              size = 1.6,
              alpha = 1 ) +
  theme_classic() +
  xlab("Cloacal Temperature (°C)") +
  ylab(bquote('CEWL (g/'*m^2*'h)')) +
```

```
  #ylab("") +
  #xlim() +
  #ylim() +
  #annotate("text", x = , y = ,
   #         label = "paste(italic(R) ^ 2, \" = 0.\")",
    #        parse = TRUE,
     #       size = 6) +
  #annotate("text", x = , y = ,
   #         label = "paste(italic(p), \" < 0.0001\")",
    #        parse = TRUE,
     #       size = 6) +
  theme(text = element_text(color = "black",
                            family = "sans",
                            size = 22),
        axis.text = element_text(color = "black",
                                 family = "sans",
                                 size = 16),
        #axis.text.y = element_blank(),
        #plot.margin = unit(c(0.1,0,0.1,0.45), "cm")
        ) -> cap_CEWL_clotemp_fig
cap_CEWL_clotemp_fig
```

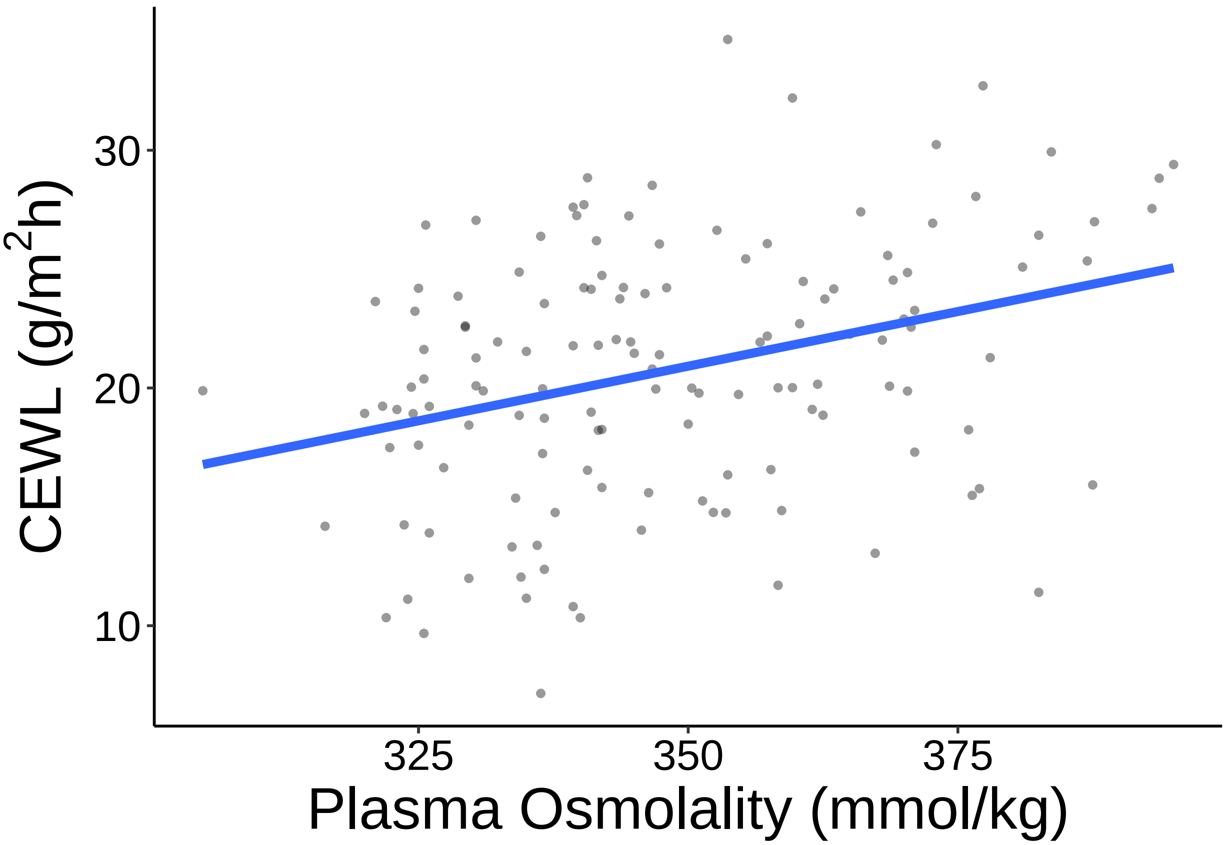



