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("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.mixed")) install.packages("broom.mixed")
library("broom.mixed") # lmer model export
if (!require("AICcmodavg")) install.packages("AICcmodavg")
library("AICcmodavg") # model selection
if (!require("car")) install.packages("car")
library("car") # VIFs
if (!require("AICcmodavg")) install.packages("AICcmodavg")
library("AICcmodavg") # model selection
if (!require("RColorBrewer")) install.packages("RColorBrewer")
library("RColorBrewer") # color
```

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 then acclimated to 4 different climate treatments. **This R file analyzes the state and variation of osmotic balance and regulation at the time of capture.** Please refer to the published scientific journal article for full details.

Load Data

```
dat <- read_rds("./data/analysis_data_capture.RDS")
summary(dat)
```

```
##  individual_ID     mass_g      hematocrit_percent     SVL_mm
##  201    :  1   Min.   : 8.80   Min.   :27.00      Min.   :60.00
##  202    :  1   1st Qu.:10.60   1st Qu.:34.25      1st Qu.:66.00
##  203    :  1   Median :11.65   Median :39.00      Median :67.00
##  204    :  1   Mean   :11.73   Mean   :38.93      Mean   :67.71
##  205    :  1   3rd Qu.:12.70   3rd Qu.:43.00      3rd Qu.:70.00
##  206    :  1   Max.   :17.40   Max.   :52.00      Max.   :77.00
##  (Other):132
##   capture_date        osmolality_mmol_kg_mean CEWL_g_m2h_mean   msmt_temp_C
##  Min.   :2021-06-16   Min.   :305.0           Min.   : 7.152   Min.   :25.90
##  1st Qu.:2021-06-26   1st Qu.:334.3           1st Qu.:17.255   1st Qu.:26.72
##  Median :2021-07-20   Median :344.6           Median :21.030   Median :26.96
##  Mean   :2021-07-16   Mean   :348.3           Mean   :20.760   Mean   :27.20
```

```
##  3rd Qu.:2021-08-08   3rd Qu.:361.9           3rd Qu.:24.416   3rd Qu.:27.50
##  Max.   :2021-08-22   Max.   :395.0           Max.   :34.660   Max.   :29.20
##
##  msmt_RH_percent cloacal_temp_C    date_time                     msmt_temp_K
##  Min.   :25.52   Min.   :25.00   Min.   :2021-06-16 09:54:00   Min.   :299.1
##  1st Qu.:45.77   1st Qu.:26.00   1st Qu.:2021-06-26 12:59:30   1st Qu.:299.9
##  Median :47.09   Median :26.00   Median :2021-07-20 13:17:00   Median :300.1
##  Mean   :44.08   Mean   :26.45   Mean   :2021-07-17 06:56:12   Mean   :300.3
##  3rd Qu.:48.44   3rd Qu.:27.00   3rd Qu.:2021-08-08 13:39:00   3rd Qu.:300.6
##  Max.   :53.15   Max.   :30.00   Max.   :2021-08-22 15:19:00   Max.   :302.4
##
##    e_s_kPa_m       e_a_kPa_m       msmt_VPD_kPa        SMI
##  Min.   :3.441   Min.   :0.9894   Min.   :1.612   Min.   : 9.122
##  1st Qu.:3.616   1st Qu.:1.6913   1st Qu.:1.846   1st Qu.:10.926
##  Median :3.669   Median :1.7342   Median :1.942   Median :11.687
##  Mean   :3.724   Mean   :1.6312   Mean   :2.093   Mean   :11.690
##  3rd Qu.:3.790   3rd Qu.:1.7865   3rd Qu.:2.053   3rd Qu.:12.347
##  Max.   :4.194   Max.   :1.8502   Max.   :3.021   Max.   :14.263
##
##  capture_date_time             hold_time_sec     hold_time_min
##  Min.   :2021-06-16 08:28:00   Length:138        Length:138
##  1st Qu.:2021-06-26 09:44:45   Class :difftime   Class :difftime
##  Median :2021-07-20 09:52:00   Mode  :numeric    Mode  :numeric
##  Mean   :2021-07-14 14:50:11
##  3rd Qu.:2021-08-08 09:56:45
##  Max.   :2021-08-22 13:25:00
##  NA's   :14
##  hold_time_hr      temp_C_interpol RH_percent_interpol  VPD_kPa_int
##  Length:138        Min.   :15.11   Min.   : 19.73      Min.   :0.0000
##  Class :difftime   1st Qu.:19.91   1st Qu.: 59.20      1st Qu.:0.5420
##  Mode  :numeric    Median :21.91   Median : 69.33      Median :0.8284
##                    Mean   :23.41   Mean   : 62.27      Mean   :1.4295
##                    3rd Qu.:23.91   3rd Qu.: 77.29      3rd Qu.:1.2321
##                    Max.   :35.83   Max.   :100.00      Max.   :4.9400
##                    NA's   :14      NA's   :14          NA's   :14
##  wind_mph_interpol solar_rad_W_sqm_interpol
##  Min.   : 0.100    Min.   : 294.7
##  1st Qu.: 2.025    1st Qu.: 682.9
##  Median : 3.100    Median : 759.9
##  Mean   : 4.406    Mean   : 762.9
##  3rd Qu.: 5.880    3rd Qu.: 873.2
##  Max.   :12.720    Max.   :1007.0
##  NA's   :14        NA's   :14
```

note IDs I do not have data for: 254, 284, 304

LMMs

We use simple linear models here because date and individual ID do not need to be random effects: we want to know how/why values varied across dates, and each individual only has one measurement.

Hematocrit

Models

First, start with a full model with every probable potential predictor in it, then check for multicollinearity.

```
hct_mod1 <- lm(data = dat,
                          # response variable
                          hematocrit_percent ~
                          # body size options
                          mass_g + SVL_mm + SMI +
                          # weather at the time of capture
                          temp_C_interpol * VPD_kPa_int +
                          wind_mph_interpol + solar_rad_W_sqm_interpol
                            )
hct_mod1_VIFs <- data.frame(VIF = car::vif(hct_mod1)) %>%
  arrange(desc(VIF))
hct_mod1_VIFs
```

```
##                                    VIF
## VPD_kPa_int                 776.842577
## temp_C_interpol:VPD_kPa_int 259.587300
## temp_C_interpol             180.895804
## mass_g                      147.299036
## SVL_mm                      137.309907
## SMI                          69.984055
## wind_mph_interpol             5.202791
## solar_rad_W_sqm_interpol      3.988220
```

remove VPD*temp interaction:

```
hct_mod2 <- lm(data = dat,
                          # response variable
                          hematocrit_percent ~
                          # body size
                          mass_g + SVL_mm + SMI +
                          # weather at the time of capture
                          temp_C_interpol + VPD_kPa_int +
                          wind_mph_interpol + solar_rad_W_sqm_interpol
                            )
hct_mod2_VIFs <- data.frame(VIF = car::vif(hct_mod2)) %>%
  arrange(desc(VIF))
hct_mod2_VIFs
```

```
##                                VIF
## mass_g                  144.935446
## SVL_mm                  134.828923
## temp_C_interpol          89.583462
## VPD_kPa_int              88.715132
## SMI                      68.677230
## wind_mph_interpol         4.086594
## solar_rad_W_sqm_interpol  2.293753
```

```
drop1(hct_mod2)
```

```
## Single term deletions
##
## Model:
```

```
## hematocrit_percent ~ mass_g + SVL_mm + SMI + temp_C_interpol +
##     VPD_kPa_int + wind_mph_interpol + solar_rad_W_sqm_interpol
##                           Df Sum of Sq    RSS    AIC
## <none>                                  2998.3 411.00
## mass_g                     1     0.970 2999.3 409.05
## SVL_mm                     1     0.725 2999.0 409.03
## SMI                        1     0.685 2999.0 409.03
## temp_C_interpol            1     4.349 3002.7 409.18
## VPD_kPa_int                1     1.631 2999.9 409.07
## wind_mph_interpol          1   250.305 3248.6 418.95
## solar_rad_W_sqm_interpol   1    77.557 3075.9 412.17
```

drop SVL:

```
hct_mod3 <- lm(data = dat,
                          # response variable
                          hematocrit_percent ~
                          # body size
                          mass_g + SMI +
                          # weather at the time of capture
                          temp_C_interpol + VPD_kPa_int +
                          wind_mph_interpol + solar_rad_W_sqm_interpol
                            )
hct_mod3_VIFs <- data.frame(VIF = car::vif(hct_mod3)) %>%
  arrange(desc(VIF))
hct_mod3_VIFs
```

```
##                                VIF
## temp_C_interpol          84.911535
## VPD_kPa_int              83.181379
## wind_mph_interpol         4.052405
## solar_rad_W_sqm_interpol  2.215093
## SMI                       1.405795
## mass_g                    1.246836
```

```
drop1(hct_mod3)
```

```
## Single term deletions
##
## Model:
## hematocrit_percent ~ mass_g + SMI + temp_C_interpol + VPD_kPa_int +
##     wind_mph_interpol + solar_rad_W_sqm_interpol
##                           Df Sum of Sq    RSS    AIC
## <none>                                  2999.0 409.03
## mass_g                     1     2.186 3001.2 407.13
## SMI                        1   136.330 3135.4 412.55
## temp_C_interpol            1     3.773 3002.8 407.19
## VPD_kPa_int                1     1.208 3000.2 407.08
## wind_mph_interpol          1   254.908 3253.9 417.15
## solar_rad_W_sqm_interpol   1    77.461 3076.5 410.20
```

drop temperature:

```
hct_mod4 <- lm(data = dat,
                          # response variable
                          hematocrit_percent ~
                          # body size
```

```
                          mass_g + SMI +
                          # weather at the time of capture
                          VPD_kPa_int +
                          wind_mph_interpol + solar_rad_W_sqm_interpol
                            )
hct_mod4_VIFs <- data.frame(VIF = car::vif(hct_mod4)) %>%
  arrange(desc(VIF))
hct_mod4_VIFs
```

```
##                               VIF
## wind_mph_interpol        4.039979
## VPD_kPa_int              4.010514
## SMI                      1.402937
## mass_g                   1.246609
## solar_rad_W_sqm_interpol 1.068123
```

```
drop1(hct_mod4)
```

```
## Single term deletions
##
## Model:
## hematocrit_percent ~ mass_g + SMI + VPD_kPa_int + wind_mph_interpol +
##     solar_rad_W_sqm_interpol
##                          Df Sum of Sq    RSS    AIC
## <none>                                3002.8 407.19
## mass_g                    1     2.110 3004.9 405.28
## SMI                       1   134.567 3137.4 410.63
## VPD_kPa_int               1    13.135 3015.9 405.73
## wind_mph_interpol         1   252.259 3255.1 415.19
## solar_rad_W_sqm_interpol  1   113.672 3116.5 409.80
```

VIFs are all below 5 now, so start backwards selection.

Drop mass first:

```
hct_mod5 <- lm(data = dat,
                          # response variable
                          hematocrit_percent ~
                          # body size
                          SMI +
                          # weather at the time of capture
                          VPD_kPa_int +
                          wind_mph_interpol + solar_rad_W_sqm_interpol
                            )
drop1(hct_mod5)
```

```
## Single term deletions
##
## Model:
## hematocrit_percent ~ SMI + VPD_kPa_int + wind_mph_interpol +
##     solar_rad_W_sqm_interpol
##                          Df Sum of Sq    RSS    AIC
## <none>                                3004.9 405.28
## SMI                       1   185.660 3190.6 410.71
## VPD_kPa_int               1    13.221 3018.1 403.82
## wind_mph_interpol         1   262.114 3267.0 413.65
```

```
## solar_rad_W_sqm_interpol  1   116.011 3120.9 407.98
```

Drop VPD:

```
hct_mod6 <- lm(data = dat,
                          # response variable
                          hematocrit_percent ~
                          # body size
                          SMI +
                          # weather at the time of capture
                          wind_mph_interpol + solar_rad_W_sqm_interpol
                            )
summary(hct_mod6)
```

```
##
## Call:
## lm(formula = hematocrit_percent ~ SMI + wind_mph_interpol + solar_rad_W_sqm_interpol,
##     data = dat)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -11.7663  -3.0319  -0.1456   3.4610  11.0669
##
## Coefficients:
##                            Estimate Std. Error t value Pr(>|t|)
## (Intercept)              17.030786   6.116508   2.784  0.00623 **
## SMI                       1.244585   0.447364   2.782  0.00628 **
## wind_mph_interpol         0.607540   0.123216   4.931 2.66e-06 ***
## solar_rad_W_sqm_interpol  0.006307   0.003098   2.036  0.04398 *
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 5.015 on 120 degrees of freedom
##   (14 observations deleted due to missingness)
## Multiple R-squared:  0.1945, Adjusted R-squared:  0.1744
## F-statistic: 9.659 on 3 and 120 DF,  p-value: 9.26e-06
```

```
drop1(hct_mod6)
```

```
## Single term deletions
##
## Model:
## hematocrit_percent ~ SMI + wind_mph_interpol + solar_rad_W_sqm_interpol
##                           Df Sum of Sq    RSS    AIC
## <none>                                  3018.1 403.82
## SMI                        1    194.66 3212.8 409.57
## wind_mph_interpol          1    611.47 3629.6 424.70
## solar_rad_W_sqm_interpol   1    104.23 3122.4 406.03
```

Drop solar:

```
hct_mod7 <- lm(data = dat,
                          # response variable
                          hematocrit_percent ~
                          # body size
                          SMI +
                          # weather at the time of capture
```

```
                          wind_mph_interpol
                            )
drop1(hct_mod7)
```

```
## Single term deletions
##
## Model:
## hematocrit_percent ~ SMI + wind_mph_interpol
##                    Df Sum of Sq    RSS    AIC
## <none>                           3122.4 406.03
## SMI                 1    171.27 3293.6 410.65
## wind_mph_interpol   1    594.00 3716.4 425.63
```

Drop SMI:

```
hct_mod8 <- lm(data = dat,
                          # response variable
                          hematocrit_percent ~
                          # weather at the time of capture
                          wind_mph_interpol
                            )
```

Finally, null model:

```
hct_mod_null <- lm(data = dat,
                          # response variable
                          hematocrit_percent ~ 1)
```

Selection

Compare models 4-8 and the null model.

```
hct_models <- list(hct_mod4, hct_mod5, hct_mod6, hct_mod7,
                   hct_mod8, hct_mod_null)

#specify model names
hct_mod_names <- c('(model 4) ~ Wind-C, SMI, Solar-C, VPD-C, Mass',
                       '(model 5) ~ Wind-C, SMI, Solar-C, VPD-C',
                       '(model 6) ~ Wind-C, SMI, Solar-C',
                       '(model 7) ~ Wind-C, SMI',
                       '(model 8) ~ Wind-C',
                       'null model')
#calculate AIC of each model
hct_AICc <- data.frame(aictab(cand.set = hct_models,
                              modnames = hct_mod_names))
hct_AICc
```

```
##                                         Modnames K     AICc Delta_AICc
## 3              (model 6) ~ Wind-C, SMI, Solar-C 5 758.2275   0.000000
## 2       (model 5) ~ Wind-C, SMI, Solar-C, VPD-C 6 759.8926   1.665102
## 4                       (model 7) ~ Wind-C, SMI 4 760.2651   2.037581
## 1 (model 4) ~ Wind-C, SMI, Solar-C, VPD-C, Mass 7 762.0530   3.825573
## 5                           (model 8) ~ Wind-C 3 764.7505   6.523000
## 6                                  null model 2 861.5454 103.317962
##       ModelLik       AICcWt        LL    Cum.Wt
## 3 1.000000e+00 5.045488e-01 -373.8595 0.5045488
```

```
## 2 4.349384e-01 2.194476e-01 -373.5873 0.7239964
## 4 3.610313e-01 1.821579e-01 -375.9645 0.9061543
## 1 1.476683e-01 7.450586e-02 -373.5438 0.9806602
## 5 3.833086e-02 1.933979e-02 -379.2752 1.0000000
## 6 3.671044e-23 1.852221e-23 -428.7283 1.0000000
```

The best models are models 6 and 5.

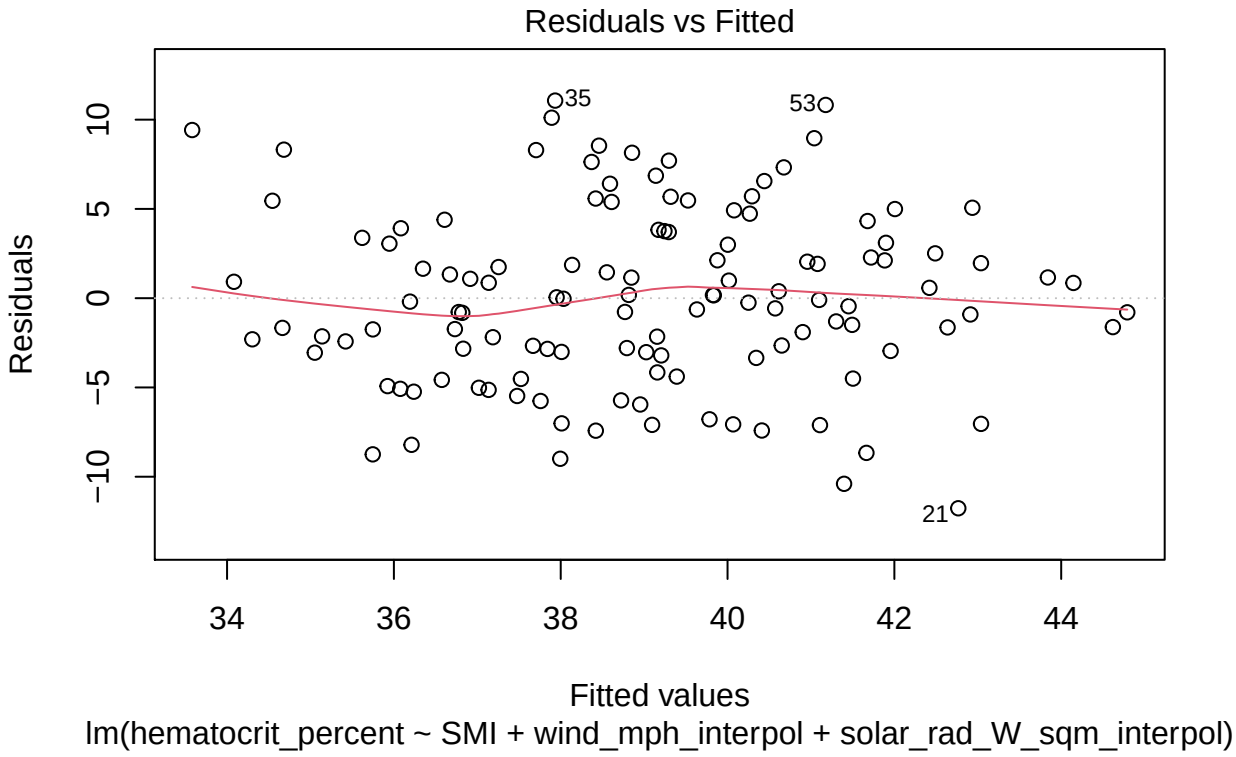
LM Conditions

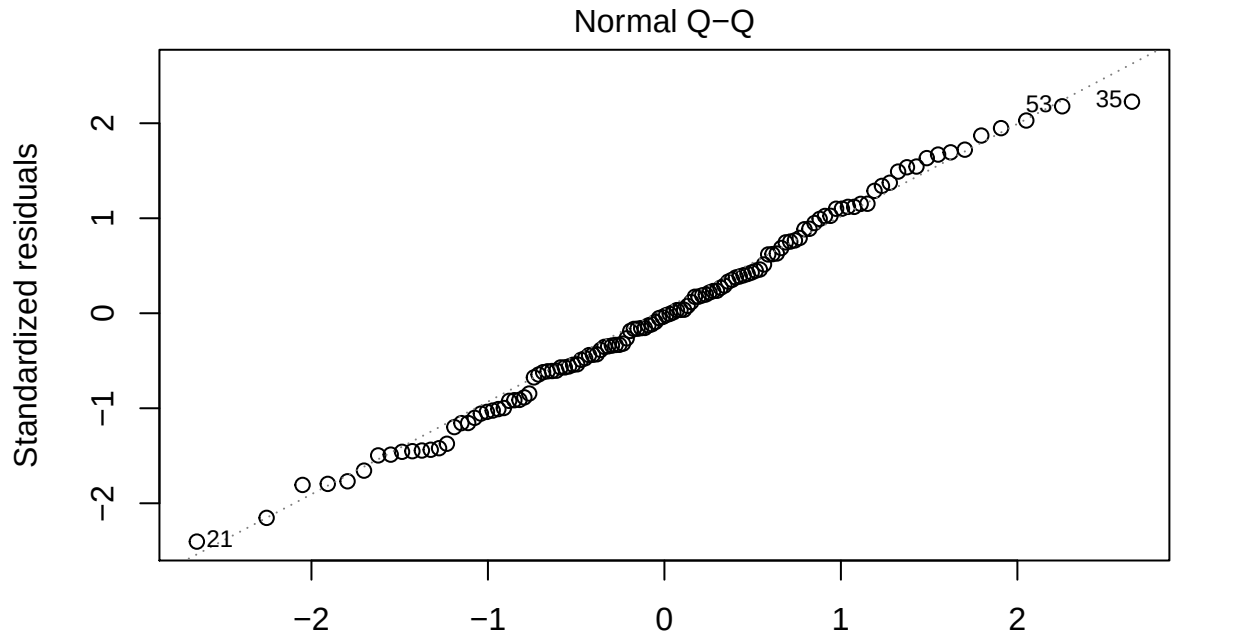
Check that the best model meets the criteria for linear regression and has no collinearity.

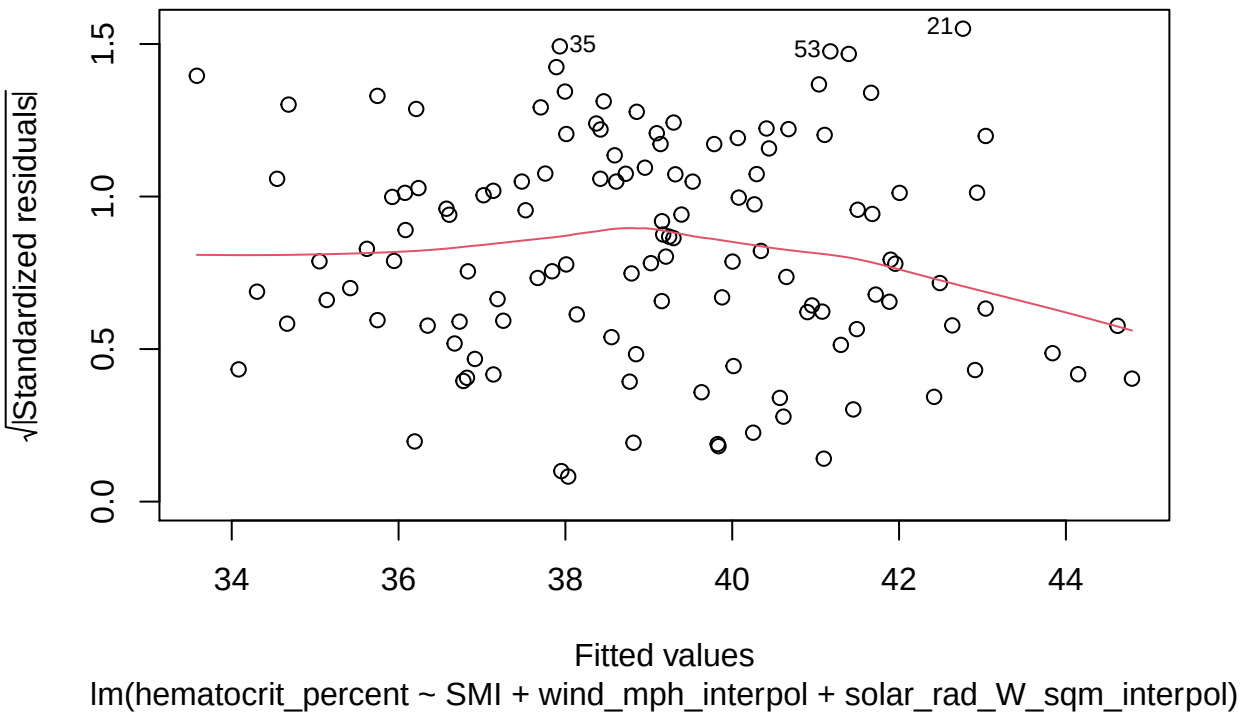
```
vif(hct_mod6)
```

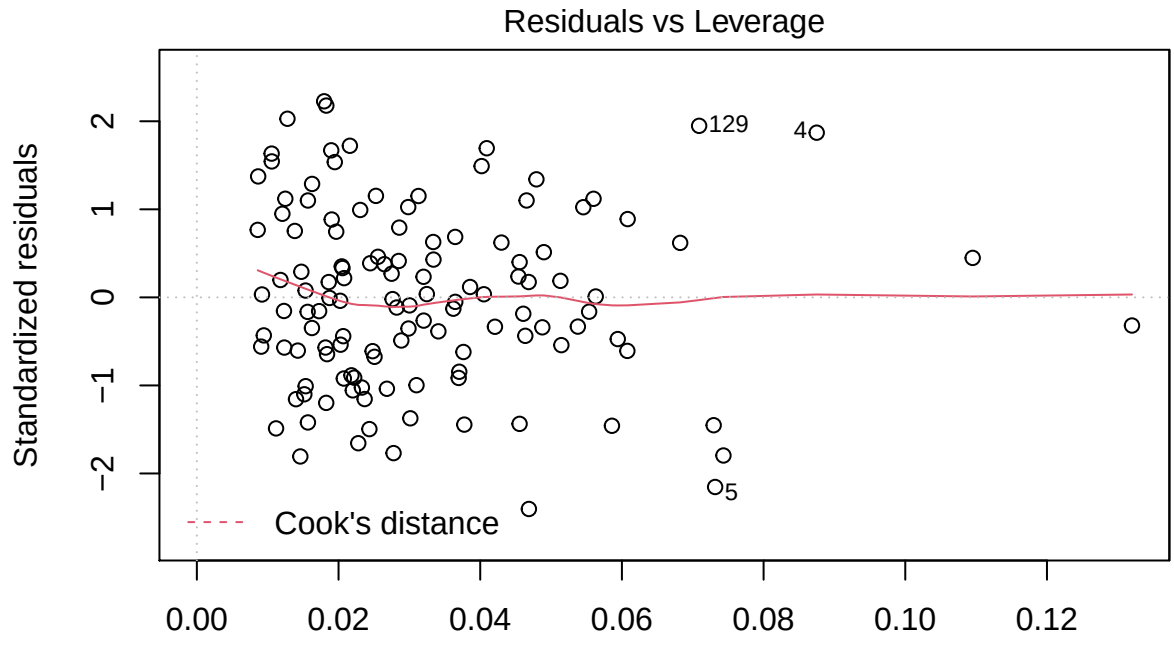
```
##                      SMI        wind_mph_interpol solar_rad_W_sqm_interpol
##                 1.124966                 1.117346                 1.008219
```