```
# export figure
#ggsave(filename = "cap_osml_mass_fig.jpeg",
 #      plot = cap_osml_mass_fig,
  #     path = "./results_figures",
   #    device = "jpeg",
```

```
    #   dpi = 1200,
     #  width = 6, height = 4)
```

CEWL ~ Plasma Osmolality

```
capture_dat_plus %>%
  ggplot() +
  geom_point(aes(x = osmolality_mmol_kg_mean,
                 y = CEWL_g_m2h_mean),
             size = 1,
             alpha = 0.4) +
  stat_smooth(aes(x = osmolality_mmol_kg_mean,
                  y = CEWL_g_m2h_mean),
              formula = y ~ x,
              method = "lm",
              se = F,
              size = 1.6,
              alpha = 1 ) +
  theme_classic() +
  xlab("Plasma Osmolality (mmol/kg)") +
  ylab(bquote('CEWL (g/'*m^2*'h)')) +
  #ylab("") +
  #xlim() +
  #ylim() +
  #annotate("text", x = , y = ,
   #        label = "paste(italic(R) ^ 2, \" = 0.\")",
    #       parse = TRUE,
     #      size = 6) +
  #annotate("text", x = , y = ,
   #        label = "paste(italic(p), \" < 0.0001\")",
    #       parse = TRUE,
     #      size = 6) +
  theme(text = element_text(color = "black",
                            family = "sans",
                            size = 22),
        axis.text = element_text(color = "black",
                                 family = "sans",
                                 size = 16),
        #axis.text.y = element_blank(),
        #plot.margin = unit(c(0.1,0,0.1,0.45), "cm")
        ) -> cap_CEWL_osml_fig
cap_CEWL_osml_fig
```




```r
# export figure
#ggsave(filename = "cap_osml_mass_fig.jpeg",
 #      plot = cap_osml_mass_fig,
  #     path = "./results_figures",
   #    device = "jpeg",
    #   dpi = 1200,
     #  width = 6, height = 4)
```

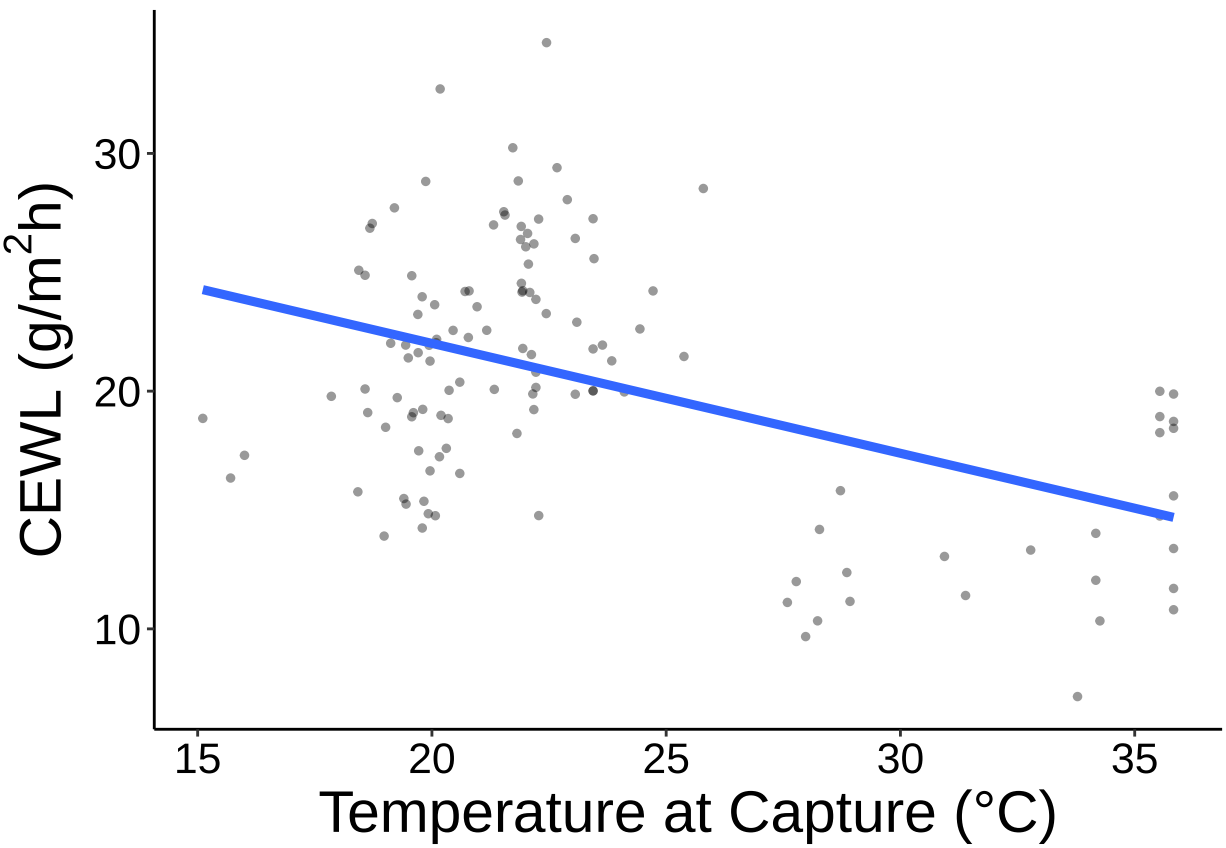
CEWL ~ Temperature at Capture