```
plot(hct_mod6)
```

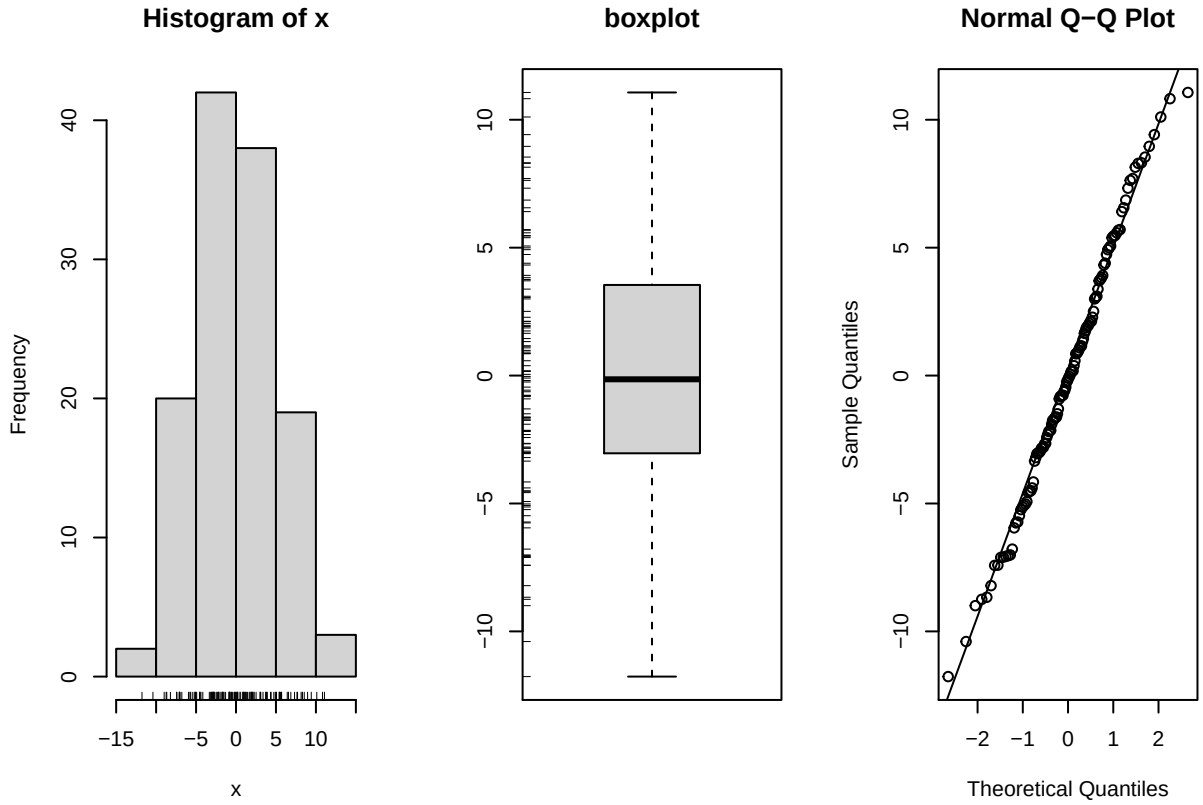



Normal Q−Q
Standardized residuals
Theoretical Quantiles
lm(hematocrit_percent ~ SMI + wind_mph_interpol + solar_rad_W_sqm_interpol)
21
53
35
−2
−1
0
1
2


Scale−Location
√|Standardized residuals|
Fitted values
lm(hematocrit_percent ~ SMI + wind_mph_interpol + solar_rad_W_sqm_interpol)
35
53
21
0.0
0.5
1.0
1.5
34
36
38
40
42
44




```
simple.eda(residuals(hct_mod6))
```



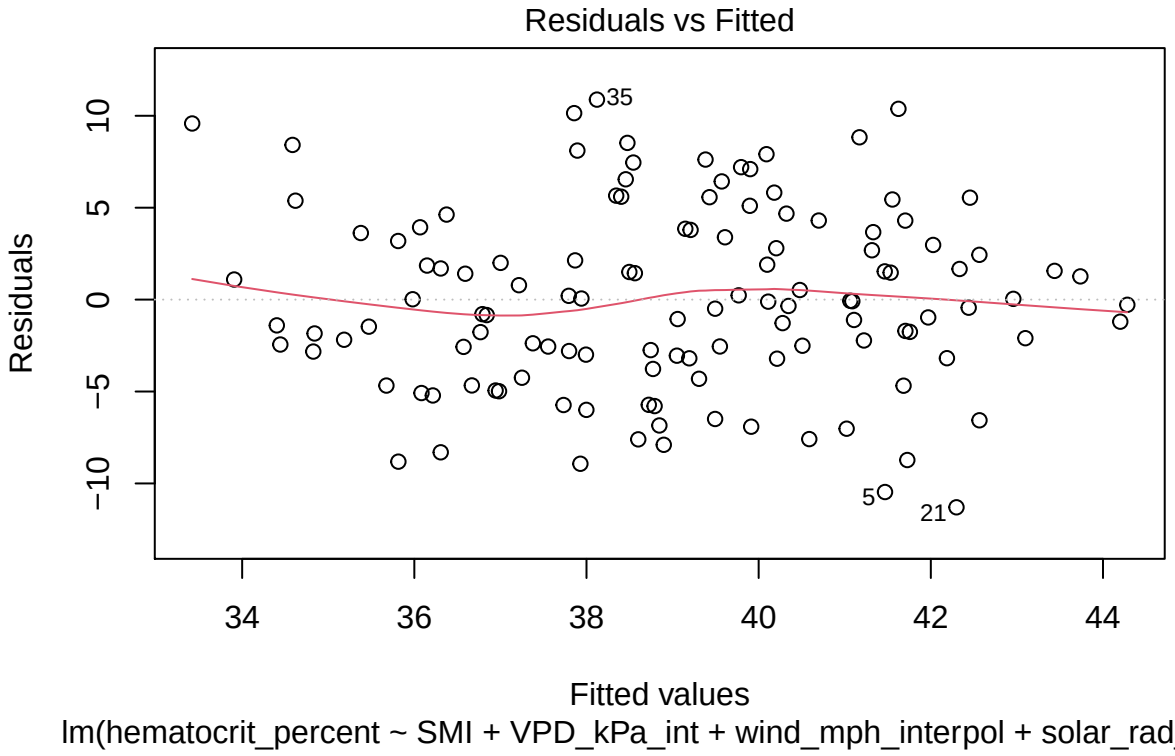
```
shapiro.test(residuals(hct_mod6))
```

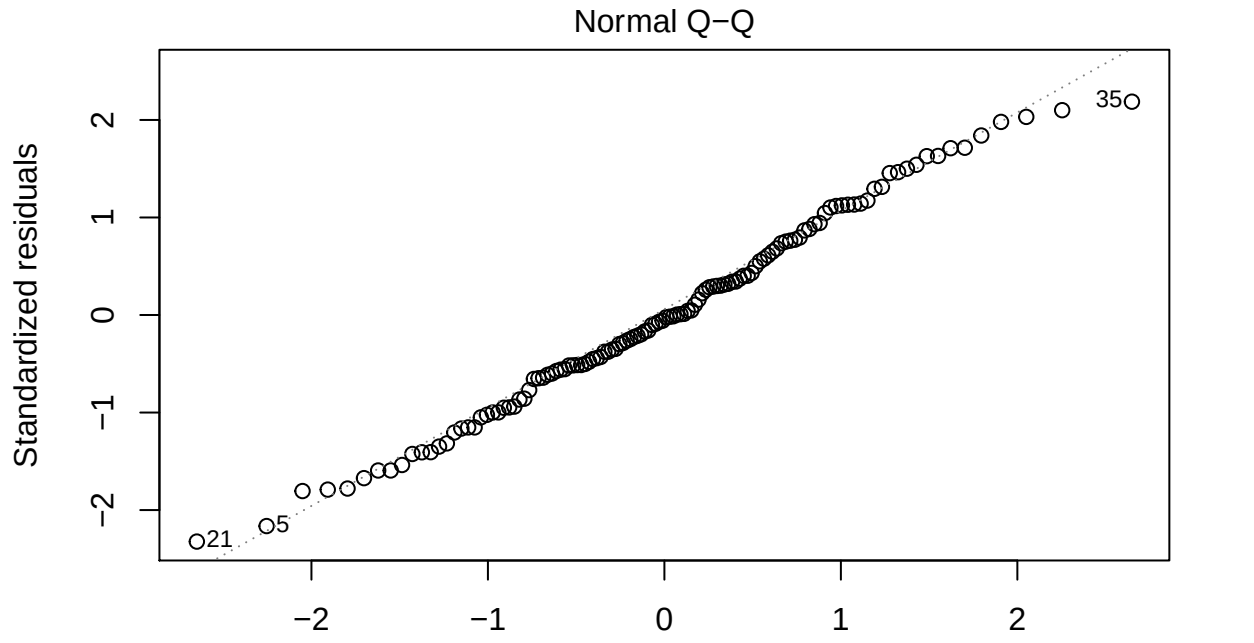
```
##
##  Shapiro-Wilk normality test
##
## data:  residuals(hct_mod6)
## W = 0.9913, p-value = 0.6322
```

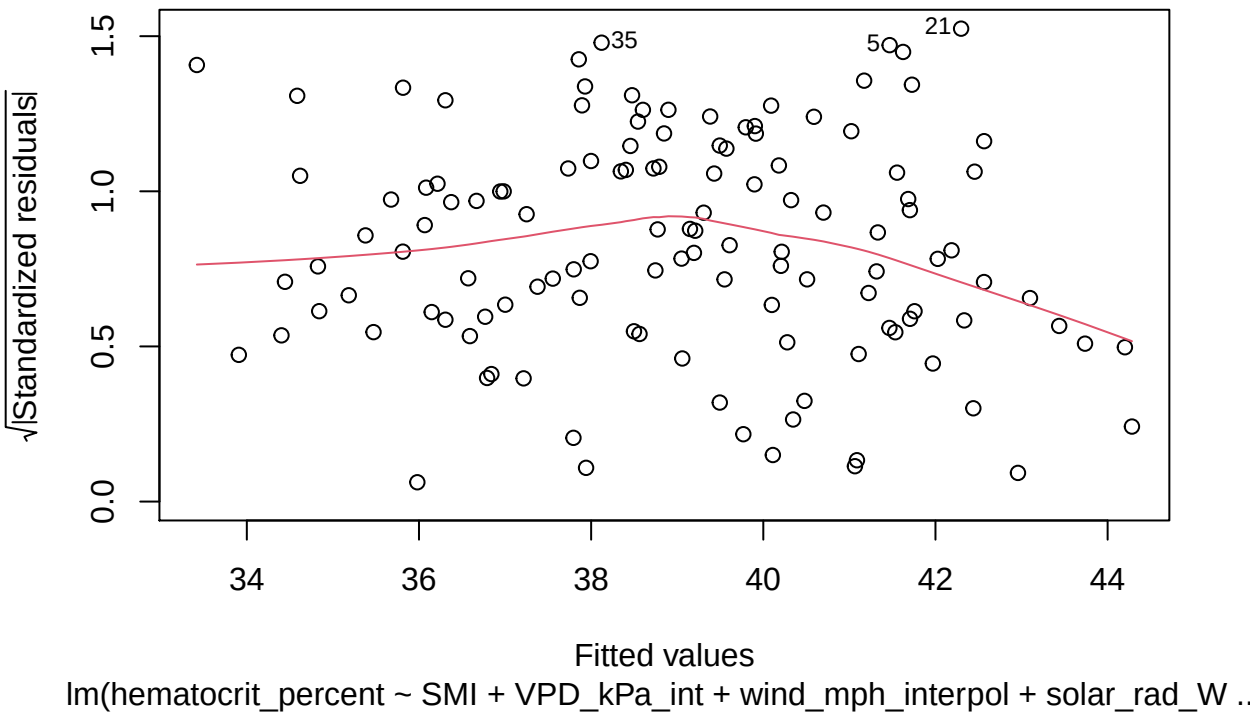
```
vif(hct_mod5)
```

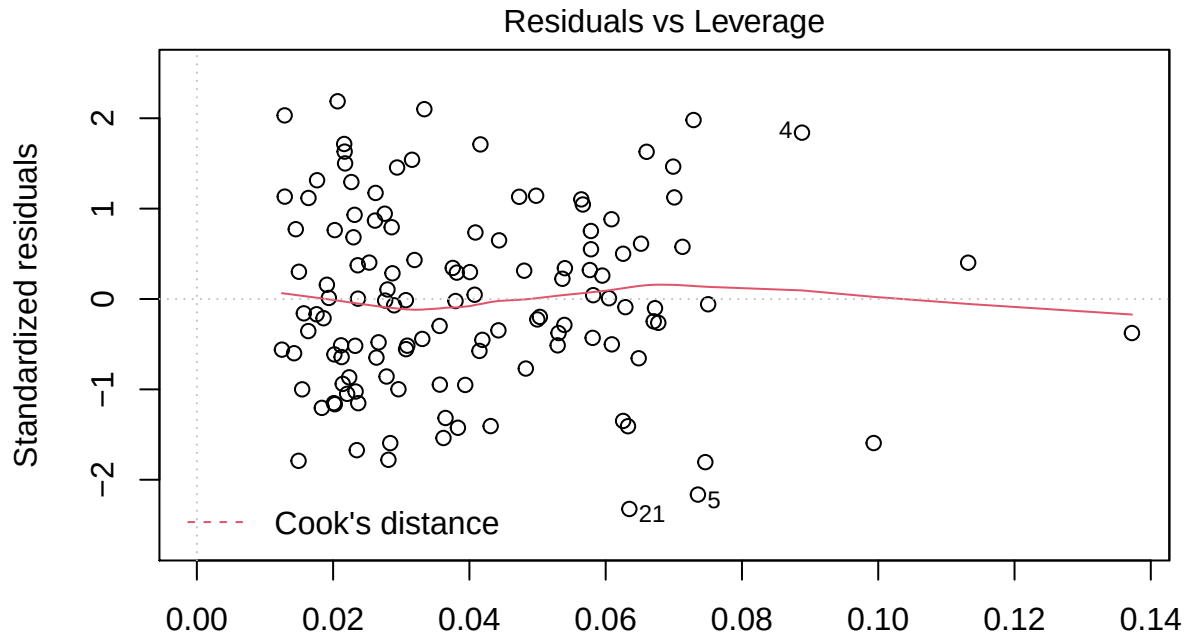
```
##                      SMI             VPD_kPa_int       wind_mph_interpol
##                 1.131865                4.010251                3.977224
## solar_rad_W_sqm_interpol
##                 1.064119
```

```
plot(hct_mod5)
```

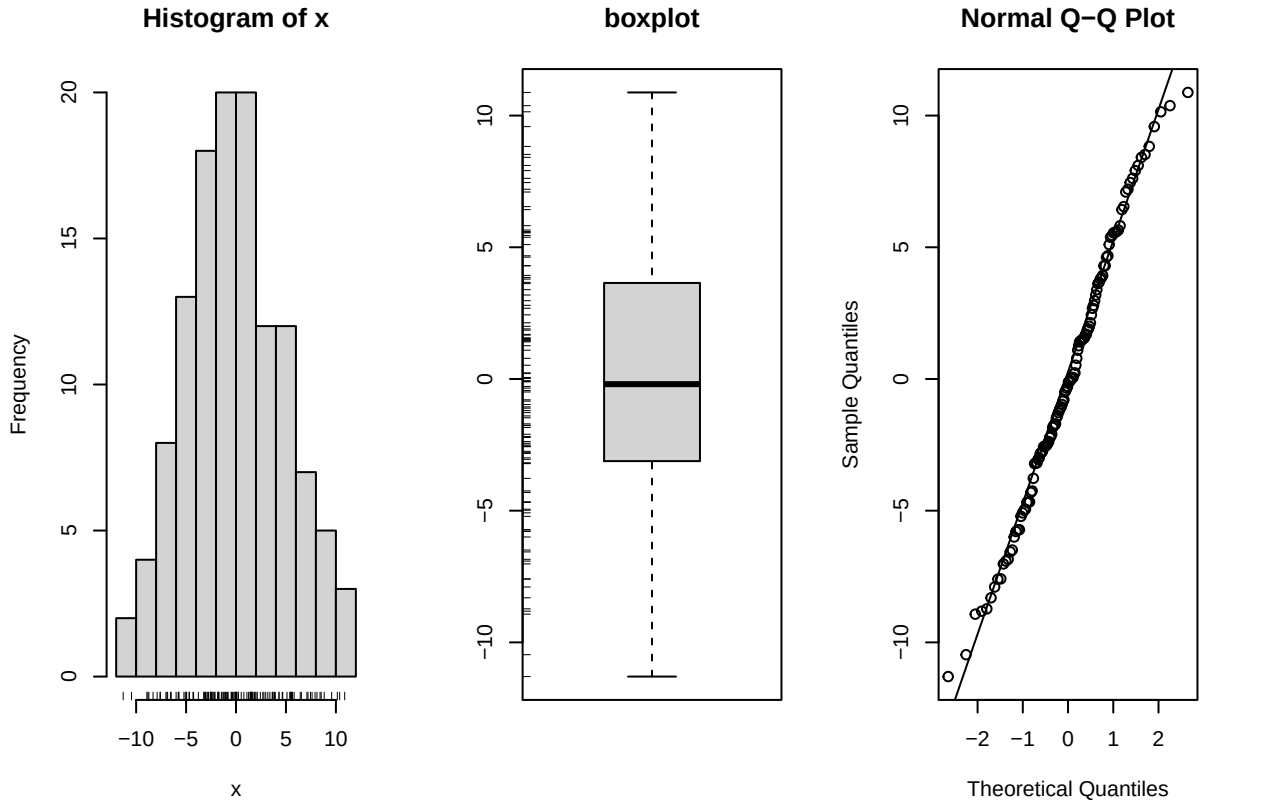



Normal Q−Q
Standardized residuals
Theoretical Quantiles
lm(hematocrit_percent ~ SMI + VPD_kPa_int + wind_mph_interpol + solar_rad_W ..
35
21
5
−2
−1
0
1
2


Scale−Location
√|Standardized residuals|
Fitted values
lm(hematocrit_percent ~ SMI + VPD_kPa_int + wind_mph_interpol + solar_rad_W ..
35
5
21
0.0
0.5
1.0
1.5
34
36
38
40
42
44




```
simple.eda(residuals(hct_mod5))
```



```
shapiro.test(residuals(hct_mod5))
```

```
##
##  Shapiro-Wilk normality test
##
## data:  residuals(hct_mod5)
## W = 0.9903, p-value = 0.5368
```

Everything is almost perfect.

Export

```
write.csv(hct_AICc, "./results_statistics/capture_hct_mod_rankings.csv")
write.csv(broom.mixed::tidy(hct_mod6),
          "./results_statistics/capture_hct_best_mod1.csv")
write.csv(broom.mixed::tidy(hct_mod5),
          "./results_statistics/capture_hct_best_mod2.csv")
```

Osmolality

Models

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.

We would also include whether or not a blood sample is hemolyzed as a random effect, but only 11 of the almost 150 samples were hemolyzed, so we will assume that any potential effects will be undetectable and/or overshadowed. We do not have concern about using those points.

First, start with a full model with every probable potential predictor in it, then check for multicollinearity.