```r
capture_dat_plus %>%
  ggplot() +
  geom_point(aes(x = temp_C_interpol,
                 y = CEWL_g_m2h_mean),
             size = 1,
             alpha = 0.4) +
  stat_smooth(aes(x = temp_C_interpol,
                  y = CEWL_g_m2h_mean),
              formula = y ~ x,
              method = "lm",
              se = F,
              size = 1.6,
              alpha = 1 ) +
  theme_classic() +
  xlab("Temperature at Capture (°C)") +
  ylab(bquote('CEWL (g/'*m^2*'h)')) +
```

```r
  #ylab("") +
  #xlim() +
  #ylim() +
  #annotate("text", x = , y = ,
   #         label = "paste(italic(R) ^ 2, \" = 0.\")",
    #       parse = TRUE,
     #      size = 6) +
  #annotate("text", x = , y = ,
   #         label = "paste(italic(p), \" < 0.0001\")",
    #       parse = TRUE,
     #      size = 6) +
  theme(text = element_text(color = "black",
                            family = "sans",
                            size = 22),
        axis.text = element_text(color = "black",
                                 family = "sans",
                                 size = 16),
        #axis.text.y = element_blank(),
        #plot.margin = unit(c(0.1,0,0.1,0.45), "cm")
        ) -> cap_CEWL_temp_fig
cap_CEWL_temp_fig
```

```
## Warning: Removed 14 rows containing non-finite values (stat_smooth).
```

```
## Warning: Removed 14 rows containing missing values (geom_point).
```



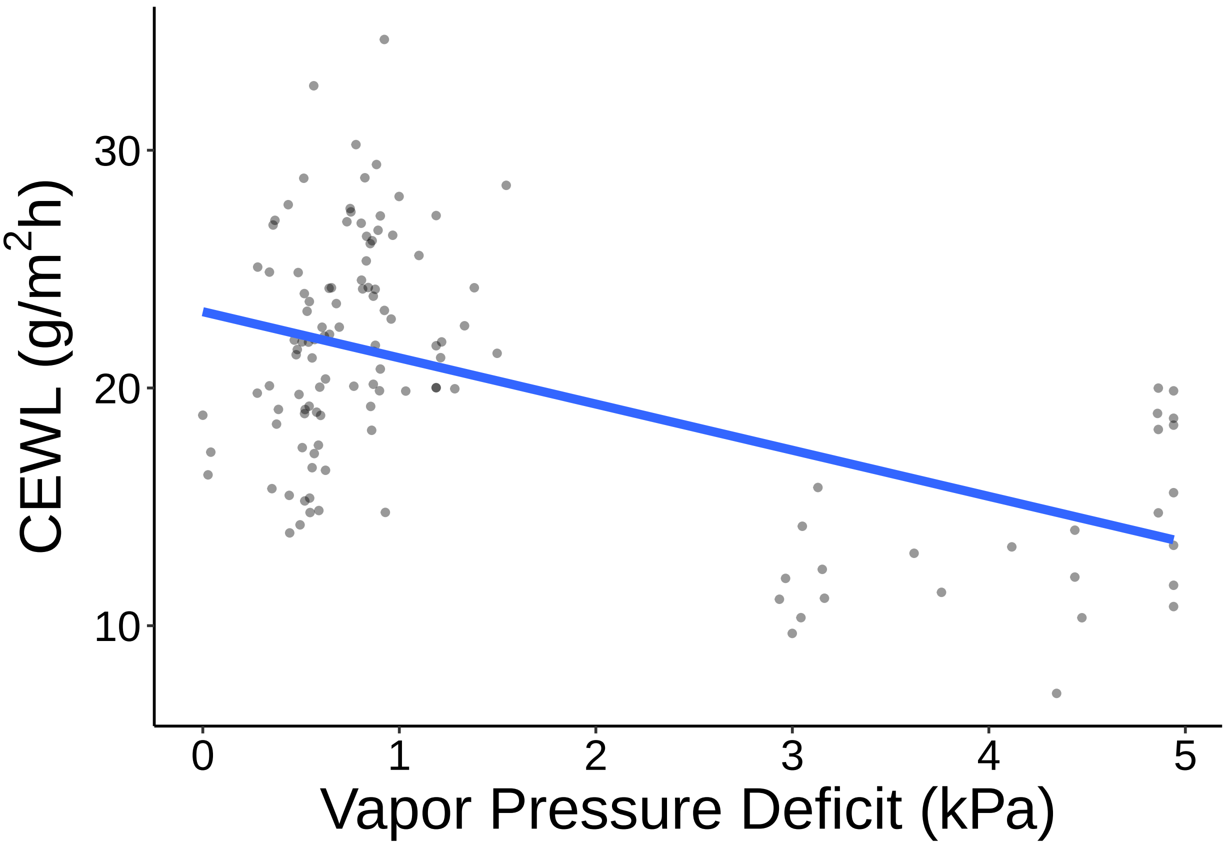

```r
# export figure
#ggsave(filename = "cap_osml_mass_fig.jpeg",
```

```
#      plot = cap_osml_mass_fig,
 #     path = "./results_figures",
  #    device = "jpeg",
   #   dpi = 1200,
    #  width = 6, height = 4)
```

CEWL ~ VPD at Capture

```
capture_dat_plus %>%
  ggplot() +
  geom_point(aes(x = VPD_kPa_int,
                 y = CEWL_g_m2h_mean),
             size = 1,
             alpha = 0.4) +
  stat_smooth(aes(x = VPD_kPa_int,
                  y = CEWL_g_m2h_mean),
              formula = y ~ x,
              method = "lm",
              se = F,
              size = 1.6,
              alpha = 1 ) +
  theme_classic() +
  xlab("Vapor Pressure Deficit (kPa)") +
  ylab(bquote('CEWL (g/'*m^2*'h)')) +
  #ylab("") +
  #xlim() +
  #ylim() +
  #annotate("text", x = , y = ,
   #        label = "paste(italic(R) ^ 2, \" = 0.\")",
    #       parse = TRUE,
     #      size = 6) +
  #annotate("text", x = , y = ,
   #        label = "paste(italic(p), \" < 0.0001\")",
    #       parse = TRUE,
     #      size = 6) +
  theme(text = element_text(color = "black",
                            family = "sans",
                            size = 22),
        axis.text = element_text(color = "black",
                                 family = "sans",
                                 size = 16),
        #axis.text.y = element_blank(),
        #plot.margin = unit(c(0.1,0,0.1,0.45), "cm")
        ) -> cap_CEWL_VPD_fig
cap_CEWL_VPD_fig
```