```
osml_mod1 <- lme4::lmer(data = dat,
                        # response variable
                        osmolality_mmol_kg_mean ~
                        # body size
                        mass_g + SVL_mm + SMI +
                        # blood sample traits
                        hematocrit_percent +
                        # weather at the time of capture
                        temp_C_interpol * VPD_kPa_int +
                        wind_mph_interpol + solar_rad_W_sqm_interpol +
                        (1|capture_date))
osml_mod1_VIFs <- data.frame(VIF = car::vif(osml_mod1)) %>%
  arrange(desc(VIF))
osml_mod1_VIFs
```

```
##                                    VIF
## VPD_kPa_int                 230.770824
## mass_g                      157.598336
## SVL_mm                      134.421136
## temp_C_interpol:VPD_kPa_int  74.795939
## temp_C_interpol              74.150446
## SMI                          68.079595
## solar_rad_W_sqm_interpol      4.986184
## wind_mph_interpol             1.733699
## hematocrit_percent            1.144594
```

VPD and temperature introduce a lot of collinearity, so start by dropping their interaction:

```
osml_mod2 <- lme4::lmer(data = dat,
                        # response variable
                        osmolality_mmol_kg_mean ~
                        # body size
                        mass_g + SVL_mm + SMI +
                        # blood sample traits
                        hematocrit_percent +
                        # weather at the time of capture
                        temp_C_interpol + VPD_kPa_int +
                        wind_mph_interpol + solar_rad_W_sqm_interpol +
                        (1|capture_date))
osml_mod2_VIFs <- data.frame(VIF = car::vif(osml_mod2)) %>%
  arrange(desc(VIF))
osml_mod2_VIFs
```

```
##                                VIF
## mass_g                  157.205557
## SVL_mm                  133.945843
## SMI                      67.851081
## temp_C_interpol          25.018579
## VPD_kPa_int              17.519956
## solar_rad_W_sqm_interpol  3.794844
## wind_mph_interpol         1.287093
## hematocrit_percent        1.135184
```

```
drop1(osml_mod2)
```

```
## Single term deletions
##
## Model:
## osmolality_mmol_kg_mean ~ mass_g + SVL_mm + SMI + hematocrit_percent +
##     temp_C_interpol + VPD_kPa_int + wind_mph_interpol + solar_rad_W_sqm_interpol +
##     (1 | capture_date)
##                           npar    AIC
## <none>                         1026.6
## mass_g                       1 1025.3
## SVL_mm                       1 1025.5
## SMI                          1 1025.2
## hematocrit_percent           1 1024.7
## temp_C_interpol              1 1026.0
## VPD_kPa_int                  1 1026.6
## wind_mph_interpol            1 1025.0
## solar_rad_W_sqm_interpol     1 1026.5
```

Drop mass next, since it's extremely collinear and we get slightly better AIC by dropping mass compared to SVL:

```
osml_mod3 <- lme4::lmer(data = dat,
                        # response variable
                        osmolality_mmol_kg_mean ~
                        # body size
                        SVL_mm + SMI +
                        # blood sample traits
                        hematocrit_percent +
```

```
                          # weather at the time of capture
                          temp_C_interpol + VPD_kPa_int +
                          wind_mph_interpol + solar_rad_W_sqm_interpol +
                          (1|capture_date))
osml_mod3_VIFs <- data.frame(VIF = car::vif(osml_mod3)) %>%
  arrange(desc(VIF))
osml_mod3_VIFs
```

```
##                                VIF
## temp_C_interpol          24.145020
## VPD_kPa_int              17.159996
## solar_rad_W_sqm_interpol  3.673673
## wind_mph_interpol         1.277514
## SMI                       1.141551
## hematocrit_percent        1.135063
## SVL_mm                    1.065997
```

```
drop1(osml_mod3)
```

```
## Single term deletions
##
## Model:
## osmolality_mmol_kg_mean ~ SVL_mm + SMI + hematocrit_percent +
##     temp_C_interpol + VPD_kPa_int + wind_mph_interpol + solar_rad_W_sqm_interpol +
##     (1 | capture_date)
##                           npar    AIC
## <none>                         1025.3
## SVL_mm                       1 1026.5
## SMI                          1 1023.5
## hematocrit_percent           1 1023.3
## temp_C_interpol              1 1024.3
## VPD_kPa_int                  1 1025.0
## wind_mph_interpol            1 1023.6
## solar_rad_W_sqm_interpol     1 1025.7
```

Temperature is still introducing a lot of multicollinearity, so drop:

```
osml_mod4 <- lme4::lmer(data = dat,
                          # response variable
                          osmolality_mmol_kg_mean ~
                          # body size
                          SVL_mm + SMI +
                          # blood sample traits
                          hematocrit_percent +
                          # weather at the time of capture
                          VPD_kPa_int +
                          wind_mph_interpol + solar_rad_W_sqm_interpol +
                          (1|capture_date))
osml_mod4_VIFs <- data.frame(VIF = car::vif(osml_mod4)) %>%
  arrange(desc(VIF))
osml_mod4_VIFs
```

```
##                                VIF
## VPD_kPa_int              2.679148
## solar_rad_W_sqm_interpol 2.423187
## wind_mph_interpol        1.190631
```

```
## SMI                       1.138075
## hematocrit_percent        1.133355
## SVL_mm                    1.064398
```

```
summary(osml_mod4)
```

```
## Linear mixed model fit by REML ['lmerMod']
## Formula: osmolality_mmol_kg_mean ~ SVL_mm + SMI + hematocrit_percent +
##     VPD_kPa_int + wind_mph_interpol + solar_rad_W_sqm_interpol +
##     (1 | capture_date)
##    Data: dat
##
## REML criterion at convergence: 1000.8
##
## Scaled residuals:
##     Min      1Q  Median      3Q     Max
## -2.3276 -0.6763 -0.0915  0.6145  3.1713
##
## Random effects:
##  Groups       Name        Variance Std.Dev.
##  capture_date (Intercept) 290.4    17.04
##  Residual                 179.4    13.39
## Number of obs: 124, groups:  capture_date, 5
##
## Fixed effects:
##                            Estimate Std. Error t value
## (Intercept)              287.94425   34.47818   8.351
## SVL_mm                     0.67238    0.38976   1.725
## SMI                       -0.49620    1.27272  -0.390
## hematocrit_percent         0.04670    0.24779   0.188
## VPD_kPa_int               -3.55091    3.96947  -0.895
## wind_mph_interpol         -0.15522    1.19310  -0.130
## solar_rad_W_sqm_interpol   0.03473    0.01316   2.639
##
## Correlation of Fixed Effects:
##             (Intr) SVL_mm SMI    hmtcr_ VPD_P_ wnd_m_
## SVL_mm      -0.836
## SMI         -0.555  0.223
## hmtcrt_prcn -0.114 -0.025 -0.244
## VPD_kPa_int  0.056  0.043  0.084 -0.104
## wnd_mph_ntr -0.058 -0.035  0.012 -0.145 -0.290
## slr_rd_W_s_ -0.136 -0.072  0.021 -0.014 -0.742  0.093
```

```
drop1(osml_mod4)
```

```
## Single term deletions
##
## Model:
## osmolality_mmol_kg_mean ~ SVL_mm + SMI + hematocrit_percent +
##     VPD_kPa_int + wind_mph_interpol + solar_rad_W_sqm_interpol +
##     (1 | capture_date)
##                          npar    AIC
## <none>                        1024.3
## SVL_mm                      1 1025.4
## SMI                         1 1022.5
```

```
## hematocrit_percent          1 1022.4
## VPD_kPa_int                 1 1023.2
## wind_mph_interpol           1 1022.4
## solar_rad_W_sqm_interpol    1 1029.8
```

Great, VIFs are well-within acceptable ranges. Now we can start backwards model selection.

Start by dropping wind:

```
osml_mod5 <- lme4::lmer(data = dat,
                        # response variable
                        osmolality_mmol_kg_mean ~
                        # body size
                        SVL_mm + SMI +
                        # blood sample traits
                        hematocrit_percent +
                        # weather at the time of capture
                        VPD_kPa_int + solar_rad_W_sqm_interpol +
                        (1|capture_date))
summary(osml_mod5)
```

```
## Linear mixed model fit by REML ['lmerMod']
## Formula: osmolality_mmol_kg_mean ~ SVL_mm + SMI + hematocrit_percent +
##     VPD_kPa_int + solar_rad_W_sqm_interpol + (1 | capture_date)
##    Data: dat
##
## REML criterion at convergence: 1003
##
## Scaled residuals:
##     Min      1Q  Median      3Q     Max
## -2.3330 -0.6846 -0.1048  0.6265  3.1859
##
## Random effects:
##  Groups       Name        Variance Std.Dev.
##  capture_date (Intercept) 285.8    16.91
##  Residual                 178.0    13.34
## Number of obs: 124, groups:  capture_date, 5
##
## Fixed effects:
##                            Estimate Std. Error t value
## (Intercept)              287.68166   34.27361   8.394
## SVL_mm                     0.67062    0.38793   1.729
## SMI                       -0.49383    1.26746  -0.390
## hematocrit_percent         0.04192    0.24416   0.172
## VPD_kPa_int               -3.70219    3.77636  -0.980
## solar_rad_W_sqm_interpol   0.03489    0.01303   2.677
##
## Correlation of Fixed Effects:
##             (Intr) SVL_mm SMI    hmtcr_ VPD_P_
## SVL_mm      -0.840
## SMI         -0.555  0.223
## hmtcrt_prcn -0.124 -0.030 -0.245
## VPD_kPa_int  0.041  0.034  0.092 -0.154
## slr_rd_W_s_ -0.131 -0.069  0.020  0.000 -0.749
```

```
drop1(osml_mod5)
```

```
## Single term deletions
##
## Model:
## osmolality_mmol_kg_mean ~ SVL_mm + SMI + hematocrit_percent +
##     VPD_kPa_int + solar_rad_W_sqm_interpol + (1 | capture_date)
##                           npar    AIC
## <none>                         1022.4
## SVL_mm                       1 1023.5
## SMI                          1 1020.6
## hematocrit_percent           1 1020.5
## VPD_kPa_int                  1 1021.6
## solar_rad_W_sqm_interpol     1 1027.9
```

Drop hematocrit:

```
osml_mod6 <- lme4::lmer(data = dat,
                        # response variable
                        osmolality_mmol_kg_mean ~
                        # body size
                        SVL_mm + SMI +
                        # weather at the time of capture
                        VPD_kPa_int + solar_rad_W_sqm_interpol +
                        (1|capture_date))
summary(osml_mod6)
```

```
## Linear mixed model fit by REML ['lmerMod']
## Formula:
## osmolality_mmol_kg_mean ~ SVL_mm + SMI + VPD_kPa_int + solar_rad_W_sqm_interpol +
##     (1 | capture_date)
##    Data: dat
##
## REML criterion at convergence: 1002
##
## Scaled residuals:
##     Min      1Q  Median      3Q     Max
## -2.3426 -0.6858 -0.0985  0.6211  3.1839
##
## Random effects:
##  Groups       Name        Variance Std.Dev.
##  capture_date (Intercept) 284.0    16.85
##  Residual                 176.5    13.29
## Number of obs: 124, groups:  capture_date, 5
##
## Fixed effects:
##                            Estimate Std. Error t value
## (Intercept)              288.41208   33.87099   8.515
## SVL_mm                     0.67263    0.38616   1.742
## SMI                       -0.44051    1.22367  -0.360
## VPD_kPa_int               -3.60191    3.71759  -0.969
## solar_rad_W_sqm_interpol   0.03489    0.01298   2.687
##
## Correlation of Fixed Effects:
##             (Intr) SVL_mm SMI    VPD_P_
```

```
## SVL_mm      -0.851
## SMI         -0.609  0.223
## VPD_kPa_int  0.023  0.030  0.056
## slr_rd_W_s_ -0.132 -0.069  0.021 -0.758
```

```
drop1(osml_mod6)
```

```
## Single term deletions
##
## Model:
## osmolality_mmol_kg_mean ~ SVL_mm + SMI + VPD_kPa_int + solar_rad_W_sqm_interpol +
##     (1 | capture_date)
##                           npar    AIC
## <none>                         1020.5
## SVL_mm                     1 1021.5
## SMI                        1 1018.6
## VPD_kPa_int                1 1019.6
## solar_rad_W_sqm_interpol    1 1025.9
```

Drop SMI:

```
osml_mod7 <- lme4::lmer(data = dat,
                        # response variable
                        osmolality_mmol_kg_mean ~
                        # body size
                        SVL_mm +
                        # weather at the time of capture
                        VPD_kPa_int + solar_rad_W_sqm_interpol +
                        (1|capture_date))
summary(osml_mod7)
```

```
## Linear mixed model fit by REML ['lmerMod']
## Formula:
## osmolality_mmol_kg_mean ~ SVL_mm + VPD_kPa_int + solar_rad_W_sqm_interpol +
##     (1 | capture_date)
##    Data: dat
##
## REML criterion at convergence: 1004.4
##
## Scaled residuals:
##     Min      1Q  Median      3Q     Max
## -2.3370 -0.6953 -0.0963  0.6058  3.2280
##
## Random effects:
##  Groups       Name        Variance Std.Dev.
##  capture_date (Intercept) 282.0    16.79
##  Residual                 175.2    13.24
## Number of obs: 124, groups:  capture_date, 5
##
## Fixed effects:
##                            Estimate Std. Error t value
## (Intercept)              280.98723   26.77002  10.496
## SVL_mm                     0.70358    0.37510   1.876
## VPD_kPa_int               -3.52647    3.69840  -0.954
## solar_rad_W_sqm_interpol   0.03499    0.01293   2.705
##
```

```
## Correlation of Fixed Effects:
##             (Intr) SVL_mm VPD_P_
## SVL_mm      -0.925
## VPD_kPa_int  0.072  0.018
## slr_rd_W_s_ -0.151 -0.075 -0.761
```

```
drop1(osml_mod7)
```

```
## Single term deletions
##
## Model:
## osmolality_mmol_kg_mean ~ SVL_mm + VPD_kPa_int + solar_rad_W_sqm_interpol +
##     (1 | capture_date)
##                            npar    AIC
## <none>                          1018.6
## SVL_mm                        1 1020.1
## VPD_kPa_int                   1 1017.7
## solar_rad_W_sqm_interpol      1 1024.1
```

Drop VPD:

```
osml_mod8 <- lme4::lmer(data = dat,
                        # response variable
                        osmolality_mmol_kg_mean ~
                        # body size
                        SVL_mm +
                        # weather at the time of capture
                        solar_rad_W_sqm_interpol +
                        (1|capture_date))
summary(osml_mod8)
```

```
## Linear mixed model fit by REML ['lmerMod']
## Formula: osmolality_mmol_kg_mean ~ SVL_mm + solar_rad_W_sqm_interpol +
##     (1 | capture_date)
##    Data: dat
##
## REML criterion at convergence: 1009.7
##
## Scaled residuals:
##     Min      1Q  Median      3Q     Max
## -2.3259 -0.6885 -0.0971  0.5530  3.2419
##
## Random effects:
##  Groups       Name        Variance Std.Dev.
##  capture_date (Intercept) 288.1    16.97
##  Residual                 175.0    13.23
## Number of obs: 124, groups:  capture_date, 5
##
## Fixed effects:
##                            Estimate Std. Error t value
## (Intercept)              2.828e+02  2.671e+01  10.589
## SVL_mm                   7.103e-01  3.748e-01   1.895
## solar_rad_W_sqm_interpol 2.560e-02  8.387e-03   3.053
##
## Correlation of Fixed Effects:
##             (Intr) SVL_mm
```

```
## SVL_mm      -0.928
## slr_rd_W_s_ -0.148 -0.095
```

Drop SVL:

```
osml_mod9 <- lme4::lmer(data = dat,
                        # response variable
                        osmolality_mmol_kg_mean ~
                        # weather at the time of capture
                        solar_rad_W_sqm_interpol +
                        (1|capture_date))
summary(osml_mod9)
```

```
## Linear mixed model fit by REML ['lmerMod']
## Formula:
## osmolality_mmol_kg_mean ~ solar_rad_W_sqm_interpol + (1 | capture_date)
##    Data: dat
##
## REML criterion at convergence: 1013.2
##
## Scaled residuals:
##     Min      1Q  Median      3Q     Max
## -2.4085 -0.6875 -0.1434  0.5776  3.3124
##
## Random effects:
##  Groups       Name        Variance Std.Dev.
##  capture_date (Intercept) 277.1    16.65
##  Residual                 179.0    13.38
## Number of obs: 124, groups:  capture_date, 5
##
## Fixed effects:
##                            Estimate Std. Error t value
## (Intercept)              3.297e+02  9.915e+00  33.256
## solar_rad_W_sqm_interpol 2.712e-02  8.444e-03   3.212
##
## Correlation of Fixed Effects:
##             (Intr)
## slr_rd_W_s_ -0.648
```

Lastly, compute null model:

```
osml_mod_null <- lme4::lmer(data = dat,
                        osmolality_mmol_kg_mean ~ 1 +
                        (1|capture_date))
summary(osml_mod_null)
```

```
## Linear mixed model fit by REML ['lmerMod']
## Formula: osmolality_mmol_kg_mean ~ 1 + (1 | capture_date)
##    Data: dat
##
## REML criterion at convergence: 1127.8
##
## Scaled residuals:
##     Min      1Q  Median      3Q     Max
## -2.4072 -0.6642 -0.1005  0.5332  3.1645
##
```

```
## Random effects:
##  Groups       Name        Variance Std.Dev.
##  capture_date (Intercept) 262.1    16.19
##  Residual                 190.9    13.82
## Number of obs: 138, groups:  capture_date, 5
##
## Fixed effects:
##             Estimate Std. Error t value
## (Intercept)  350.168      7.338   47.72
```

Selection

Compare models 4-9 and null.

```
osml_models <- list(osml_mod4, osml_mod5, osml_mod6,
                    osml_mod7, osml_mod8, osml_mod9,
                    osml_mod_null)
#specify model names
osml_mod_names <- c('(model 4) ~ Solar-C, SVL, VPD-C, SMI, Hct, Wind-C',
                    '(model 5) ~ Solar-C, SVL, VPD-C, SMI, Hct',
                    '(model 6) ~ Solar-C, SVL, VPD-C, SMI',
                    '(model 7) ~ Solar-C, SVL, VPD-C',
                    '(model 8) ~ Solar-C, SVL',
                    '(model 9) ~ Solar-C',
                    'null model')
#calculate AIC of each model
osml_AICc <- data.frame(aictab(cand.set = osml_models,
                               modnames = osml_mod_names))
```

```
## Warning in aictab.AIClmerMod(cand.set = osml_models, modnames = osml_mod_names):
## Model selection for fixed effects is only appropriate with ML estimation:
## REML (default) should only be used to select random effects for a constant set of fixed effects
```

```
osml_AICc
```

```
##                                          Modnames K     AICc  Delta_AICc
## 3              (model 6) ~ Solar-C, SVL, VPD-C, SMI 7 1016.982   0.0000000
## 4                   (model 7) ~ Solar-C, SVL, VPD-C 6 1017.103   0.1204429
## 2         (model 5) ~ Solar-C, SVL, VPD-C, SMI, Hct 8 1020.225   3.2431270
## 5                           (model 8) ~ Solar-C, SVL 5 1020.255   3.2728106
## 1 (model 4) ~ Solar-C, SVL, VPD-C, SMI, Hct, Wind-C 9 1020.348   3.3662143
## 6                               (model 9) ~ Solar-C 4 1021.516   4.5333722
## 7                                        null model 3 1133.960 116.9777599
##       ModelLik       AICcWt    Res.LL    Cum.Wt
## 3 1.000000e+00 3.812029e-01 -501.0083 0.3812029
## 4 9.415560e-01 3.589239e-01 -502.1923 0.7401267
## 2 1.975895e-01 7.532170e-02 -501.4865 0.8154484
## 5 1.946786e-01 7.421204e-02 -504.8732 0.8896605
## 1 1.857958e-01 7.082589e-02 -500.3847 0.9604864
## 6 1.036551e-01 3.951363e-02 -506.5897 1.0000000
## 7 3.968279e-26 1.512719e-26 -563.8904 1.0000000
```

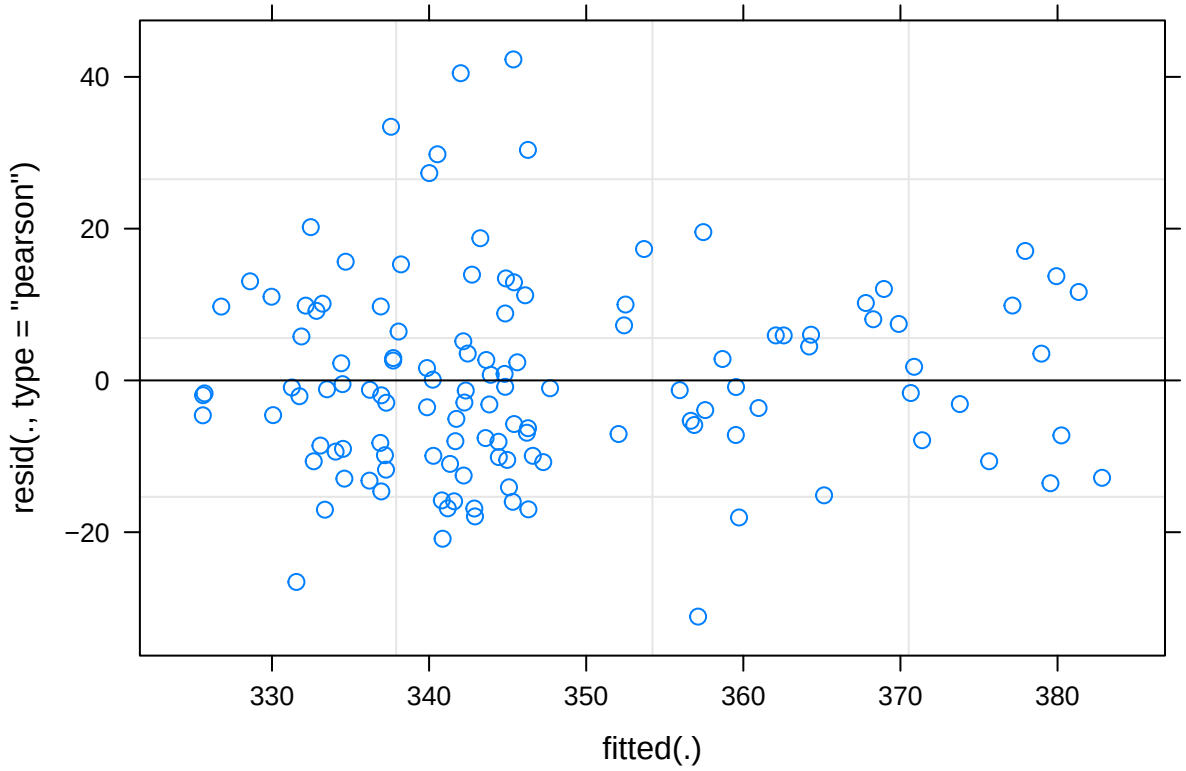
LM Conditions

Check residual plots and VIFs

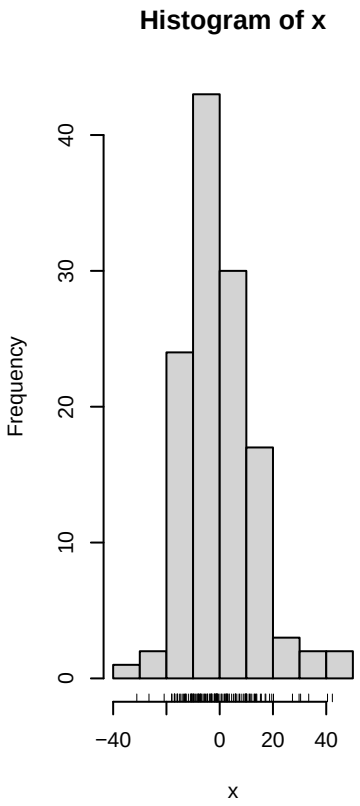
```
vif(osml_mod6)
```

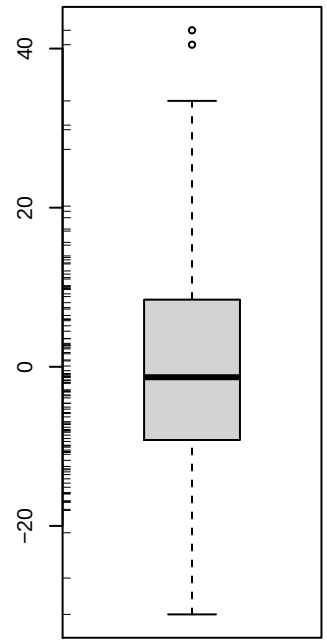
```
##                   SVL_mm                      SMI             VPD_kPa_int
##                 1.062154                 1.069446                2.391413
## solar_rad_W_sqm_interpol
##                 2.397751
```

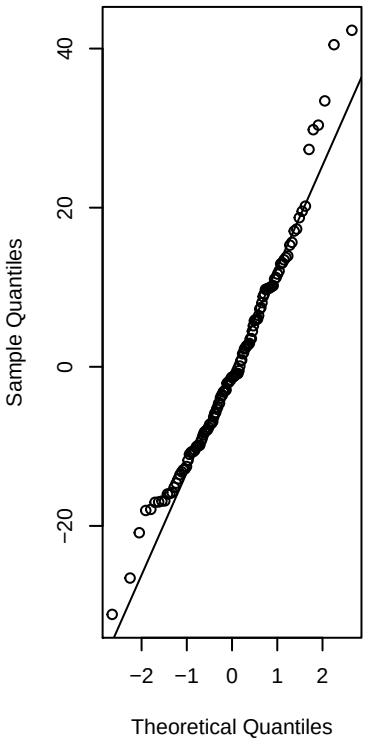
```
plot(osml_mod6)
```




```
simple.eda(residuals(osml_mod6))
```







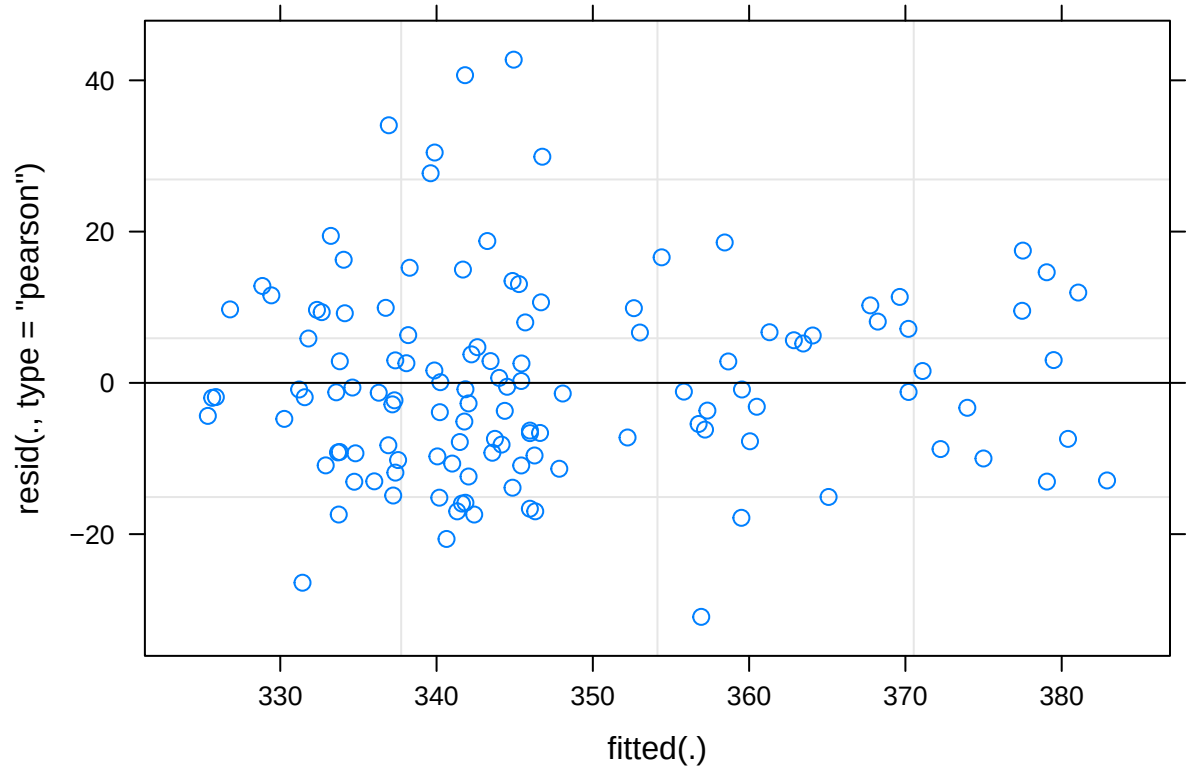

```
shapiro.test(residuals(osml_mod6))
```

```
##
##  Shapiro-Wilk normality test
##
## data:  residuals(osml_mod6)
## W = 0.96768, p-value = 0.004547
```

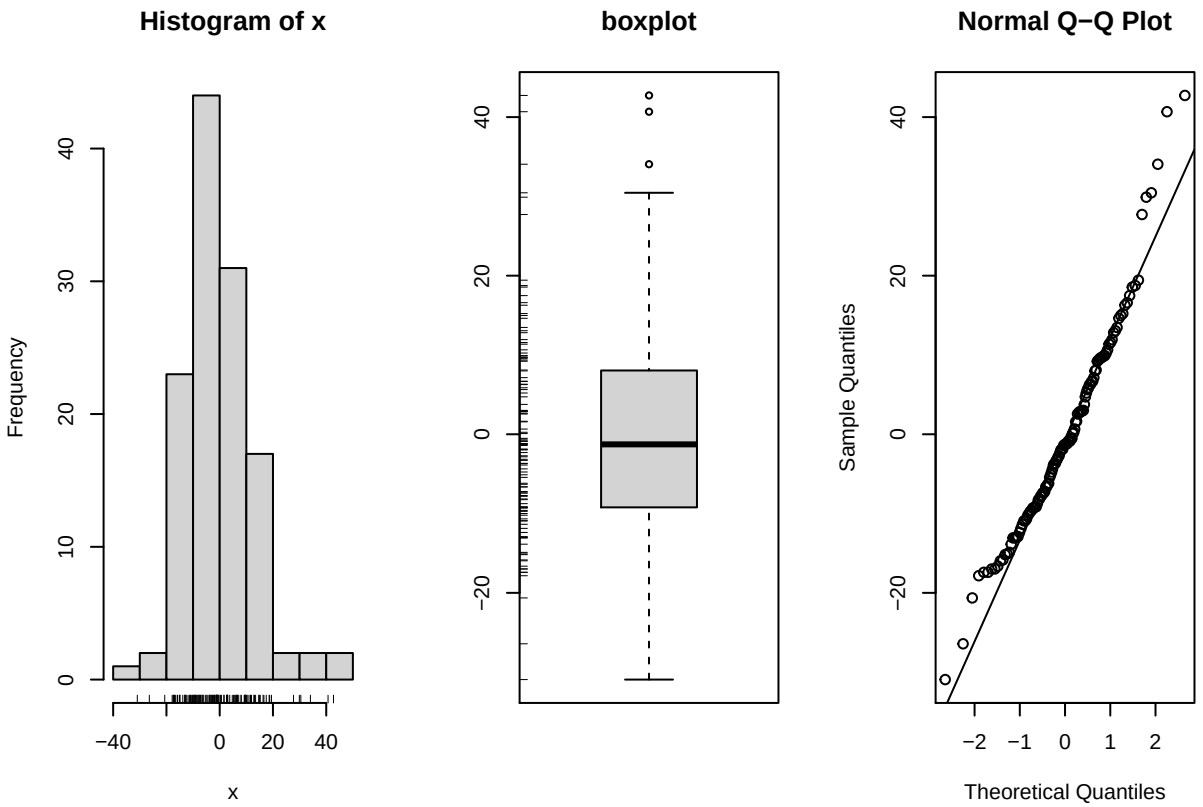
```
vif(osml_mod7)
```

```
##                   SVL_mm             VPD_kPa_int solar_rad_W_sqm_interpol
##                 1.009504                2.383988                 2.396868
```

```
plot(osml_mod7)
```




```
simple.eda(residuals(osml_mod7))
```



```
shapiro.test(residuals(osml_mod7))
```

```
##
##  Shapiro-Wilk normality test
##
## data:  residuals(osml_mod7)
## W = 0.96557, p-value = 0.002973
```

There is no clear pattern in the residuals ~ fitted plot, so linearity seems satisfied. slight fanning, but equal error variance seems fine. Normality seems fine, even though the Shapiro-Wilk normality test is significant. VIFs essentially negligible.

Export

First, re-run for p-values:

```
osml_mod6p <- lmerTest::lmer(data = dat,
                          # response variable
                          osmolality_mmol_kg_mean ~
                          # body size
                          SVL_mm + SMI +
                          # weather at the time of capture
                          VPD_kPa_int + solar_rad_W_sqm_interpol +
                          (1|capture_date))
summary(osml_mod6p)
```

```
## Linear mixed model fit by REML. t-tests use Satterthwaite's method [
## lmerModLmerTest]
## Formula:
## osmolality_mmol_kg_mean ~ SVL_mm + SMI + VPD_kPa_int + solar_rad_W_sqm_interpol +
##     (1 | capture_date)
##    Data: dat
##
## REML criterion at convergence: 1002
##
## Scaled residuals:
##     Min      1Q  Median      3Q     Max
## -2.3426 -0.6858 -0.0985  0.6211  3.1839
##
## Random effects:
##  Groups       Name        Variance Std.Dev.
##  capture_date (Intercept) 284.0    16.85
##  Residual                 176.5    13.29
## Number of obs: 124, groups:  capture_date, 5
##
## Fixed effects:
##                            Estimate Std. Error        df t value Pr(>|t|)
## (Intercept)              288.41208   33.87099 117.08658   8.515 6.54e-14 ***
## SVL_mm                     0.67263    0.38616 116.54146   1.742   0.0842 .
## SMI                       -0.44051    1.22367 115.79045  -0.360   0.7195
## VPD_kPa_int               -3.60191    3.71759  15.08255  -0.969   0.3479
## solar_rad_W_sqm_interpol   0.03489    0.01298  34.46638   2.687   0.0110 *
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
```

```
## Correlation of Fixed Effects:
##             (Intr) SVL_mm SMI    VPD_P_
## SVL_mm      -0.851
## SMI         -0.609  0.223
## VPD_kPa_int  0.023  0.030  0.056
## slr_rd_W_s_ -0.132 -0.069  0.021 -0.758
```

```
osml_mod7p <- lmerTest::lmer(data = dat,
                         # response variable
                         osmolality_mmol_kg_mean ~
                         # body size
                         SVL_mm +
                         # weather at the time of capture
                         VPD_kPa_int + solar_rad_W_sqm_interpol +
                         (1|capture_date))
summary(osml_mod7p)
```

```
## Linear mixed model fit by REML. t-tests use Satterthwaite's method [
## lmerModLmerTest]
## Formula:
## osmolality_mmol_kg_mean ~ SVL_mm + VPD_kPa_int + solar_rad_W_sqm_interpol +
##     (1 | capture_date)
##    Data: dat
##
## REML criterion at convergence: 1004.4
##
## Scaled residuals:
##     Min      1Q  Median      3Q     Max
## -2.3370 -0.6953 -0.0963  0.6058  3.2280
##
## Random effects:
##  Groups       Name        Variance Std.Dev.
##  capture_date (Intercept) 282.0    16.79
##  Residual                 175.2    13.24
## Number of obs: 124, groups:  capture_date, 5
##
## Fixed effects:
##                            Estimate Std. Error        df t value Pr(>|t|)
## (Intercept)              280.98723   26.77002 109.79196  10.496   <2e-16 ***
## SVL_mm                     0.70358    0.37510 117.63142   1.876   0.0632 .
## VPD_kPa_int               -3.52647    3.69840  14.98489  -0.954   0.3555
## solar_rad_W_sqm_interpol   0.03499    0.01293  34.53408   2.705   0.0105 *
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Correlation of Fixed Effects:
##             (Intr) SVL_mm VPD_P_
## SVL_mm      -0.925
## VPD_kPa_int  0.072  0.018
## slr_rd_W_s_ -0.151 -0.075 -0.761
```

Save the model output.

```
write.csv(broom.mixed::tidy(osml_mod6p),
          "./results_statistics/capture_osml_best_model1.csv")
write.csv(broom.mixed::tidy(osml_mod7p),
```

```
          "./results_statistics/capture_osml_best_model2.csv")
write.csv(osml_AICc, "./results_statistics/capture_osml_mod_rankings.csv")
```

To report in paper:

The best models to predict the variation in baseline plasma osmolality included SVL, SMI, VPD, and solar radiation at the time of capture as fixed effects. Date was included as a random effect. The final model had acceptable LM conditions. The full model included mass, SVL, SMI, 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.

I didn't calculate holding time!!!!!!!!!!!!!!!!!!!

Models

Start with the full model of all potential predictor variables. We will again include date as a random effect. Individual ID is not included as a random effect bc each lizard only has one set of capture observations.

When we have this many variables, it's extremely important to start with checking for multicollinearity.

```
CEWL_mod1 <- lme4::lmer(data = dat,
                        # 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 +
                        # microclimate at the time of msmt
                        msmt_temp_C + msmt_VPD_kPa +
                        # weather at the time of capture
                        temp_C_interpol * VPD_kPa_int +
                        wind_mph_interpol + solar_rad_W_sqm_interpol +
                        # time between capture and measurements
                        hold_time_hr +
                        (1|capture_date))
CEWL_mod1_VIFs <- data.frame(VIF = car::vif(CEWL_mod1)) %>%
  arrange(desc(VIF))
CEWL_mod1_VIFs
```

```
##                                    VIF
## VPD_kPa_int                 856.642445
## temp_C_interpol:VPD_kPa_int 272.795884
## temp_C_interpol             171.003017
## mass_g                      160.346694
## SVL_mm                      138.353857
## SMI                          69.684728
## msmt_VPD_kPa                 30.887901
## msmt_temp_C                  12.625546
## solar_rad_W_sqm_interpol      4.956034
## wind_mph_interpol             3.480824
```

```
## hold_time_hr                  1.961889
## hematocrit_percent            1.220159
## osmolality_mmol_kg_mean       1.179014
## cloacal_temp_C                1.152096
```

```
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 + msmt_temp_C + msmt_VPD_kPa + temp_C_interpol *
##     VPD_kPa_int + wind_mph_interpol + solar_rad_W_sqm_interpol +
##     hold_time_hr + (1 | capture_date)
##                              npar    AIC
## <none>                            653.45
## cloacal_temp_C                  1 651.49
## mass_g                          1 654.50
## SVL_mm                          1 654.36
## SMI                             1 654.13
## osmolality_mmol_kg_mean         1 663.51
## hematocrit_percent              1 651.54
## msmt_temp_C                     1 667.57
## msmt_VPD_kPa                    1 658.33
## wind_mph_interpol               1 658.51
## solar_rad_W_sqm_interpol        1 652.77
## hold_time_hr                    1 658.03
## temp_C_interpol:VPD_kPa_int     1 651.89
```

Just as for osmolality, VPD and temperature introduce a lot of collinearity. Start with dropping their interaction:

```
CEWL_mod2 <- lme4::lmer(data = dat,
                        # 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 +
                        # microclimate at the time of msmt
                        msmt_temp_C + msmt_VPD_kPa +
                        # weather at the time of capture
                        temp_C_interpol + VPD_kPa_int +
                        wind_mph_interpol + solar_rad_W_sqm_interpol +
                        # time between capture and measurements
                        hold_time_hr +
                        (1|capture_date))
CEWL_mod2_VIFs <- data.frame(VIF = car::vif(CEWL_mod2)) %>%
  arrange(desc(VIF))
CEWL_mod2_VIFs
```

```
##                                VIF
## mass_g                  160.075943
## SVL_mm                  138.388861
```

```
## SMI                         69.706986
## temp_C_interpol             34.379121
## VPD_kPa_int                 30.735088
## msmt_VPD_kPa                11.232713
## msmt_temp_C                  5.060439
## solar_rad_W_sqm_interpol     4.618568
## wind_mph_interpol            3.757447
## hold_time_hr                 1.738348
## hematocrit_percent           1.213102
## osmolality_mmol_kg_mean      1.182087
## cloacal_temp_C               1.151022
```

```
drop1(CEWL_mod2)
```

```
## Single term deletions
##
## Model:
## CEWL_g_m2h_mean ~ cloacal_temp_C + mass_g + SVL_mm + SMI + osmolality_mmol_kg_mean +
##     hematocrit_percent + msmt_temp_C + msmt_VPD_kPa + temp_C_interpol +
##     VPD_kPa_int + wind_mph_interpol + solar_rad_W_sqm_interpol +
##     hold_time_hr + (1 | capture_date)
##                            npar    AIC
## <none>                          651.89
## cloacal_temp_C                1 649.91
## mass_g                        1 652.94
## SVL_mm                        1 652.82
## SMI                           1 652.60
## osmolality_mmol_kg_mean       1 662.07
## hematocrit_percent            1 650.01
## msmt_temp_C                   1 677.25
## msmt_VPD_kPa                  1 661.94
## temp_C_interpol               1 658.23
## VPD_kPa_int                   1 660.20
## wind_mph_interpol             1 656.88
## solar_rad_W_sqm_interpol      1 651.88
## hold_time_hr                  1 656.12
```

MUCH better. Drop SVL next:

```
CEWL_mod3 <- lme4::lmer(data = dat,
                        # response variable
                        CEWL_g_m2h_mean ~
                        # essential covariate
                        cloacal_temp_C +
                        # body size
                        mass_g + SMI +
                        # blood
                        osmolality_mmol_kg_mean + hematocrit_percent +
                        # microclimate at the time of msmt
                        msmt_temp_C + msmt_VPD_kPa +
                        # weather at the time of capture
                        temp_C_interpol + VPD_kPa_int +
                        wind_mph_interpol + solar_rad_W_sqm_interpol +
                        # time between capture and measurements
                        hold_time_hr +
                        (1|capture_date))
```

```
CEWL_mod3_VIFs <- data.frame(VIF = car::vif(CEWL_mod3)) %>%
  arrange(desc(VIF))
CEWL_mod3_VIFs
```

```
##                                VIF
## temp_C_interpol          32.331655
## VPD_kPa_int              29.352386
## msmt_VPD_kPa             10.735526
## msmt_temp_C               5.021935
## solar_rad_W_sqm_interpol  4.459750
## wind_mph_interpol         3.641960
## hold_time_hr              1.716197
## SMI                       1.376741
## mass_g                    1.347833
## hematocrit_percent        1.212158
## osmolality_mmol_kg_mean   1.167705
## cloacal_temp_C            1.143432
```

```
drop1(CEWL_mod3)
```

```
## Single term deletions
##
## Model:
## CEWL_g_m2h_mean ~ cloacal_temp_C + mass_g + SMI + osmolality_mmol_kg_mean +
##     hematocrit_percent + msmt_temp_C + msmt_VPD_kPa + temp_C_interpol +
##     VPD_kPa_int + wind_mph_interpol + solar_rad_W_sqm_interpol +
##     hold_time_hr + (1 | capture_date)
##                           npar    AIC
## <none>                         652.82
## cloacal_temp_C               1 650.82
## mass_g                       1 651.04
## SMI                          1 650.93
## osmolality_mmol_kg_mean      1 663.97
## hematocrit_percent           1 650.93
## msmt_temp_C                  1 677.25
## msmt_VPD_kPa                 1 661.74
## temp_C_interpol              1 657.40
## VPD_kPa_int                  1 659.57
## wind_mph_interpol            1 657.23
## solar_rad_W_sqm_interpol     1 652.00
## hold_time_hr                 1 656.12
```

Next drop temperature at the time of capture:

```
CEWL_mod4 <- lme4::lmer(data = dat,
                        # response variable
                        CEWL_g_m2h_mean ~
                        # essential covariate
                        cloacal_temp_C +
                        # body size
                        mass_g + SMI +
                        # blood
                        osmolality_mmol_kg_mean + hematocrit_percent +
                        # microclimate at the time of msmt
                        msmt_temp_C + msmt_VPD_kPa +
```

```
                          # weather at the time of capture
                          VPD_kPa_int +
                          wind_mph_interpol + solar_rad_W_sqm_interpol +
                          # time between capture and measurements
                          hold_time_hr +
                          (1|capture_date))
CEWL_mod4_VIFs <- data.frame(VIF = car::vif(CEWL_mod4)) %>%
  arrange(desc(VIF))
CEWL_mod4_VIFs
```

```
##                               VIF
## msmt_VPD_kPa             8.374622
## VPD_kPa_int              4.949436
## msmt_temp_C              4.856765
## solar_rad_W_sqm_interpol 3.215116
## wind_mph_interpol        2.950819
## hold_time_hr             1.692077
## SMI                      1.363902
## mass_g                   1.342405
## hematocrit_percent       1.203612
## osmolality_mmol_kg_mean  1.150762
## cloacal_temp_C           1.108965
```

```
summary(CEWL_mod4)
```

```
## Linear mixed model fit by REML ['lmerMod']
## Formula:
## CEWL_g_m2h_mean ~ cloacal_temp_C + mass_g + SMI + osmolality_mmol_kg_mean +
##     hematocrit_percent + msmt_temp_C + msmt_VPD_kPa + VPD_kPa_int +
##     wind_mph_interpol + solar_rad_W_sqm_interpol + hold_time_hr +
##     (1 | capture_date)
##    Data: dat
##
## REML criterion at convergence: 644.8
##
## Scaled residuals:
##     Min      1Q  Median      3Q     Max
## -2.1622 -0.6141 -0.0049  0.4957  3.3967
##
## Random effects:
##  Groups       Name        Variance Std.Dev.
##  capture_date (Intercept) 4.956    2.226
##  Residual                 9.386    3.064
## Number of obs: 124, groups:  capture_date, 5
##
## Fixed effects:
##                            Estimate Std. Error t value
## (Intercept)              -1.663e+02  3.531e+01  -4.709
## cloacal_temp_C            1.330e-01  4.045e-01   0.329
## mass_g                   -1.465e-01  2.012e-01  -0.728
## SMI                      -1.918e-02  3.177e-01  -0.060
## osmolality_mmol_kg_mean   7.173e-02  2.080e-02   3.448
## hematocrit_percent        1.522e-02  5.822e-02   0.261
## msmt_temp_C               7.148e+00  1.501e+00   4.763
```

```
## msmt_VPD_kPa             -1.893e+01  6.283e+00  -3.012
## VPD_kPa_int              -1.576e+00  1.057e+00  -1.490
## wind_mph_interpol         8.408e-01  3.434e-01   2.449
## solar_rad_W_sqm_interpol  2.313e-03  3.463e-03   0.668
## hold_time_hr              6.129e-01  3.234e-01   1.895
##
## Correlation of Fixed Effects:
##             (Intr) clc__C mass_g SMI    osm___ hmtcr_ msm__C m_VPD_ VPD_P_
## clocl_tmp_C -0.309
## mass_g      -0.023  0.072
## SMI         -0.100 -0.063 -0.443
## osmllty_m__ -0.299  0.038 -0.125  0.117
## hmtcrt_prcn  0.027 -0.012 -0.021 -0.202 -0.019
## msmt_temp_C -0.899  0.043  0.016  0.022  0.095 -0.118
## msmt_VPD_kP  0.494 -0.176 -0.049  0.019 -0.057  0.232 -0.699
## VPD_kPa_int  0.126  0.024  0.011  0.037  0.028 -0.202  0.056 -0.526
## wnd_mph_ntr -0.329  0.193  0.048  0.008  0.110 -0.229  0.391 -0.624  0.035
## slr_rd_W_s_  0.352  0.024  0.002  0.015 -0.221  0.090 -0.505  0.588 -0.636
## hold_tim_hr  0.113  0.245  0.207 -0.085  0.063 -0.031 -0.155 -0.214  0.170
##             wnd_m_ s__W__
## clocl_tmp_C
## mass_g
## SMI
## osmllty_m__
## hmtcrt_prcn
## msmt_temp_C
## msmt_VPD_kP
## VPD_kPa_int
## wnd_mph_ntr
## slr_rd_W_s_ -0.174
## hold_tim_hr  0.413  0.067
```

```
drop1(CEWL_mod4)
```

```
## Single term deletions
##
## Model:
## CEWL_g_m2h_mean ~ cloacal_temp_C + mass_g + SMI + osmolality_mmol_kg_mean +
##     hematocrit_percent + msmt_temp_C + msmt_VPD_kPa + VPD_kPa_int +
##     wind_mph_interpol + solar_rad_W_sqm_interpol + hold_time_hr +
##     (1 | capture_date)
##                           npar    AIC
## <none>                         657.40
## cloacal_temp_C               1 655.48
## mass_g                       1 655.92
## SMI                          1 655.40
## osmolality_mmol_kg_mean      1 668.42
## hematocrit_percent           1 655.45
## msmt_temp_C                  1 678.51
## msmt_VPD_kPa                 1 665.68
## VPD_kPa_int                  1 657.64
## wind_mph_interpol            1 662.39
## solar_rad_W_sqm_interpol     1 655.71
## hold_time_hr                 1 659.19
```

Great, VIFs are minimal and we're ready to start backwards selection!

Start with dropping SMI:

```
CEWL_mod5 <- lme4::lmer(data = dat,
                        # response variable
                        CEWL_g_m2h_mean ~
                        # essential covariate
                        cloacal_temp_C +
                        # body size
                        mass_g +
                        # blood
                        osmolality_mmol_kg_mean + hematocrit_percent +
                        # microclimate at the time of msmt
                        msmt_temp_C + msmt_VPD_kPa +
                        # weather at the time of capture
                        VPD_kPa_int +
                        wind_mph_interpol + solar_rad_W_sqm_interpol +
                        # time between capture and measurements
                        hold_time_hr +
                        (1|capture_date))
summary(CEWL_mod5)
```

```
## Linear mixed model fit by REML ['lmerMod']
## Formula: CEWL_g_m2h_mean ~ cloacal_temp_C + mass_g + osmolality_mmol_kg_mean +
##     hematocrit_percent + msmt_temp_C + msmt_VPD_kPa + VPD_kPa_int +
##     wind_mph_interpol + solar_rad_W_sqm_interpol + hold_time_hr +
##     (1 | capture_date)
##    Data: dat
##
## REML criterion at convergence: 644.3
##
## Scaled residuals:
##     Min      1Q  Median      3Q     Max
## -2.1751 -0.6201 -0.0115  0.4975  3.4051
##
## Random effects:
##  Groups       Name        Variance Std.Dev.
##  capture_date (Intercept) 4.952    2.225
##  Residual                 9.302    3.050
## Number of obs: 124, groups:  capture_date, 5
##
## Fixed effects:
##                             Estimate Std. Error t value
## (Intercept)              -1.665e+02  3.499e+01  -4.758
## cloacal_temp_C            1.316e-01  4.019e-01   0.328
## mass_g                   -1.519e-01  1.795e-01  -0.846
## osmolality_mmol_kg_mean   7.186e-02  2.057e-02   3.493
## hematocrit_percent        1.453e-02  5.677e-02   0.256
## msmt_temp_C               7.148e+00  1.494e+00   4.784
## msmt_VPD_kPa             -1.891e+01  6.258e+00  -3.023
## VPD_kPa_int              -1.574e+00  1.052e+00  -1.496
## wind_mph_interpol         8.407e-01  3.420e-01   2.458
## solar_rad_W_sqm_interpol  2.321e-03  3.448e-03   0.673
## hold_time_hr              6.113e-01  3.208e-01   1.905
```