```
## Warning: Removed 14 rows containing non-finite values (stat_smooth).
## Warning: Removed 14 rows containing missing values (geom_point).
```

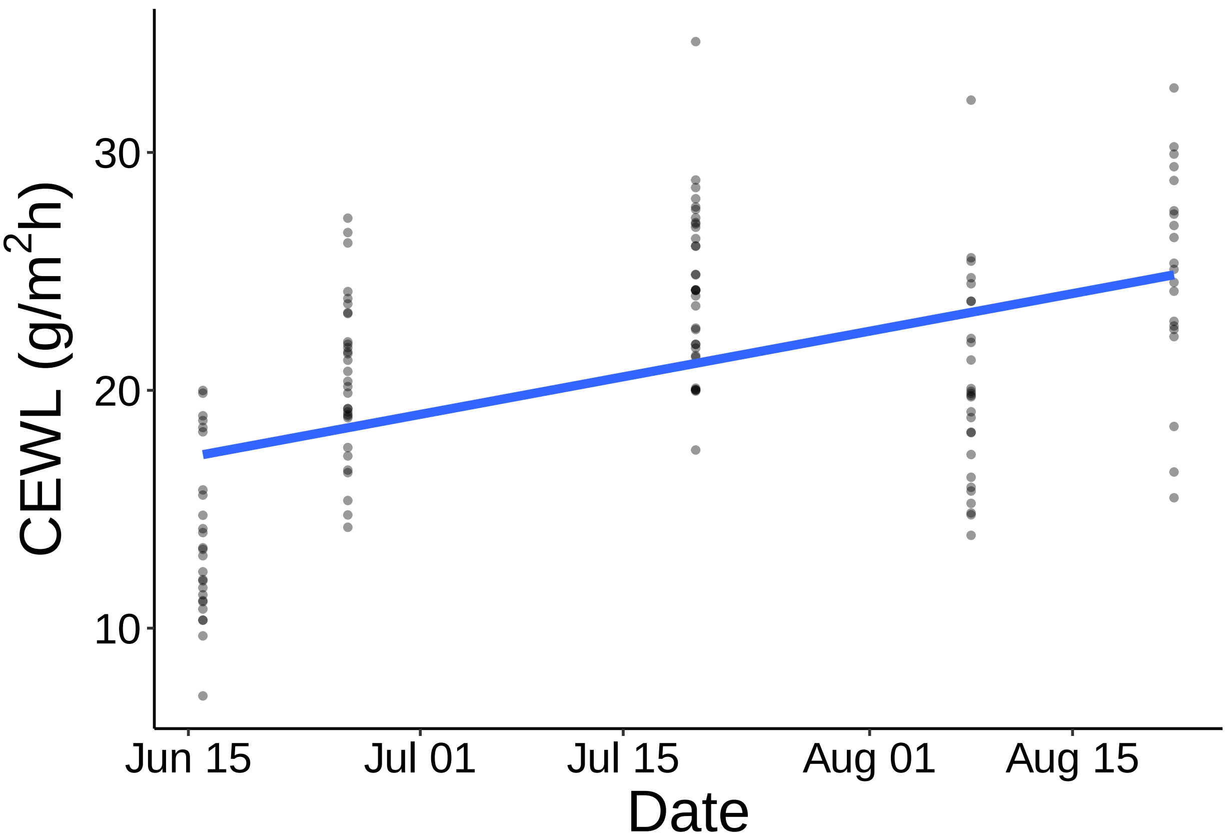



```
# export figure
#ggsave(filename = "cap_osml_mass_fig.jpeg",
 #      plot = cap_osml_mass_fig,
  #     path = "./results_figures",
   #    device = "jpeg",
    #   dpi = 1200,
     #  width = 6, height = 4)
```

CEWL ~ Date

```
capture_dat_plus %>%
  ggplot() +
  geom_point(aes(x = capture_date,
                 y = CEWL_g_m2h_mean),
             size = 1,
             alpha = 0.4) +
  stat_smooth(aes(x = capture_date,
                  y = CEWL_g_m2h_mean),
              formula = y ~ x,
              method = "lm",
              se = F,
              size = 1.6,
              alpha = 1 ) +
  theme_classic() +
  xlab("Date") +
  ylab(bquote('CEWL (g/'*m^2*'h)')) +
```

```
  #ylab("") +
  #xlim() +
  #ylim() +
  #annotate("text", x = , y = ,
   #         label = "paste(italic(R) ^ 2, \" = 0.\")",
    #       parse = TRUE,
     #      size = 6) +
  #annotate("text", x = , y = ,
   #         label = "paste(italic(p), \" < 0.0001\")",
    #       parse = TRUE,
     #      size = 6) +
  theme(text = element_text(color = "black",
                            family = "sans",
                            size = 22),
        axis.text = element_text(color = "black",
                                 family = "sans",
                                 size = 16),
        #axis.text.y = element_blank(),
        #plot.margin = unit(c(0.1,0,0.1,0.45), "cm")
        ) -> cap_CEWL_date_fig
cap_CEWL_date_fig
```




```
# export figure
#ggsave(filename = "cap_osml_mass_fig.jpeg",
 #      plot = cap_osml_mass_fig,
  #     path = "./results_figures",
   #    device = "jpeg",
```

```
#   dpi = 1200,
 #  width = 6, height = 4)
```