```
##
## Correlation of Fixed Effects:
##             (Intr) clc__C mass_g osm___ hmtcr_ msm__C m_VPD_ VPD_P_ wnd_m_
## clocl_tmp_C -0.318
## mass_g      -0.076  0.050
## osmllty_m__ -0.291  0.046 -0.082
## hmtcrt_prcn  0.007 -0.026 -0.126  0.005
## msmt_temp_C -0.902  0.045  0.029  0.093 -0.116
## msmt_VPD_kP  0.499 -0.175 -0.045 -0.060  0.241 -0.700
## VPD_kPa_int  0.131  0.026  0.030  0.024 -0.198  0.055 -0.526
## wnd_mph_ntr -0.329  0.194  0.058  0.110 -0.232  0.390 -0.624  0.034
## slr_rd_W_s_  0.355  0.025  0.009 -0.225  0.095 -0.505  0.587 -0.637 -0.173
## hold_tim_hr  0.105  0.241  0.189  0.074 -0.050 -0.153 -0.213  0.173  0.415
##             s__W__
## clocl_tmp_C
## mass_g
## osmllty_m__
## hmtcrt_prcn
## msmt_temp_C
## msmt_VPD_kP
## VPD_kPa_int
## wnd_mph_ntr
## slr_rd_W_s_
## hold_tim_hr  0.069
```

```
drop1(CEWL_mod5)
```

```
## Single term deletions
##
## Model:
## CEWL_g_m2h_mean ~ cloacal_temp_C + mass_g + osmolality_mmol_kg_mean +
##     hematocrit_percent + msmt_temp_C + msmt_VPD_kPa + VPD_kPa_int +
##     wind_mph_interpol + solar_rad_W_sqm_interpol + hold_time_hr +
##     (1 | capture_date)
##                           npar    AIC
## <none>                         655.40
## cloacal_temp_C               1 653.49
## mass_g                       1 654.11
## osmolality_mmol_kg_mean      1 666.64
## hematocrit_percent           1 653.45
## msmt_temp_C                  1 676.54
## msmt_VPD_kPa                 1 663.68
## VPD_kPa_int                  1 655.64
## wind_mph_interpol            1 660.40
## solar_rad_W_sqm_interpol     1 653.72
## hold_time_hr                 1 657.19
```

next drop cloacal temperature (What?!):

```
CEWL_mod6 <- lme4::lmer(data = dat,
                        # response variable
                        CEWL_g_m2h_mean ~
                        # body size
                        mass_g +
                        # blood
                        osmolality_mmol_kg_mean + hematocrit_percent +
```

```
                          # microclimate at the time of msmt
                          msmt_temp_C + msmt_VPD_kPa +
                          # weather at the time of capture
                          VPD_kPa_int +
                          wind_mph_interpol + solar_rad_W_sqm_interpol +
                          # time between capture and measurements
                          hold_time_hr +
                          (1|capture_date))
summary(CEWL_mod6)
```

```
## Linear mixed model fit by REML ['lmerMod']
## Formula:
## CEWL_g_m2h_mean ~ mass_g + osmolality_mmol_kg_mean + hematocrit_percent +
##     msmt_temp_C + msmt_VPD_kPa + VPD_kPa_int + wind_mph_interpol +
##     solar_rad_W_sqm_interpol + hold_time_hr + (1 | capture_date)
##    Data: dat
##
## REML criterion at convergence: 644.4
##
## Scaled residuals:
##     Min      1Q  Median      3Q     Max
## -2.1956 -0.6066 -0.0044  0.5205  3.4154
##
## Random effects:
##  Groups       Name        Variance Std.Dev.
##  capture_date (Intercept) 4.863    2.205
##  Residual                 9.231    3.038
## Number of obs: 124, groups:  capture_date, 5
##
## Fixed effects:
##                             Estimate Std. Error t value
## (Intercept)              -1.629e+02  3.303e+01  -4.931
## mass_g                   -1.547e-01  1.786e-01  -0.866
## osmolality_mmol_kg_mean   7.158e-02  2.047e-02   3.497
## hematocrit_percent        1.498e-02  5.653e-02   0.265
## msmt_temp_C               7.129e+00  1.486e+00   4.796
## msmt_VPD_kPa             -1.857e+01  6.133e+00  -3.027
## VPD_kPa_int              -1.582e+00  1.047e+00  -1.511
## wind_mph_interpol         8.193e-01  3.340e-01   2.453
## solar_rad_W_sqm_interpol  2.287e-03  3.433e-03   0.666
## hold_time_hr              5.858e-01  3.101e-01   1.889
##
## Correlation of Fixed Effects:
##             (Intr) mass_g osm___ hmtcr_ msm__C m_VPD_ VPD_P_ wnd_m_ s__W__
## mass_g      -0.064
## osmllty_m__ -0.292 -0.084
## hmtcrt_prcn -0.001 -0.125  0.007
## msmt_temp_C -0.937  0.026  0.091 -0.115
## msmt_VPD_kP  0.475 -0.037 -0.053  0.240 -0.703
## VPD_kPa_int  0.147  0.029  0.023 -0.198  0.055 -0.531
## wnd_mph_ntr -0.288  0.049  0.103 -0.231  0.390 -0.611  0.030
## slr_rd_W_s_  0.383  0.008 -0.226  0.096 -0.507  0.601 -0.638 -0.182
## hold_tim_hr  0.198  0.183  0.065 -0.045 -0.169 -0.179  0.172  0.387  0.065
```

```
drop1(CEWL_mod6)
```

```
## Single term deletions
##
## Model:
## CEWL_g_m2h_mean ~ mass_g + osmolality_mmol_kg_mean + hematocrit_percent +
##     msmt_temp_C + msmt_VPD_kPa + VPD_kPa_int + wind_mph_interpol +
##     solar_rad_W_sqm_interpol + hold_time_hr + (1 | capture_date)
##                           npar    AIC
## <none>                         653.49
## mass_g                     1 652.21
## osmolality_mmol_kg_mean    1 664.67
## hematocrit_percent         1 651.54
## msmt_temp_C                1 674.57
## msmt_VPD_kPa               1 661.72
## VPD_kPa_int                1 653.73
## wind_mph_interpol          1 658.45
## solar_rad_W_sqm_interpol   1 651.79
## hold_time_hr               1 655.24
```

next drop hematocrit:

```
CEWL_mod7 <- lme4::lmer(data = dat,
                        # response variable
                        CEWL_g_m2h_mean ~
                        # body size
                        mass_g +
                        # blood
                        osmolality_mmol_kg_mean +
                        # microclimate at the time of msmt
                        msmt_temp_C + msmt_VPD_kPa +
                        # weather at the time of capture
                        VPD_kPa_int +
                        wind_mph_interpol + solar_rad_W_sqm_interpol +
                        # time between capture and measurements
                        hold_time_hr +
                        (1|capture_date))
summary(CEWL_mod7)
```

```
## Linear mixed model fit by REML ['lmerMod']
## Formula: CEWL_g_m2h_mean ~ mass_g + osmolality_mmol_kg_mean + msmt_temp_C +
##     msmt_VPD_kPa + VPD_kPa_int + wind_mph_interpol + solar_rad_W_sqm_interpol +
##     hold_time_hr + (1 | capture_date)
##    Data: dat
##
## REML criterion at convergence: 640.6
##
## Scaled residuals:
##     Min      1Q  Median      3Q     Max
## -2.1691 -0.6099  0.0036  0.5315  3.4388
##
## Random effects:
##  Groups       Name        Variance Std.Dev.
##  capture_date (Intercept) 4.814    2.194
##  Residual                 9.157    3.026
```

```
## Number of obs: 124, groups:  capture_date, 5
##
## Fixed effects:
##                             Estimate Std. Error t value
## (Intercept)              -1.629e+02  3.290e+01  -4.952
## mass_g                   -1.488e-01  1.765e-01  -0.843
## osmolality_mmol_kg_mean   7.154e-02  2.038e-02   3.510
## msmt_temp_C               7.174e+00  1.470e+00   4.880
## msmt_VPD_kPa             -1.896e+01  5.929e+00  -3.198
## VPD_kPa_int              -1.527e+00  1.022e+00  -1.494
## wind_mph_interpol         8.399e-01  3.236e-01   2.596
## solar_rad_W_sqm_interpol  2.199e-03  3.403e-03   0.646
## hold_time_hr              5.895e-01  3.085e-01   1.911
##
## Correlation of Fixed Effects:
##             (Intr) mass_g osm___ msm__C m_VPD_ VPD_P_ wnd_m_ s__W__
## mass_g      -0.064
## osmllty_m__ -0.292 -0.084
## msmt_temp_C -0.944  0.012  0.092
## msmt_VPD_kP  0.489 -0.007 -0.056 -0.700
## VPD_kPa_int  0.149  0.004  0.025  0.033 -0.509
## wnd_mph_ntr -0.297  0.021  0.108  0.376 -0.588 -0.017
## slr_rd_W_s_  0.385  0.020 -0.228 -0.502  0.599 -0.634 -0.165
## hold_tim_hr  0.198  0.179  0.065 -0.176 -0.173  0.167  0.387  0.069
```

```
drop1(CEWL_mod7)
```

```
## Single term deletions
##
## Model:
## CEWL_g_m2h_mean ~ mass_g + osmolality_mmol_kg_mean + msmt_temp_C +
##     msmt_VPD_kPa + VPD_kPa_int + wind_mph_interpol + solar_rad_W_sqm_interpol +
##     hold_time_hr + (1 | capture_date)
##                           npar    AIC
## <none>                         651.54
## mass_g                     1 650.23
## osmolality_mmol_kg_mean    1 662.72
## msmt_temp_C                1 673.17
## msmt_VPD_kPa               1 660.75
## VPD_kPa_int                1 651.74
## wind_mph_interpol          1 657.21
## solar_rad_W_sqm_interpol   1 649.82
## hold_time_hr               1 653.34
```

next drop solar radiation:

```
CEWL_mod8 <- lme4::lmer(data = dat,
                        # response variable
                        CEWL_g_m2h_mean ~
                        # body size
                        mass_g +
                        # blood
                        osmolality_mmol_kg_mean +
                        # microclimate at the time of msmt
                        msmt_temp_C + msmt_VPD_kPa +
                        # weather at the time of capture
```

```
                          VPD_kPa_int +
                          wind_mph_interpol +
                          # time between capture and measurements
                          hold_time_hr +
                          (1|capture_date))
summary(CEWL_mod8)
```

```
## Linear mixed model fit by REML ['lmerMod']
## Formula: CEWL_g_m2h_mean ~ mass_g + osmolality_mmol_kg_mean + msmt_temp_C +
##     msmt_VPD_kPa + VPD_kPa_int + wind_mph_interpol + hold_time_hr +
##     (1 | capture_date)
##    Data: dat
##
## REML criterion at convergence: 631.5
##
## Scaled residuals:
##     Min      1Q  Median      3Q     Max
## -2.1289 -0.6630  0.0006  0.5170  3.4722
##
## Random effects:
##  Groups       Name        Variance Std.Dev.
##  capture_date (Intercept) 4.368    2.090
##  Residual                 9.129    3.021
## Number of obs: 124, groups:  capture_date, 5
##
## Fixed effects:
##                            Estimate Std. Error t value
## (Intercept)             -171.43335   30.15878  -5.684
## mass_g                    -0.15039    0.17619  -0.854
## osmolality_mmol_kg_mean    0.07461    0.01977   3.773
## msmt_temp_C                7.66653    1.25869   6.091
## msmt_VPD_kPa             -21.30228    4.66496  -4.566
## VPD_kPa_int               -1.10894    0.78696  -1.409
## wind_mph_interpol          0.87805    0.31656   2.774
## hold_time_hr               0.57564    0.30695   1.875
##
## Correlation of Fixed Effects:
##             (Intr) mass_g osm___ msm__C m_VPD_ VPD_P_ wnd_m_
## mass_g      -0.079
## osmllty_m__ -0.228 -0.081
## msmt_temp_C -0.940  0.026 -0.026
## msmt_VPD_kP  0.343 -0.025  0.105 -0.571
## VPD_kPa_int  0.549  0.022 -0.161 -0.423 -0.221
## wnd_mph_ntr -0.259  0.024  0.079  0.346 -0.624 -0.160
## hold_tim_hr  0.186  0.178  0.085 -0.165 -0.270  0.275  0.403
```

```
drop1(CEWL_mod8)
```

```
## Single term deletions
##
## Model:
## CEWL_g_m2h_mean ~ mass_g + osmolality_mmol_kg_mean + msmt_temp_C +
##     msmt_VPD_kPa + VPD_kPa_int + wind_mph_interpol + hold_time_hr +
##     (1 | capture_date)
```

```
##                           npar    AIC
## <none>                         649.82
## mass_g                     1 648.51
## osmolality_mmol_kg_mean    1 662.57
## msmt_temp_C                1 674.36
## msmt_VPD_kPa               1 664.06
## VPD_kPa_int                1 650.01
## wind_mph_interpol          1 656.43
## hold_time_hr               1 651.50
```

next drop mass:

```
CEWL_mod9 <- lme4::lmer(data = dat,
                        # response variable
                        CEWL_g_m2h_mean ~
                        # blood
                        osmolality_mmol_kg_mean +
                        # microclimate at the time of msmt
                        msmt_temp_C + msmt_VPD_kPa +
                        # weather at the time of capture
                        VPD_kPa_int +
                        wind_mph_interpol +
                        # time between capture and measurements
                        hold_time_hr +
                        (1|capture_date))
summary(CEWL_mod9)
```

```
## Linear mixed model fit by REML ['lmerMod']
## Formula:
## CEWL_g_m2h_mean ~ osmolality_mmol_kg_mean + msmt_temp_C + msmt_VPD_kPa +
##     VPD_kPa_int + wind_mph_interpol + hold_time_hr + (1 | capture_date)
##    Data: dat
##
## REML criterion at convergence: 630.6
##
## Scaled residuals:
##     Min      1Q  Median      3Q     Max
## -2.1586 -0.6440  0.0060  0.5491  3.3550
##
## Random effects:
##  Groups       Name        Variance Std.Dev.
##  capture_date (Intercept) 4.231    2.057
##  Residual                 9.114    3.019
## Number of obs: 124, groups:  capture_date, 5
##
## Fixed effects:
##                            Estimate Std. Error t value
## (Intercept)             -173.58299   29.99067  -5.788
## osmolality_mmol_kg_mean    0.07327    0.01968   3.723
## msmt_temp_C                7.70005    1.25371   6.142
## msmt_VPD_kPa             -21.41767    4.63600  -4.620
## VPD_kPa_int               -1.09462    0.78545  -1.394
## wind_mph_interpol          0.88553    0.31553   2.807
## hold_time_hr               0.62206    0.30170   2.062
##
```

```
## Correlation of Fixed Effects:
##             (Intr) osm___ msm__C m_VPD_ VPD_P_ wnd_m_
## osmllty_m__ -0.237
## msmt_temp_C -0.941 -0.024
## msmt_VPD_kP  0.341  0.104 -0.568
## VPD_kPa_int  0.552 -0.161 -0.422 -0.225
## wnd_mph_ntr -0.259  0.083  0.347 -0.625 -0.161
## hold_tim_hr  0.204  0.102 -0.174 -0.270  0.276  0.405
```

```
drop1(CEWL_mod9)
```

```
## Single term deletions
##
## Model:
## CEWL_g_m2h_mean ~ osmolality_mmol_kg_mean + msmt_temp_C + msmt_VPD_kPa +
##     VPD_kPa_int + wind_mph_interpol + hold_time_hr + (1 | capture_date)
##                          npar    AIC
## <none>                        648.51
## osmolality_mmol_kg_mean    1 660.83
## msmt_temp_C                1 673.00
## msmt_VPD_kPa               1 662.83
## VPD_kPa_int                1 648.64
## wind_mph_interpol          1 655.26
## hold_time_hr               1 650.87
```

next drop VPD:

```
CEWL_mod10 <- lme4::lmer(data = dat,
                         # response variable
                         CEWL_g_m2h_mean ~
                         # blood
                         osmolality_mmol_kg_mean +
                         # microclimate at the time of msmt
                         msmt_temp_C + msmt_VPD_kPa +
                         # weather at the time of capture
                         wind_mph_interpol +
                         # time between capture and measurements
                         hold_time_hr +
                         (1|capture_date))
summary(CEWL_mod10)
```

```
## Linear mixed model fit by REML ['lmerMod']
## Formula:
## CEWL_g_m2h_mean ~ osmolality_mmol_kg_mean + msmt_temp_C + msmt_VPD_kPa +
##     wind_mph_interpol + hold_time_hr + (1 | capture_date)
##    Data: dat
##
## REML criterion at convergence: 633.8
##
## Scaled residuals:
##     Min      1Q  Median      3Q     Max
## -2.3031 -0.6815  0.0296  0.6037  3.2530
##
## Random effects:
##  Groups       Name        Variance Std.Dev.
##  capture_date (Intercept) 4.417    2.102
```

```
##  Residual                 9.179    3.030
## Number of obs: 124, groups:  capture_date, 5
##
## Fixed effects:
##                            Estimate Std. Error t value
## (Intercept)             -150.31800   25.12710  -5.982
## osmolality_mmol_kg_mean    0.06886    0.01951   3.529
## msmt_temp_C                6.95213    1.14343   6.080
## msmt_VPD_kPa             -22.82527    4.56608  -4.999
## wind_mph_interpol          0.81352    0.31334   2.596
## hold_time_hr               0.73782    0.29121   2.534
##
## Correlation of Fixed Effects:
##             (Intr) osm___ msm__C m_VPD_ wnd_m_
## osmllty_m__ -0.180
## msmt_temp_C -0.937 -0.103
## msmt_VPD_kP  0.572  0.071 -0.751
## wnd_mph_ntr -0.206  0.056  0.311 -0.684
## hold_tim_hr  0.065  0.153 -0.065 -0.223  0.474
```

```
# can't test drop1 bc of NA's
```

based on t-values, wind should be dropped next:

```
CEWL_mod11 <- lme4::lmer(data = dat,
                         # response variable
                         CEWL_g_m2h_mean ~
                         # blood
                         osmolality_mmol_kg_mean +
                         # microclimate at the time of msmt
                         msmt_temp_C + msmt_VPD_kPa +
                         # time between capture and measurements
                         hold_time_hr +
                         (1|capture_date))
summary(CEWL_mod11)
```

```
## Linear mixed model fit by REML ['lmerMod']
## Formula:
## CEWL_g_m2h_mean ~ osmolality_mmol_kg_mean + msmt_temp_C + msmt_VPD_kPa +
##     hold_time_hr + (1 | capture_date)
##    Data: dat
##
## REML criterion at convergence: 639.7
##
## Scaled residuals:
##     Min      1Q  Median      3Q     Max
## -2.3700 -0.7378  0.0347  0.5964  3.2260
##
## Random effects:
##  Groups       Name        Variance Std.Dev.
##  capture_date (Intercept) 6.893    2.625
##  Residual                 9.510    3.084
## Number of obs: 124, groups:  capture_date, 5
##
## Fixed effects:
```

```
##                            Estimate Std. Error t value
## (Intercept)              -136.16631   25.49925  -5.340
## osmolality_mmol_kg_mean    0.06695    0.02004   3.341
## msmt_temp_C                5.96258    1.14748   5.196
## msmt_VPD_kPa             -14.35840    3.88834  -3.693
## hold_time_hr               0.38517    0.26150   1.473
##
## Correlation of Fixed Effects:
##             (Intr) osm___ msm__C m_VPD_
## osmllty_m__ -0.177
## msmt_temp_C -0.936 -0.115
## msmt_VPD_kP  0.598  0.118 -0.779
## hold_tim_hr  0.175  0.144 -0.229  0.110
```

drop hold time:

```
CEWL_mod11a <- lme4::lmer(data = dat,
                          # response variable
                          CEWL_g_m2h_mean ~
                          # blood
                          osmolality_mmol_kg_mean +
                          # microclimate at the time of msmt
                          msmt_temp_C + msmt_VPD_kPa +
                          (1|capture_date))
summary(CEWL_mod11a)
```

```
## Linear mixed model fit by REML ['lmerMod']
## Formula:
## CEWL_g_m2h_mean ~ osmolality_mmol_kg_mean + msmt_temp_C + msmt_VPD_kPa +
##     (1 | capture_date)
##    Data: dat
##
## REML criterion at convergence: 740.7
##
## Scaled residuals:
##     Min      1Q  Median      3Q     Max
## -2.0076 -0.6511 -0.0032  0.6792  3.4191
##
## Random effects:
##  Groups       Name        Variance Std.Dev.
##  capture_date (Intercept)  2.828   1.682
##  Residual                 12.064   3.473
## Number of obs: 138, groups:  capture_date, 5
##
## Fixed effects:
##                            Estimate Std. Error t value
## (Intercept)              -137.99713   26.31861  -5.243
## osmolality_mmol_kg_mean    0.05162    0.02061   2.505
## msmt_temp_C                6.44585    1.11981   5.756
## msmt_VPD_kPa             -16.51862    2.96126  -5.578
##
## Correlation of Fixed Effects:
##             (Intr) osm___ msm__C
## osmllty_m__ -0.195
## msmt_temp_C -0.944 -0.102
```

```
## msmt_VPD_kP  0.624  0.169 -0.783
```

drop osmolality:

```
CEWL_mod12 <- lme4::lmer(data = dat,
                         # response variable
                         CEWL_g_m2h_mean ~
                         # microclimate at the time of msmt
                         msmt_temp_C + msmt_VPD_kPa +
                         (1|capture_date))
summary(CEWL_mod12)
```

```
## Linear mixed model fit by REML ['lmerMod']
## Formula: CEWL_g_m2h_mean ~ msmt_temp_C + msmt_VPD_kPa + (1 | capture_date)
##    Data: dat
##
## REML criterion at convergence: 740.9
##
## Scaled residuals:
##     Min      1Q  Median      3Q     Max
## -2.1447 -0.6565 -0.0485  0.6256  3.3559
##
## Random effects:
##  Groups       Name        Variance Std.Dev.
##  capture_date (Intercept)  2.385   1.544
##  Residual                 12.581   3.547
## Number of obs: 138, groups:  capture_date, 5
##
## Fixed effects:
##              Estimate Std. Error t value
## (Intercept)  -125.832     26.094  -4.822
## msmt_temp_C     6.769      1.119   6.048
## msmt_VPD_kPa  -17.893      2.795  -6.401
##
## Correlation of Fixed Effects:
##             (Intr) msm__C
## msmt_temp_C -0.990
## msmt_VPD_kP  0.692 -0.786
```

```
drop1(CEWL_mod12)
```

```
## Single term deletions
##
## Model:
## CEWL_g_m2h_mean ~ msmt_temp_C + msmt_VPD_kPa + (1 | capture_date)
##              npar    AIC
## <none>            756.56
## msmt_temp_C     1 779.51
## msmt_VPD_kPa    1 768.96
```

drop VPD at the time of msmt:

```
CEWL_mod13 <- lme4::lmer(data = dat,
                         # response variable
                         CEWL_g_m2h_mean ~
                         # microclimate at the time of msmt
                         msmt_temp_C +
```

```
                          (1|capture_date))
summary(CEWL_mod13)
```

```
## Linear mixed model fit by REML ['lmerMod']
## Formula: CEWL_g_m2h_mean ~ msmt_temp_C + (1 | capture_date)
##    Data: dat
##
## REML criterion at convergence: 755.7
##
## Scaled residuals:
##     Min      1Q  Median      3Q     Max
## -2.1664 -0.6915 -0.0549  0.5410  3.2942
##
## Random effects:
##  Groups       Name        Variance Std.Dev.
##  capture_date (Intercept) 39.63    6.295
##  Residual                 12.55    3.543
## Number of obs: 138, groups:  capture_date, 5
##
## Fixed effects:
##             Estimate Std. Error t value
## (Intercept) -72.3114    22.5292  -3.210
## msmt_temp_C   3.4235     0.8222   4.164
##
## Correlation of Fixed Effects:
##             (Intr)
## msmt_temp_C -0.992
```

And finally, null model:

```
CEWL_mod_null <- lme4::lmer(data = dat,
                          # response variable
                          CEWL_g_m2h_mean ~ 1 +
                          (1|capture_date))
summary(CEWL_mod_null)
```

```
## Linear mixed model fit by REML ['lmerMod']
## Formula: CEWL_g_m2h_mean ~ 1 + (1 | capture_date)
##    Data: dat
##
## REML criterion at convergence: 772.6
##
## Scaled residuals:
##     Min      1Q  Median      3Q     Max
## -2.4713 -0.6736 -0.0596  0.7187  3.1910
##
## Random effects:
##  Groups       Name        Variance Std.Dev.
##  capture_date (Intercept) 19.32    4.396
##  Residual                 14.29    3.780
## Number of obs: 138, groups:  capture_date, 5
##
## Fixed effects:
##             Estimate Std. Error t value
## (Intercept)   20.746      1.993   10.41
```

Selection

compare models 4-13 and the null

```
CEWL_models <- list(CEWL_mod4, CEWL_mod5, CEWL_mod6, CEWL_mod7,
                    CEWL_mod8, CEWL_mod9, CEWL_mod10, CEWL_mod11, CEWL_mod11a,
                    CEWL_mod12, CEWL_mod13, CEWL_mod_null)

#specify model names
CEWL_mod_names <- c('(model 4) ~ Temp-M, VPD-M, Osml, Wind-C, VPD-C, Mass, Solar-C, Hct, Temp-Clo, SMI,
                    '(model 5) ~ Temp-M, VPD-M, Osml, Wind-C, VPD-C, Mass, Solar-C, Hct, Temp-Clo, Hold
                    '(model 6) ~ Temp-M, VPD-M, Osml, Wind-C, VPD-C, Mass, Solar-C, Hct, Hold',
                      '(model 7) ~ Temp-M, VPD-M, Osml, Wind-C, VPD-C, Mass, Solar-C, Hold',
                      '(model 8) ~ Temp-M, VPD-M, Osml, Wind-C, VPD-C, Mass, Hold',
                      '(model 9) ~ Temp-M, VPD-M, Osml, Wind-C, VPD-C, Hold',
                      '(model 10) ~ Temp-M, VPD-M, Osml, Wind-C, Hold',
                      '(model 11) ~ Temp-M, VPD-M, Osml, Hold',
                    '(model 11a) ~ Temp-M, VPD-M, Osml',
                     '(model 12) ~ Temp-M, VPD-M',
                     '(model 13) ~ Temp-M',
                     'null model')
#calculate AIC of each model
CEWL_AICc <- data.frame(aictab(cand.set = CEWL_models,
                               modnames = CEWL_mod_names))
```

```
## Warning in aictab.AIClmerMod(cand.set = CEWL_models, modnames = CEWL_mod_names):
## Model selection for fixed effects is only appropriate with ML estimation:
## REML (default) should only be used to select random effects for a constant set of fixed effects
```

```
CEWL_AICc
```

```
##                                                                                 Modnames
## 6                                    (model 9) ~ Temp-M, VPD-M, Osml, Wind-C, VPD-C, Hold
## 7                                         (model 10) ~ Temp-M, VPD-M, Osml, Wind-C, Hold
## 5                                (model 8) ~ Temp-M, VPD-M, Osml, Wind-C, VPD-C, Mass, Hold
## 8                                             (model 11) ~ Temp-M, VPD-M, Osml, Hold
## 4                       (model 7) ~ Temp-M, VPD-M, Osml, Wind-C, VPD-C, Mass, Solar-C, Hold
## 3                    (model 6) ~ Temp-M, VPD-M, Osml, Wind-C, VPD-C, Mass, Solar-C, Hct, Hold
## 2         (model 5) ~ Temp-M, VPD-M, Osml, Wind-C, VPD-C, Mass, Solar-C, Hct, Temp-Clo, Hold
## 1  (model 4) ~ Temp-M, VPD-M, Osml, Wind-C, VPD-C, Mass, Solar-C, Hct, Temp-Clo, SMI, Hold
## 10                                                                 (model 12) ~ Temp-M, VPD-M
## 9                                                        (model 11a) ~ Temp-M, VPD-M, Osml
## 11                                                                (model 13) ~ Temp-M
## 12                                                                          null model
##     K     AICc  Delta_AICc     ModelLik       AICcWt    Res.LL    Cum.Wt
## 6   9 650.1317   0.0000000 1.000000e+00 5.223517e-01 -315.2764 0.5223517
## 7   8 651.0968   0.9650419 6.172254e-01 3.224088e-01 -316.9223 0.8447604
## 5  10 653.4071   3.2753338 1.944331e-01 1.015625e-01 -315.7301 0.9463229
## 8   7 654.6950   4.5632966 1.021158e-01 5.334033e-02 -319.8648 0.9996633
## 4  11 664.9398  14.8080831 6.087873e-04 3.180011e-04 -320.2913 0.9999813
## 3  12 671.2351  21.1033836 2.614920e-05 1.365908e-05 -322.2122 0.9999949
## 2  13 673.6151  23.4834176 7.955009e-06 4.155312e-06 -322.1530 0.9999991
## 1  14 676.6154  26.4837148 1.774739e-06 9.270377e-07 -322.3811 1.0000000
## 10  5 751.3494 101.2176916 1.049198e-22 5.480505e-23 -370.4474 1.0000000
## 9   6 753.3335 103.2017320 3.890708e-23 2.032318e-23 -370.3461 1.0000000
## 11  4 764.0328 113.9010693 1.847979e-25 9.652950e-26 -377.8660 1.0000000
```

```
## 12  3 778.7422 128.6105011 1.181910e-28 6.173728e-29 -386.2816 1.0000000
```

The best two models are 9 & 10, which included Temp-M, VPD-M, Osml, Wind-C, VPD-C (not in 10), and Hold time.

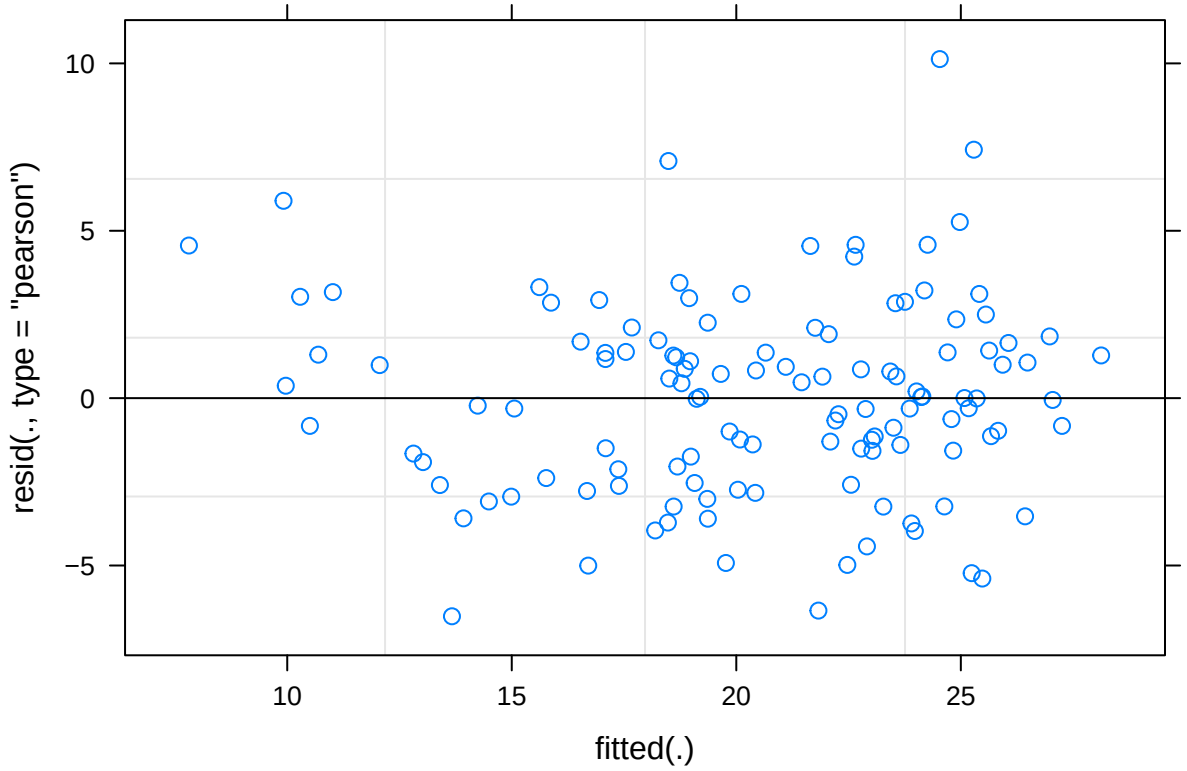
LM Conditions

Check that the best model meets the criteria for linear regression and has no collinearity.

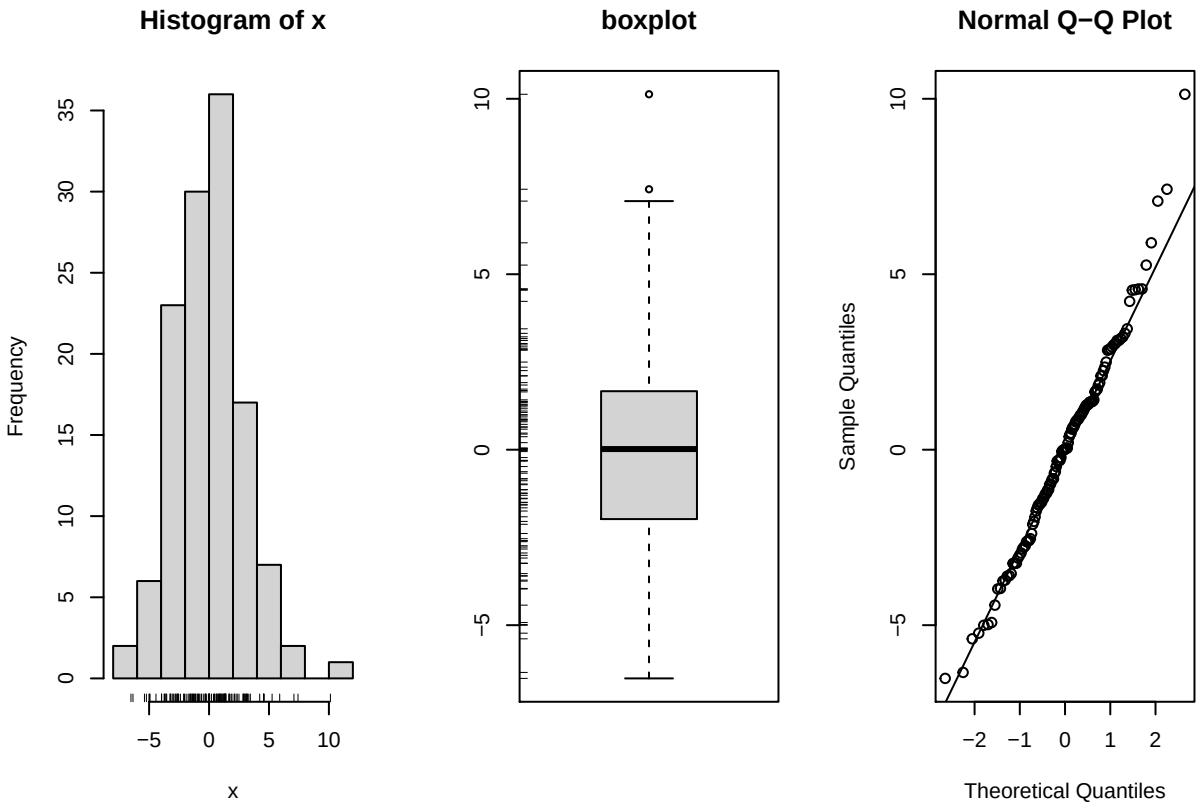
```
vif(CEWL_mod9)
```

```
## osmolality_mmol_kg_mean            msmt_temp_C            msmt_VPD_kPa
##                1.070914               3.562068               5.117716
##             VPD_kPa_int       wind_mph_interpol            hold_time_hr
##                2.957004               2.743307               1.520147
```

```
plot(CEWL_mod9)
```




```
simple.eda(residuals(CEWL_mod9))
```



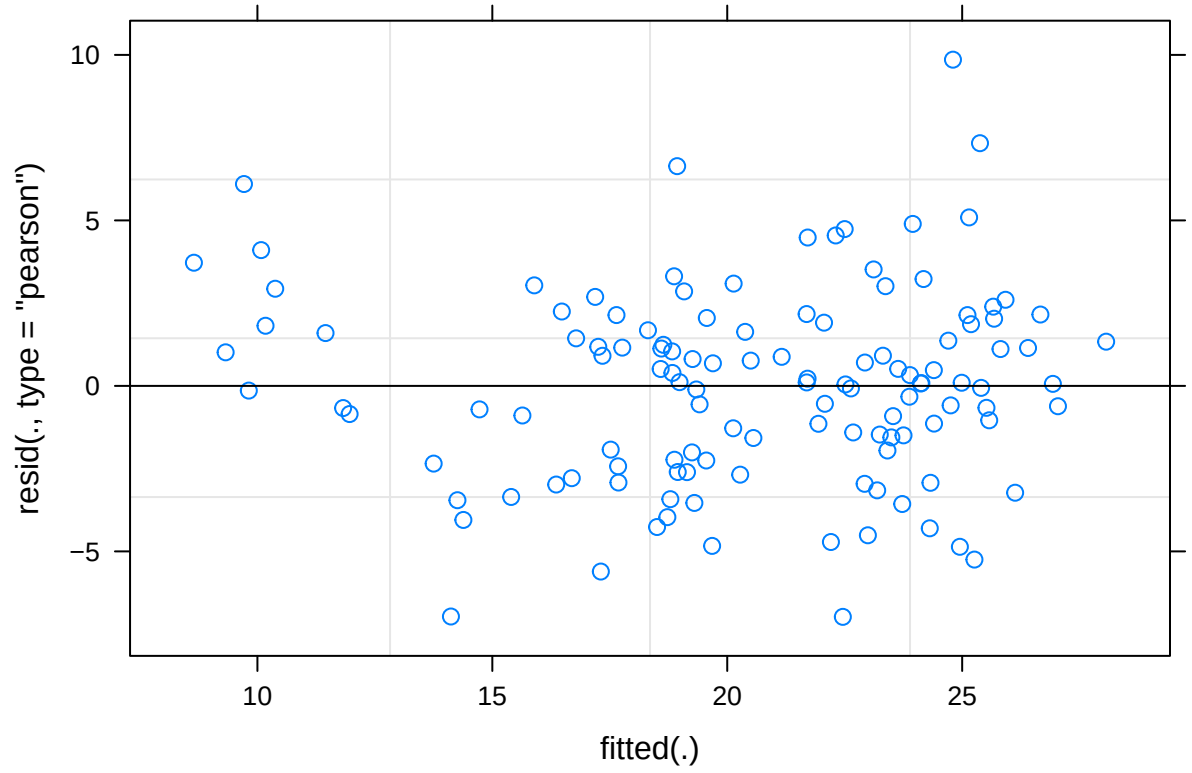

```
shapiro.test(residuals(CEWL_mod9))
```

```
##
##  Shapiro-Wilk normality test
##
## data:  residuals(CEWL_mod9)
## W = 0.98747, p-value = 0.315
```

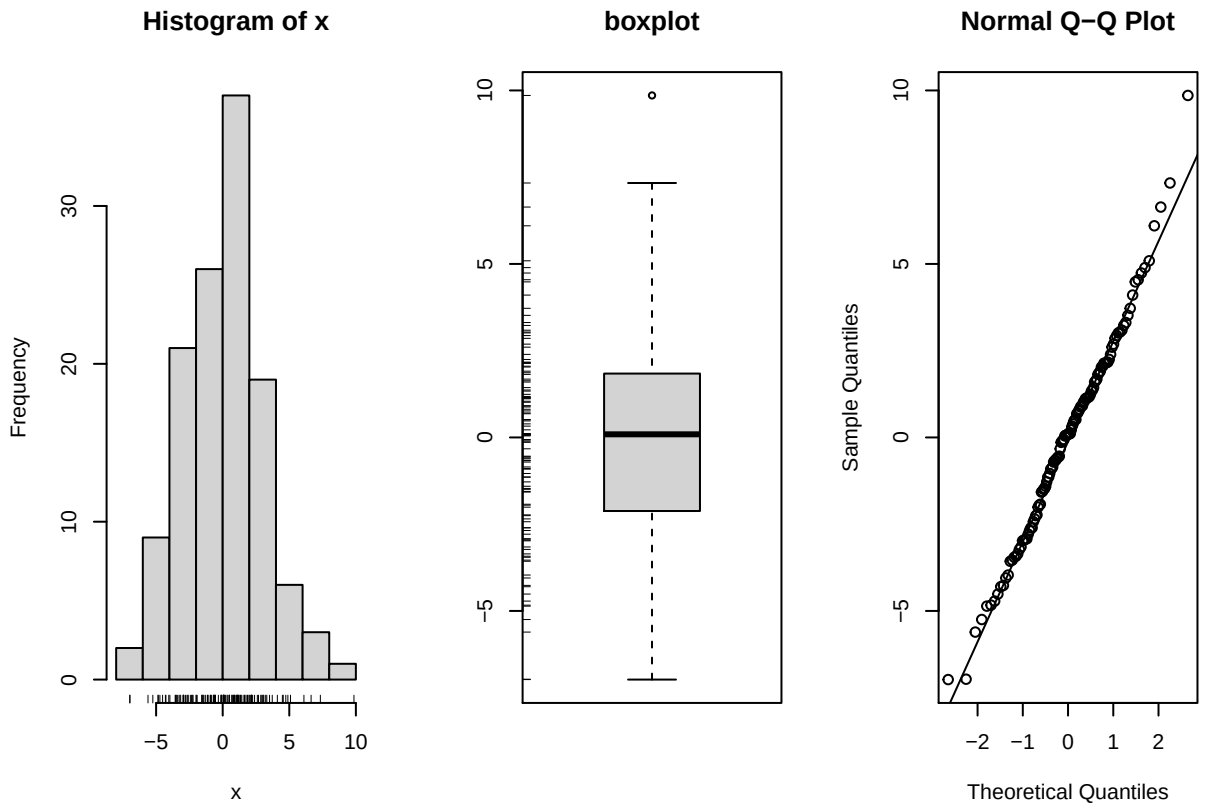
```
vif(CEWL_mod10)
```

```
## osmolality_mmol_kg_mean            msmt_temp_C            msmt_VPD_kPa
##                1.042362               2.924902                4.811710
##       wind_mph_interpol           hold_time_hr
##                2.636065               1.405275
```

```
plot(CEWL_mod10)
```




```
simple.eda(residuals(CEWL_mod10))
```



```
shapiro.test(residuals(CEWL_mod10))
```

```
##
##  Shapiro-Wilk normality test
##
## data:  residuals(CEWL_mod10)
## W = 0.99091, p-value = 0.594
```

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 and VIFs are very low.

Export

First, re-run the best model using lmerTest for p-values.

```
CEWL_mod9p <- lmerTest::lmer(data = dat,
                         # response variable
                         CEWL_g_m2h_mean ~
                         # blood
                         osmolality_mmol_kg_mean +
                         # microclimate at the time of msmt
                         msmt_temp_C + msmt_VPD_kPa +
                         # weather at the time of capture
                         VPD_kPa_int +
                         wind_mph_interpol + hold_time_hr +
                         (1|capture_date))
summary(CEWL_mod9p)
```

```
## Linear mixed model fit by REML. t-tests use Satterthwaite's method [
## lmerModLmerTest]
## Formula:
## CEWL_g_m2h_mean ~ osmolality_mmol_kg_mean + msmt_temp_C + msmt_VPD_kPa +
##     VPD_kPa_int + wind_mph_interpol + hold_time_hr + (1 | capture_date)
##    Data: dat
##
## REML criterion at convergence: 630.6
##
## Scaled residuals:
##     Min      1Q  Median      3Q     Max
## -2.1586 -0.6440  0.0060  0.5491  3.3550
##
## Random effects:
##  Groups       Name        Variance Std.Dev.
##  capture_date (Intercept) 4.231    2.057
##  Residual                 9.114    3.019
## Number of obs: 124, groups:  capture_date, 5
##
## Fixed effects:
##                            Estimate Std. Error         df t value Pr(>|t|)
## (Intercept)             -173.58299   29.99067   85.43506  -5.788 1.15e-07 ***
## osmolality_mmol_kg_mean    0.07327    0.01968  113.48079   3.723 0.000308 ***
## msmt_temp_C                7.70005    1.25371   51.02494   6.142 1.23e-07 ***
## msmt_VPD_kPa             -21.41767    4.63600   19.93145  -4.620 0.000167 ***
## VPD_kPa_int               -1.09462    0.78545  110.73114  -1.394 0.166224
## wind_mph_interpol          0.88553    0.31553   66.73483   2.807 0.006558 **
```

```
## hold_time_hr               0.62206    0.30170  116.90288   2.062 0.041437 *
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Correlation of Fixed Effects:
##             (Intr) osm___ msm__C m_VPD_ VPD_P_ wnd_m_
## osmllty_m__ -0.237
## msmt_temp_C -0.941 -0.024
## msmt_VPD_kP  0.341  0.104 -0.568
## VPD_kPa_int  0.552 -0.161 -0.422 -0.225
## wnd_mph_ntr -0.259  0.083  0.347 -0.625 -0.161
## hold_tim_hr  0.204  0.102 -0.174 -0.270  0.276  0.405
```

```
CEWL_mod10p <- lmerTest::lmer(data = dat,
                          # response variable
                          CEWL_g_m2h_mean ~
                          # blood
                          osmolality_mmol_kg_mean +
                          # microclimate at the time of msmt
                          msmt_temp_C + msmt_VPD_kPa +
                          # weather at the time of capture
                          wind_mph_interpol + hold_time_hr +
                          (1|capture_date))
summary(CEWL_mod10p)
```

```
## Linear mixed model fit by REML. t-tests use Satterthwaite's method [
## lmerModLmerTest]
## Formula:
## CEWL_g_m2h_mean ~ osmolality_mmol_kg_mean + msmt_temp_C + msmt_VPD_kPa +
##     wind_mph_interpol + hold_time_hr + (1 | capture_date)
##    Data: dat
##
## REML criterion at convergence: 633.8
##
## Scaled residuals:
##     Min      1Q  Median      3Q     Max
## -2.3031 -0.6815  0.0296  0.6037  3.2530
##
## Random effects:
##  Groups       Name        Variance Std.Dev.
##  capture_date (Intercept) 4.417    2.102
##  Residual                 9.179    3.030
## Number of obs: 124, groups:  capture_date, 5
##
## Fixed effects:
##                            Estimate Std. Error         df t value Pr(>|t|)
## (Intercept)             -150.31800   25.12710  106.33080  -5.982 3.00e-08 ***
## osmolality_mmol_kg_mean    0.06886    0.01951  112.56853   3.529 0.000605 ***
## msmt_temp_C                6.95213    1.14343   68.01507   6.080 6.15e-08 ***
## msmt_VPD_kPa             -22.82527    4.56608   14.34413  -4.999 0.000181 ***
## wind_mph_interpol          0.81352    0.31334   67.59866   2.596 0.011553 *
## hold_time_hr               0.73782    0.29121  117.56630   2.534 0.012605 *
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
```

```
## Correlation of Fixed Effects:
##             (Intr) osm___ msm__C m_VPD_ wnd_m_
## osmllty_m__ -0.180
## msmt_temp_C -0.937 -0.103
## msmt_VPD_kP  0.572  0.071 -0.751
## wnd_mph_ntr -0.206  0.056  0.311 -0.684
## hold_tim_hr  0.065  0.153 -0.065 -0.223  0.474
```

Save the best CEWL model output.

```
write.csv(broom.mixed::tidy(CEWL_mod9p),
          "./results_statistics/capture_CEWL_best_model1.csv")
write.csv(broom.mixed::tidy(CEWL_mod10p),
          "./results_statistics/capture_CEWL_best_model2.csv")
write.csv(CEWL_AICc,
          "./results_statistics/capture_CEWL_mod_rankings.csv")
```

To report in paper:

The best model to predict CEWL included plasma osmolality, temperature and VPD at the time of measurement, and VPD and wind at the time of capture. The final model met all linear regression conditions for linearity, normality, and equal error variance, and there was no multicollinearity.

Pub Figures

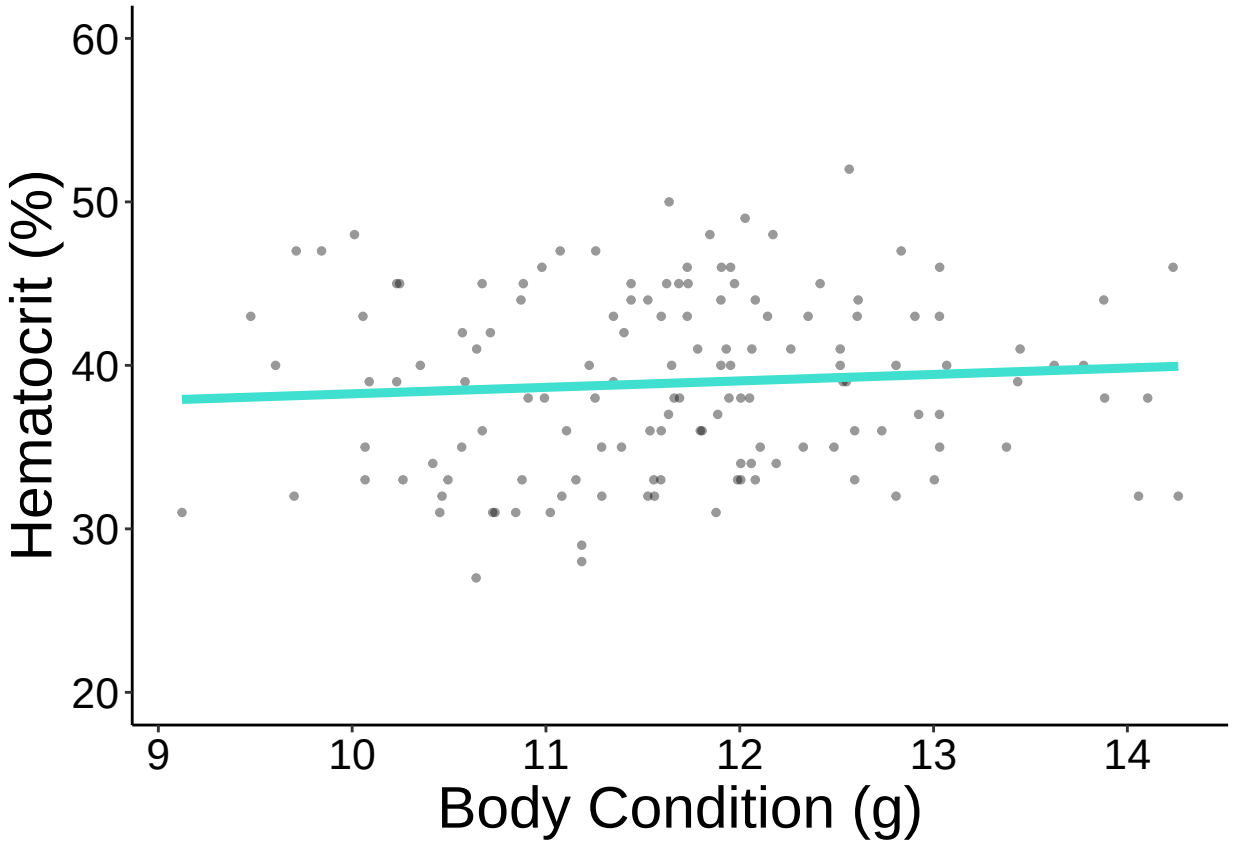
Custom Colors

```
lizard_color = "turquoise"
VPD_color = "blue"
temp_color = "gray"
solar_color = "orange"
wind_color = "orange"
date_color = "gray"
osml_color  <- c(brewer.pal(6, "Set2")[c(2)])
```

Hct ~ SMI

```
ggplot(dat) +
  aes(x = SMI,
      y = hematocrit_percent) +
  geom_point(size = 1,
             alpha = 0.4) +
  stat_smooth(formula = y ~ x,
              method = "lm",
              se = F,
              size = 1.6,
              color = lizard_color,
              alpha = 1) +
  theme_classic() +
  xlab("Body Condition (g)") +
  ylab("Hematocrit (%)") +
  #ylab("") +
  #xlim() +
  ylim(20,60) +
```

```
  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_hct_SMI_fig
cap_hct_SMI_fig
```



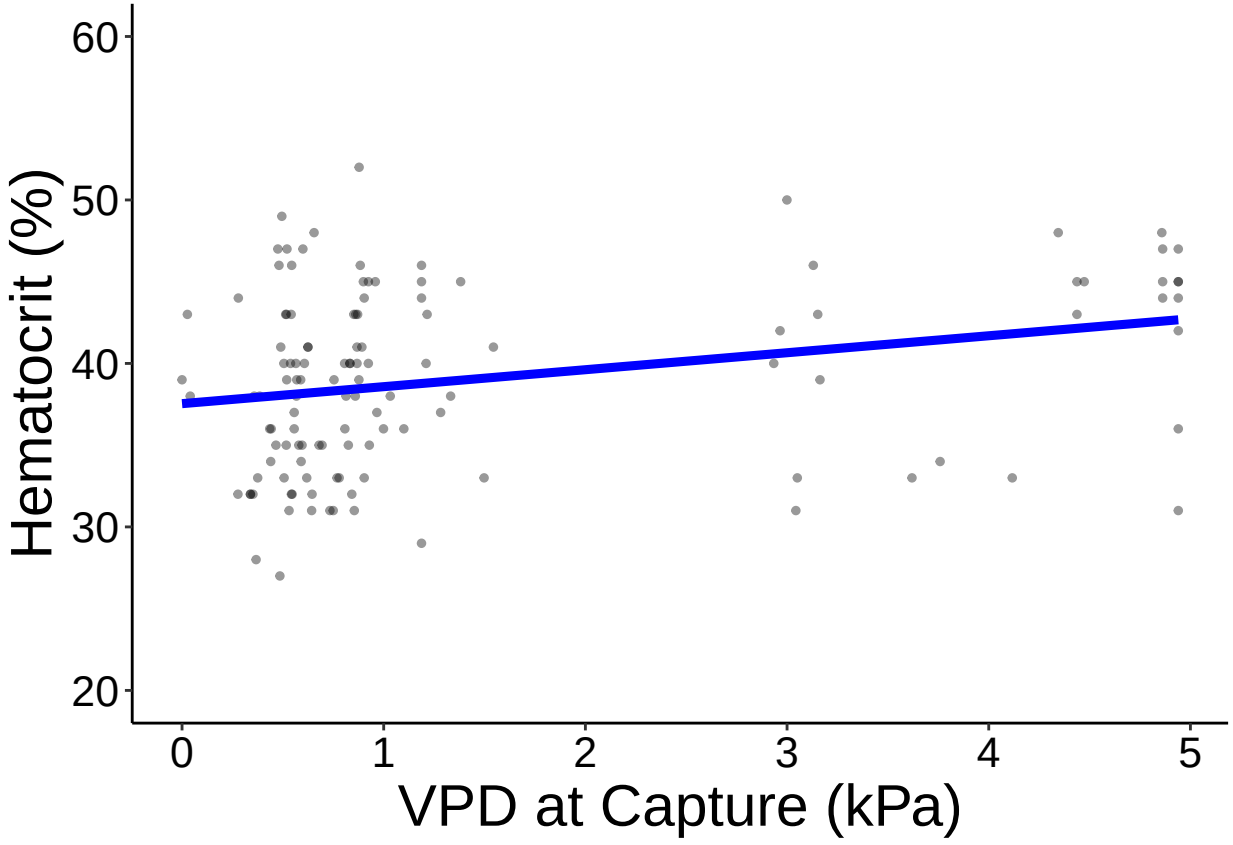
Hct ~ VPD at Capture

```
ggplot(dat) +
  aes(x = VPD_kPa_int,
      y = hematocrit_percent) +
  geom_point(size = 1,
             alpha = 0.4) +
  stat_smooth(formula = y ~ x,
              method = "lm",
              se = F,
              color = VPD_color,
              size = 1.6,
              alpha = 1 ) +
  theme_classic() +
  xlab("VPD at Capture (kPa)") +
```

```
  ylab("Hematocrit (%)") +
  #ylab("") +
  #xlim() +
  ylim(20,60) +
  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_hct_VPD_fig
cap_hct_VPD_fig
```

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

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



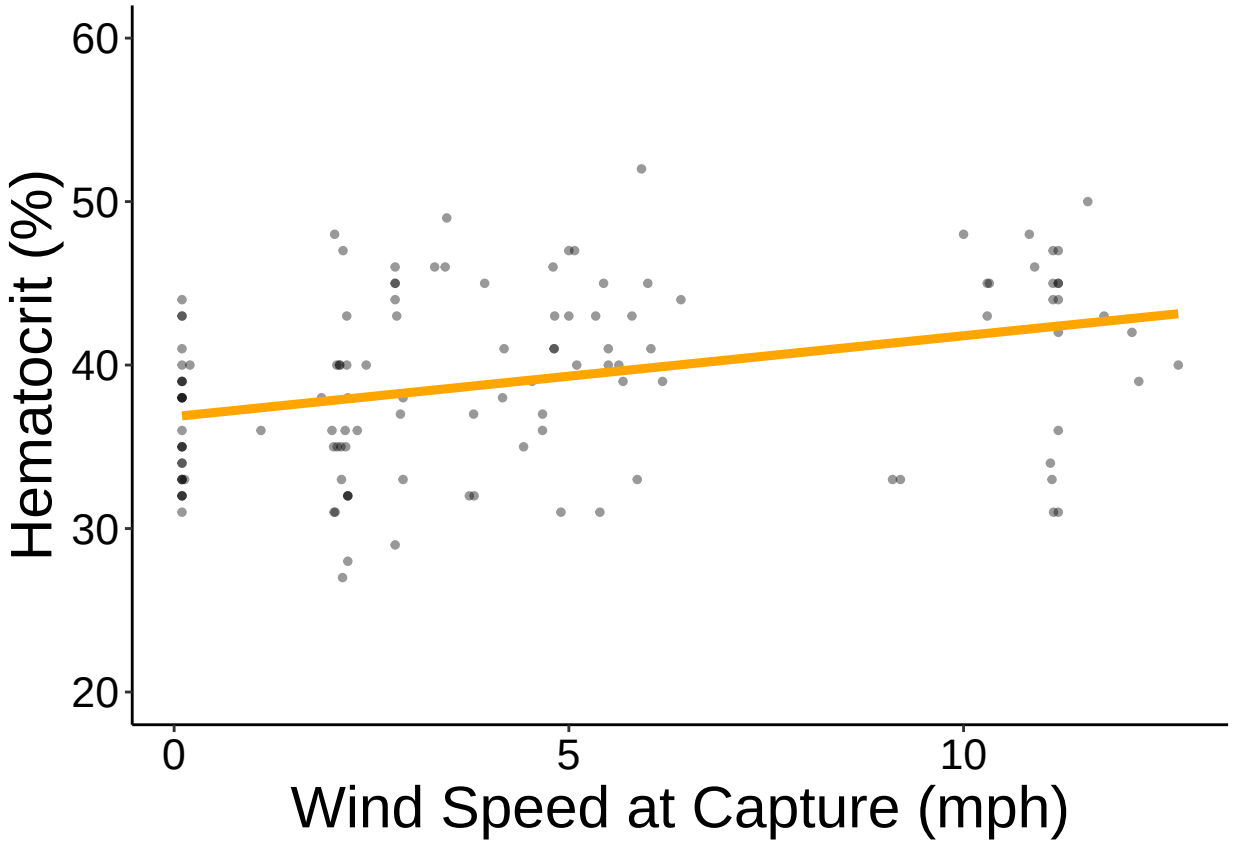
Hct ~ Wind Speed at Capture

```
ggplot(dat) +
  aes(x = wind_mph_interpol,
      y = hematocrit_percent)+
  geom_point(size = 1,
             alpha = 0.4) +
  stat_smooth(formula = y ~ x,
```

```
              method = "lm",
              se = F,
              color = wind_color,
              size = 1.6,
              alpha = 1 ) +
  theme_classic() +
  xlab("Wind Speed at Capture (mph)") +
  ylab("Hematocrit (%)") +
  #ylab("") +
  #xlim() +
  ylim(20, 60) +
  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_hct_wind_fig
cap_hct_wind_fig
```

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

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

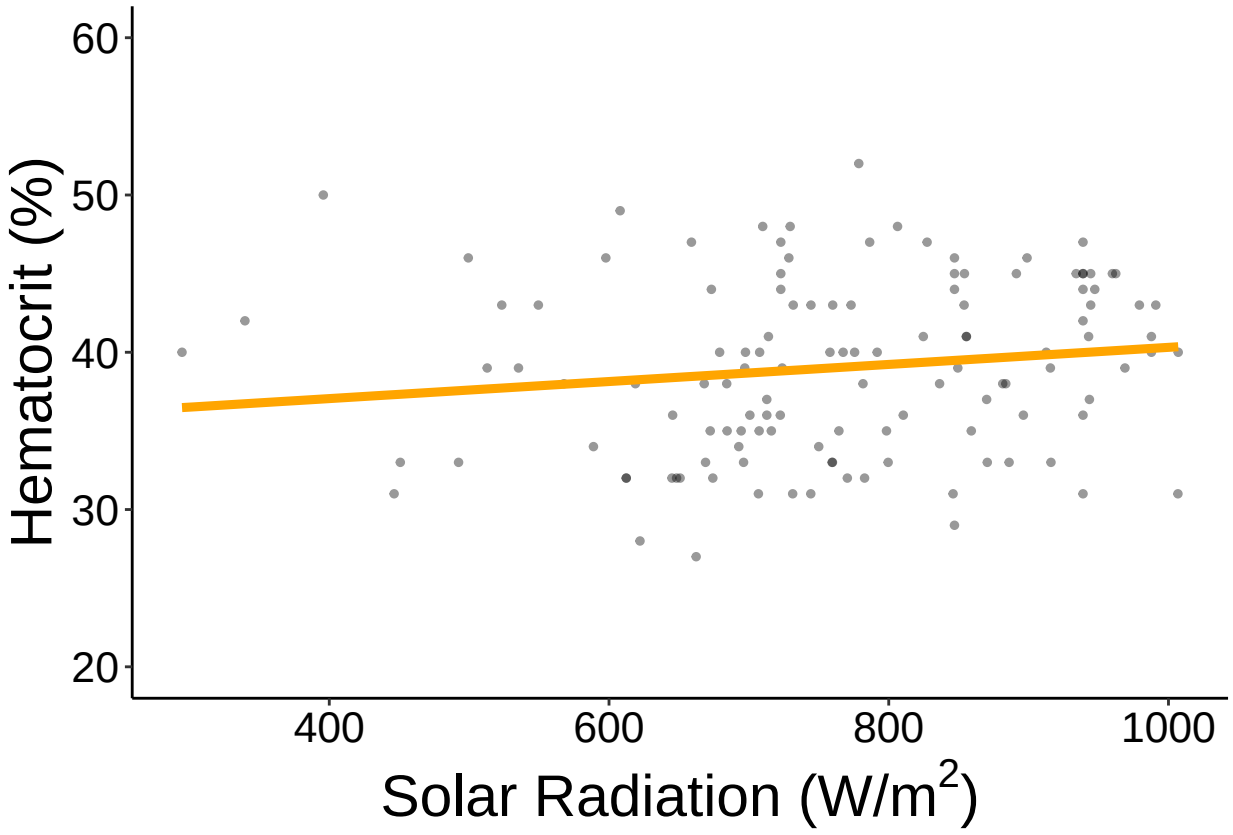


Hct ~ Solar Radiation at Capture

```
ggplot(dat) +
  aes(x = solar_rad_W_sqm_interpol,
      y = hematocrit_percent) +
  geom_point(size = 1,
             alpha = 0.4) +
  stat_smooth(formula = y ~ x,
              method = "lm",
              se = F,
              color = solar_color,
              size = 1.6,
              alpha = 1 ) +
  theme_classic() +
  xlab(bquote('Solar Radiation (W/'*m^2*')')) +
  ylab("Hematocrit (%)") +
  #ylab("") +
  ylim(20, 60) +
  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_hct_sorad_fig
cap_hct_sorad_fig
```

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

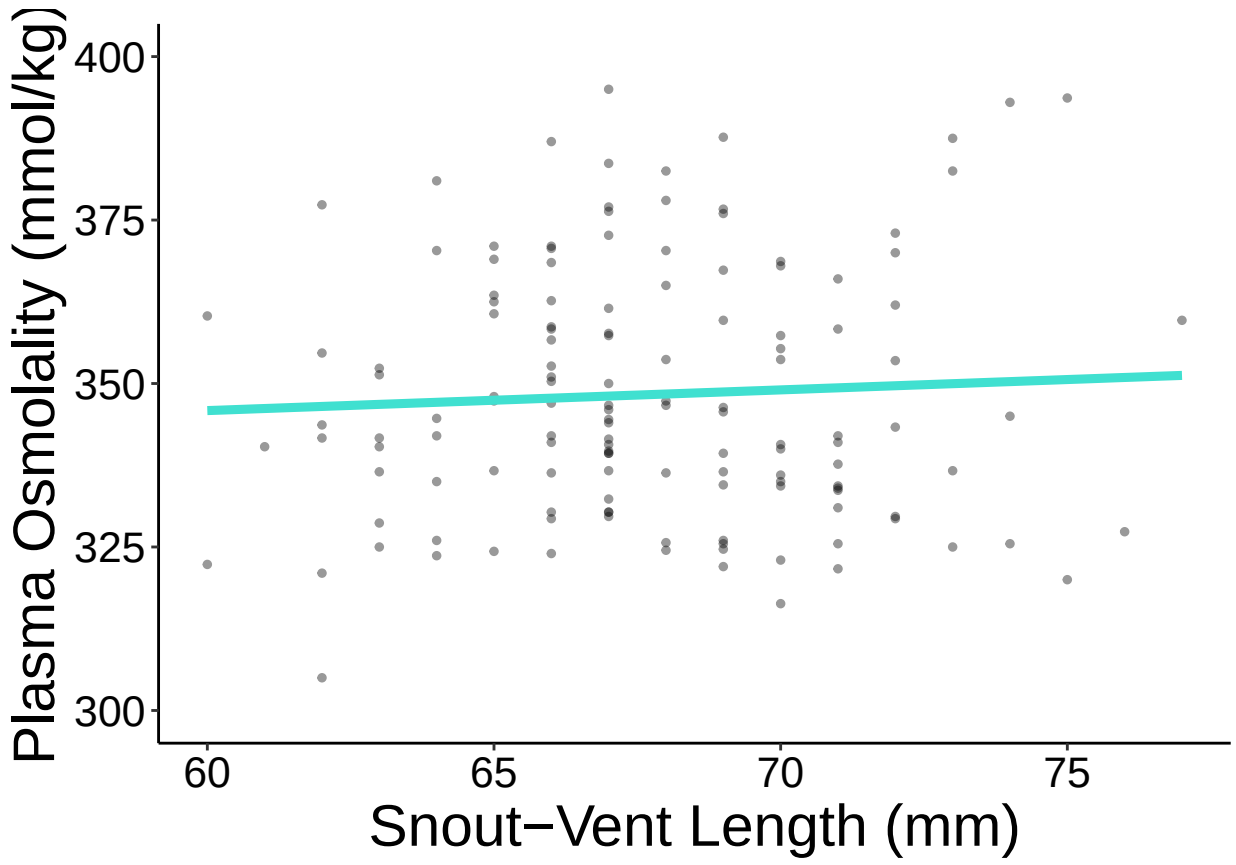
```
## Warning: Removed 14 rows containing missing values (geom_point).
```



Osmolality ~ SVL

```
ggplot(dat) +
  aes(x = SVL_mm,
      y = osmolality_mmol_kg_mean) +
  geom_point(size = 1,
             alpha = 0.4) +
  stat_smooth(formula = y ~ x,
              method = "lm",
              se = F,
              size = 1.6,
              color = lizard_color,
              alpha = 1) +
  theme_classic() +
  xlab("Snout-Vent Length (mm)") +
  ylab("Plasma Osmolality (mmol/kg)") +
  #ylab("") +
  #xlim() +
  ylim(300,400) +
  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(),
```

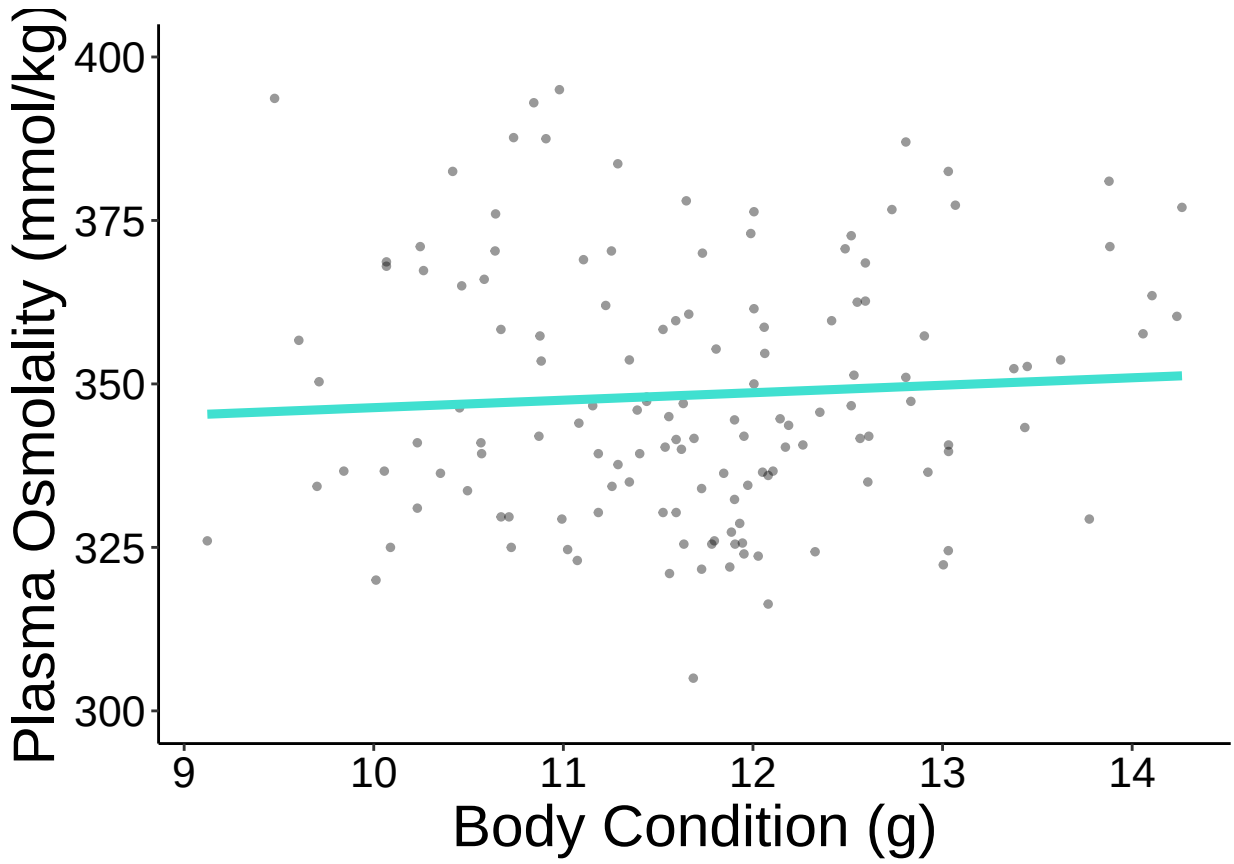
```
        #plot.margin = unit(c(0.1,0,0.1,0.45), "cm")
        ) -> cap_osml_SVL_fig
cap_osml_SVL_fig
```



Osmolality ~ SMI

```
ggplot(dat) +
  aes(x = SMI,
      y = osmolality_mmol_kg_mean) +
  geom_point(size = 1,
             alpha = 0.4) +
  stat_smooth(formula = y ~ x,
              method = "lm",
              se = F,
              size = 1.6,
              color = lizard_color,
              alpha = 1) +
  theme_classic() +
  xlab("Body Condition (g)") +
  ylab("Plasma Osmolality (mmol/kg)") +
  #ylab("") +
  #xlim() +
  ylim(300,400) +
  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_SMI_fig
cap_osml_SMI_fig
```



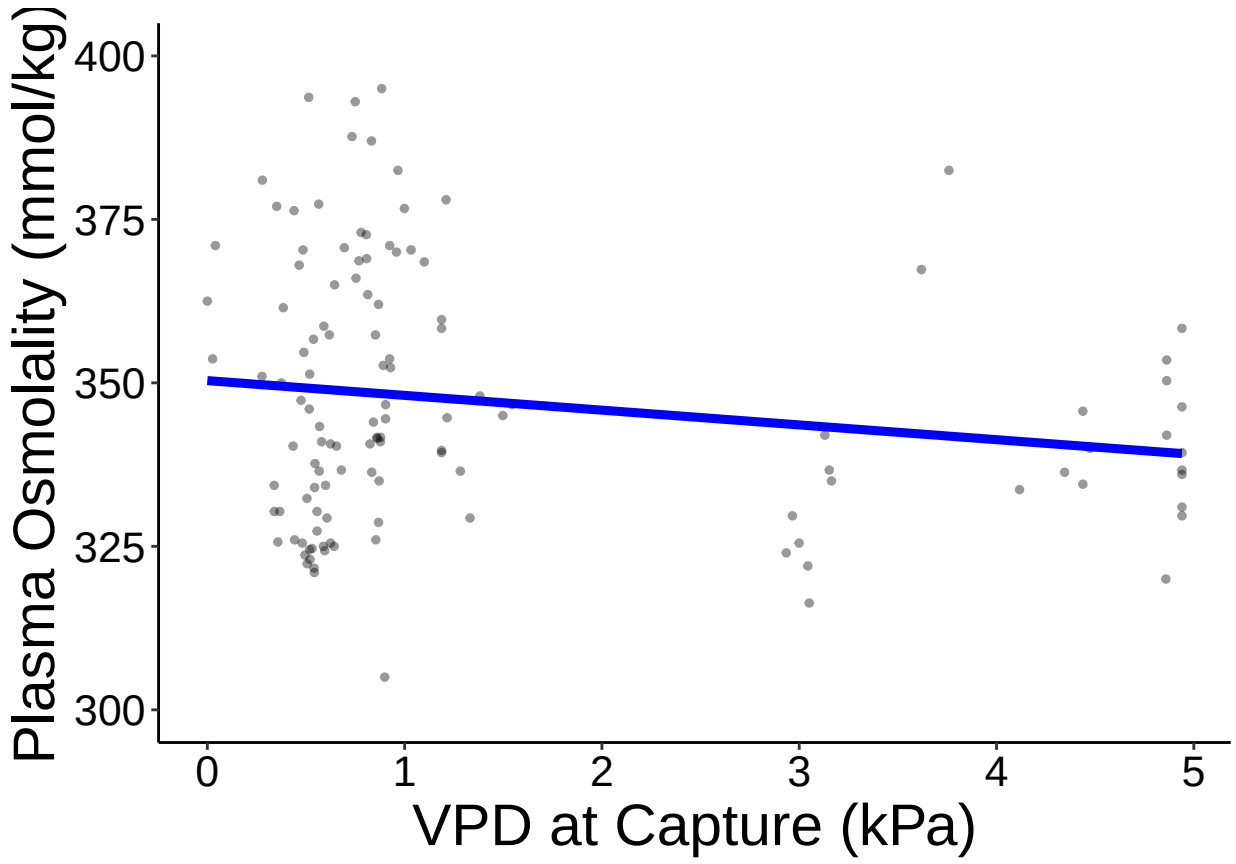
Osmolality ~ VPD at Capture

```
ggplot(dat) +
  aes(x = VPD_kPa_int,
      y = osmolality_mmol_kg_mean) +
  geom_point(size = 1,
             alpha = 0.4) +
  stat_smooth(formula = y ~ x,
              method = "lm",
              se = F,
              color = VPD_color,
              size = 1.6,
              alpha = 1 ) +
  theme_classic() +
  xlab("VPD at Capture (kPa)") +
  ylab("Plasma Osmolality (mmol/kg)") +
```

```
  #ylab("") +
  #xlim() +
  ylim(300,400) +
  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_VPD_fig
cap_osml_VPD_fig
```

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

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



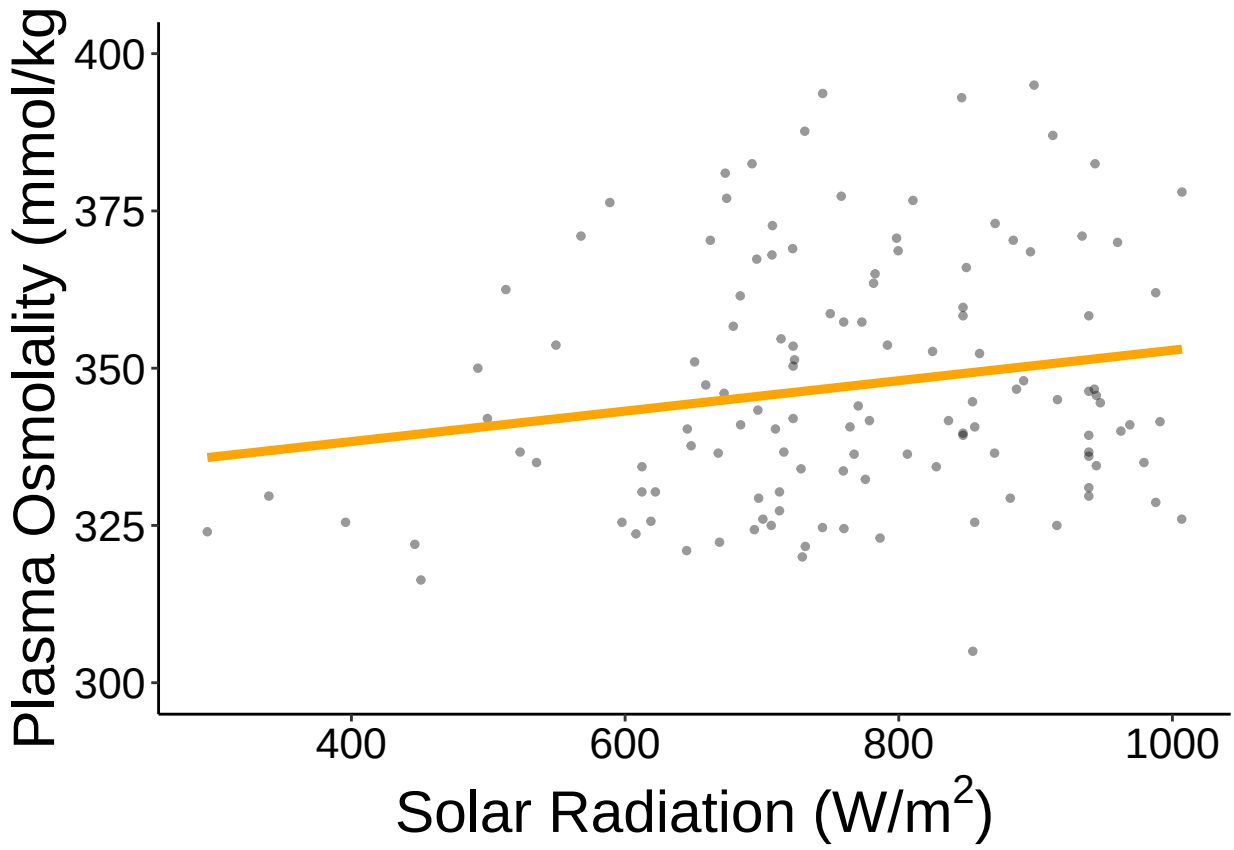
Osmolality ~ Solar Radiation at Capture

```
ggplot(dat) +
  aes(x = solar_rad_W_sqm_interpol,
      y = osmolality_mmol_kg_mean) +
  geom_point(size = 1,
             alpha = 0.4) +
  stat_smooth(formula = y ~ x,
```

```
              method = "lm",
              se = F,
              color = solar_color,
              size = 1.6,
              alpha = 1 ) +
  theme_classic() +
  xlab(bquote('Solar Radiation (W/'*m^2*')')) +
  ylab("Plasma Osmolality (mmol/kg)") +
  #ylab("") +
  ylim(300,400) +
  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
```

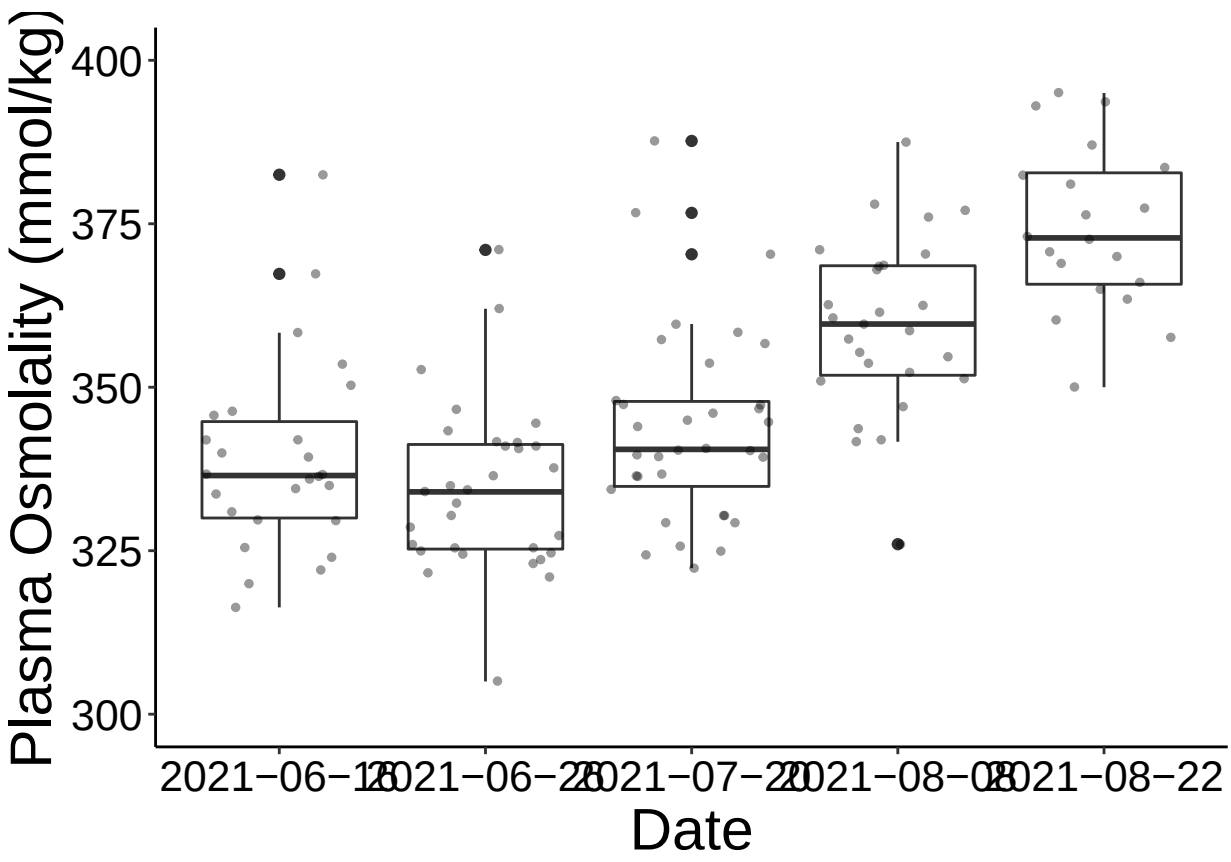
```
## Warning: Removed 14 rows containing non-finite values (stat_smooth).
```

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



Osmolality ~ Date

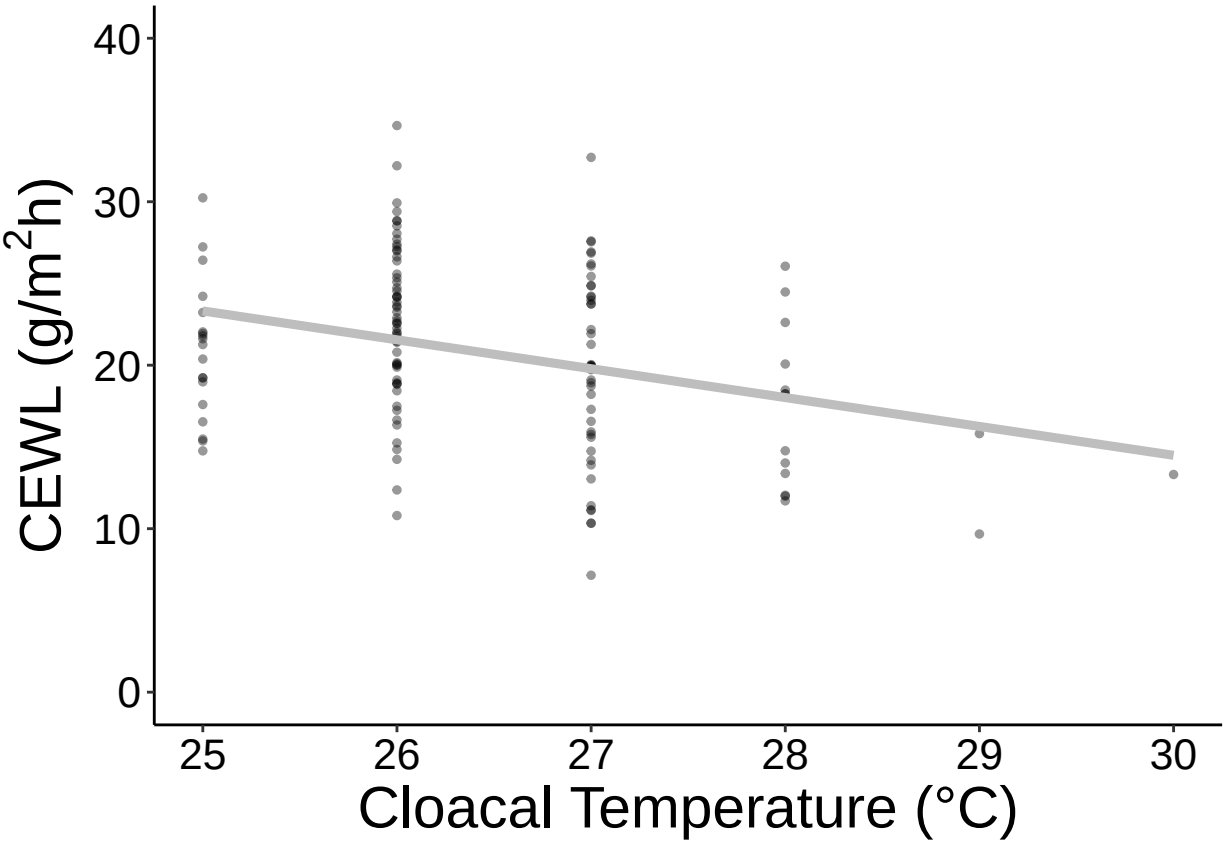
```
ggplot(dat) +
  aes(x = as.factor(capture_date),
      y = osmolality_mmol_kg_mean,
      group = as.factor(capture_date)) +
  geom_boxplot() +
  geom_jitter(size = 1,
              alpha = 0.4) +
  theme_classic() +
  xlab("Date") +
  ylab("Plasma Osmolality (mmol/kg)") +
  #ylab("") +
  #xlim() +
  ylim(300, 400) +
  #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
```



CEWL ~ Cloacal Temperature

```
ggplot(dat) +
  aes(x = cloacal_temp_C,
      y = CEWL_g_m2h_mean) +
  geom_point(size = 1,
             alpha = 0.4) +
  stat_smooth(formula = y ~ x,
              method = "lm",
              se = F,
              color = temp_color,
              size = 1.6,
              alpha = 1) +
  theme_classic() +
  xlab("Cloacal Temperature (°C)") +
  ylab(bquote('CEWL (g/'*m^2*'h)')) +
  #ylab("") +
  #xlim() +
  ylim(0, 40) +
  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(),
```

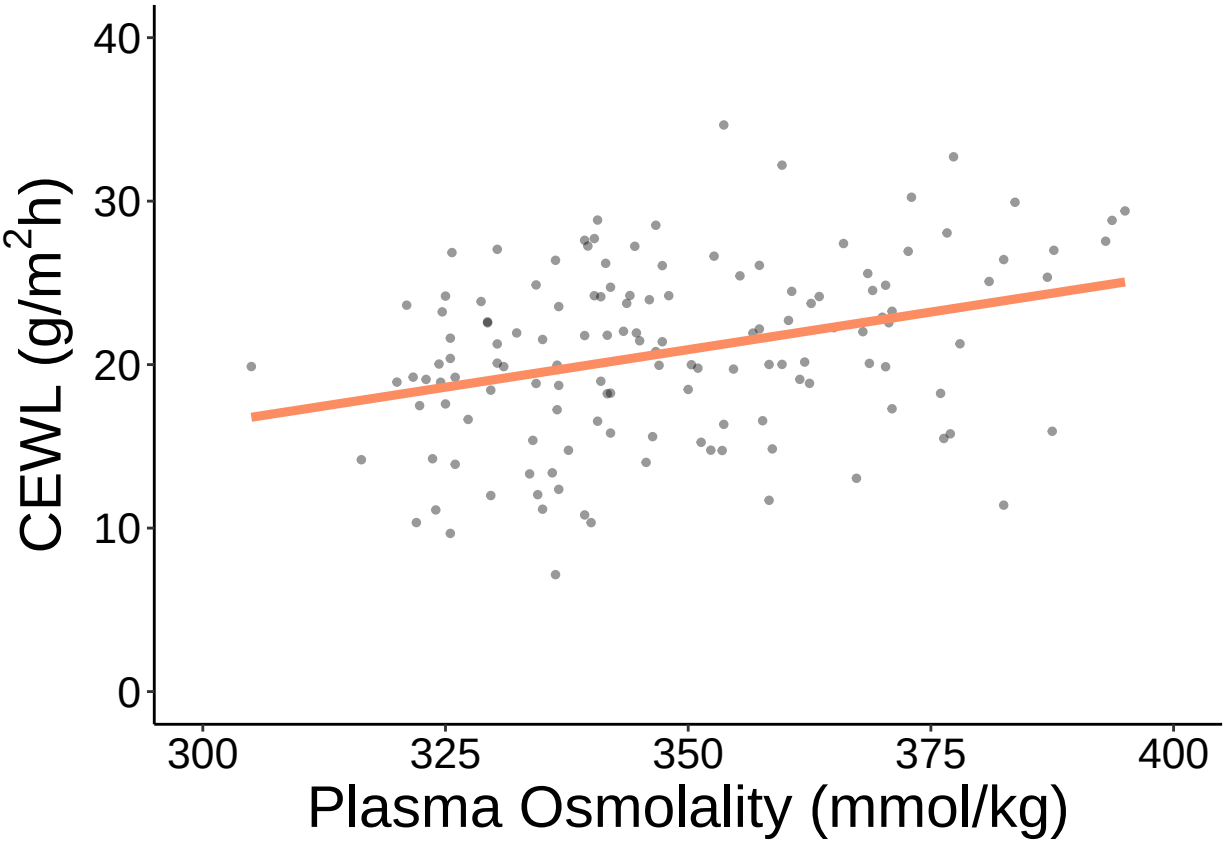
```
        #plot.margin = unit(c(0.1,0,0.1,0.45), "cm")
        ) -> cap_CEWL_clotemp_fig
cap_CEWL_clotemp_fig
```



CEWL ~ Plasma Osmolality

```
ggplot(dat) +
  aes(x = osmolality_mmol_kg_mean,
                y = CEWL_g_m2h_mean) +
  geom_point(size = 1,
             alpha = 0.4) +
  stat_smooth(formula = y ~ x,
              method = "lm",
              se = F,
              color = osml_color,
              size = 1.6,
              alpha = 1) +
  theme_classic() +
  xlab("Plasma Osmolality (mmol/kg)") +
  ylab(bquote('CEWL (g/'*m^2*'h)')) +
  #ylab("") +
  xlim(300, 400) +
  ylim(0, 40) +
#  manual_color_brewer(, name = "") +
  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
```

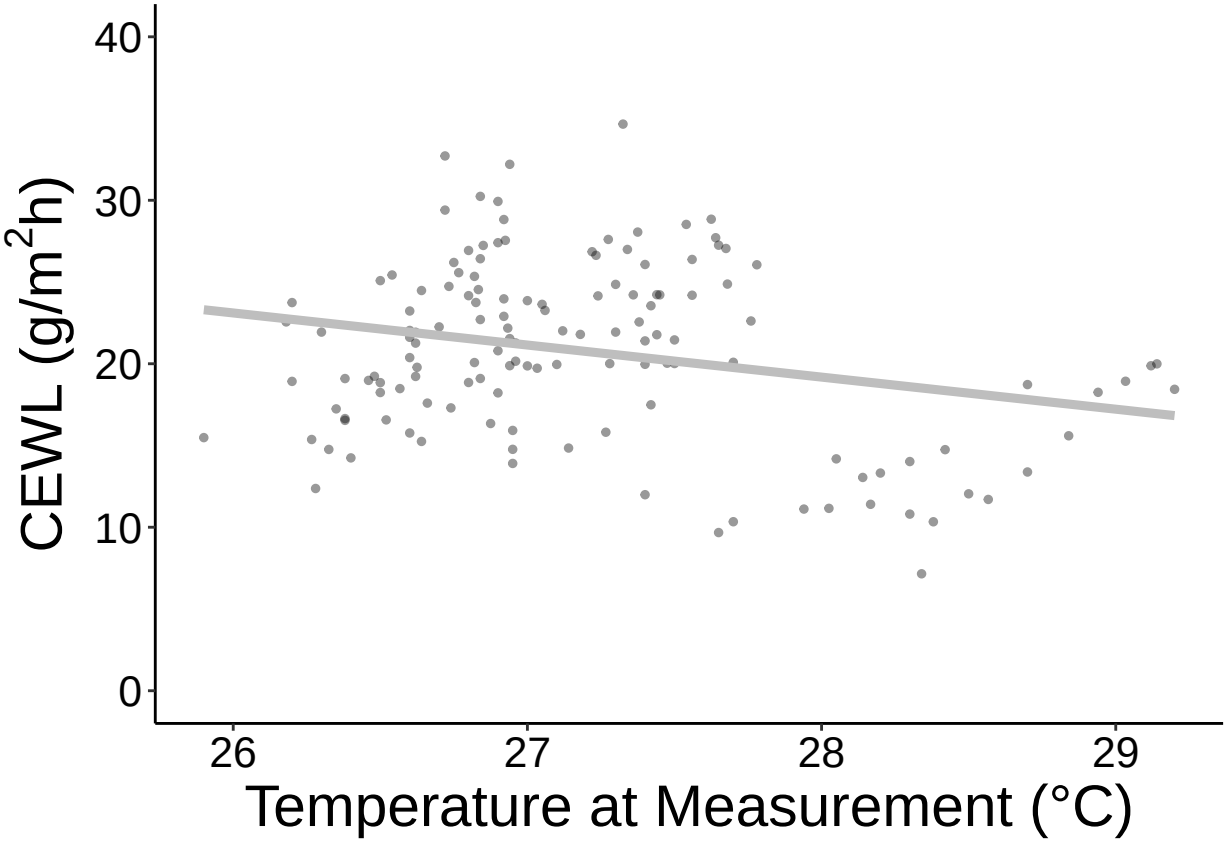



```
ggsave(filename = "cap_CEWL_osml_fig.jpeg",
       plot = cap_CEWL_osml_fig,
       path = "./results_figures",
       device = "jpeg",
       dpi = 600,
       width = 6, height = 4)
```

CEWL ~ Temperature at Measurement

```
ggplot(dat) +
  aes(x = msmt_temp_C,
      y = CEWL_g_m2h_mean) +
  geom_point(size = 1,
             alpha = 0.4) +
  stat_smooth(formula = y ~ x,
              method = "lm",
              se = F,
```

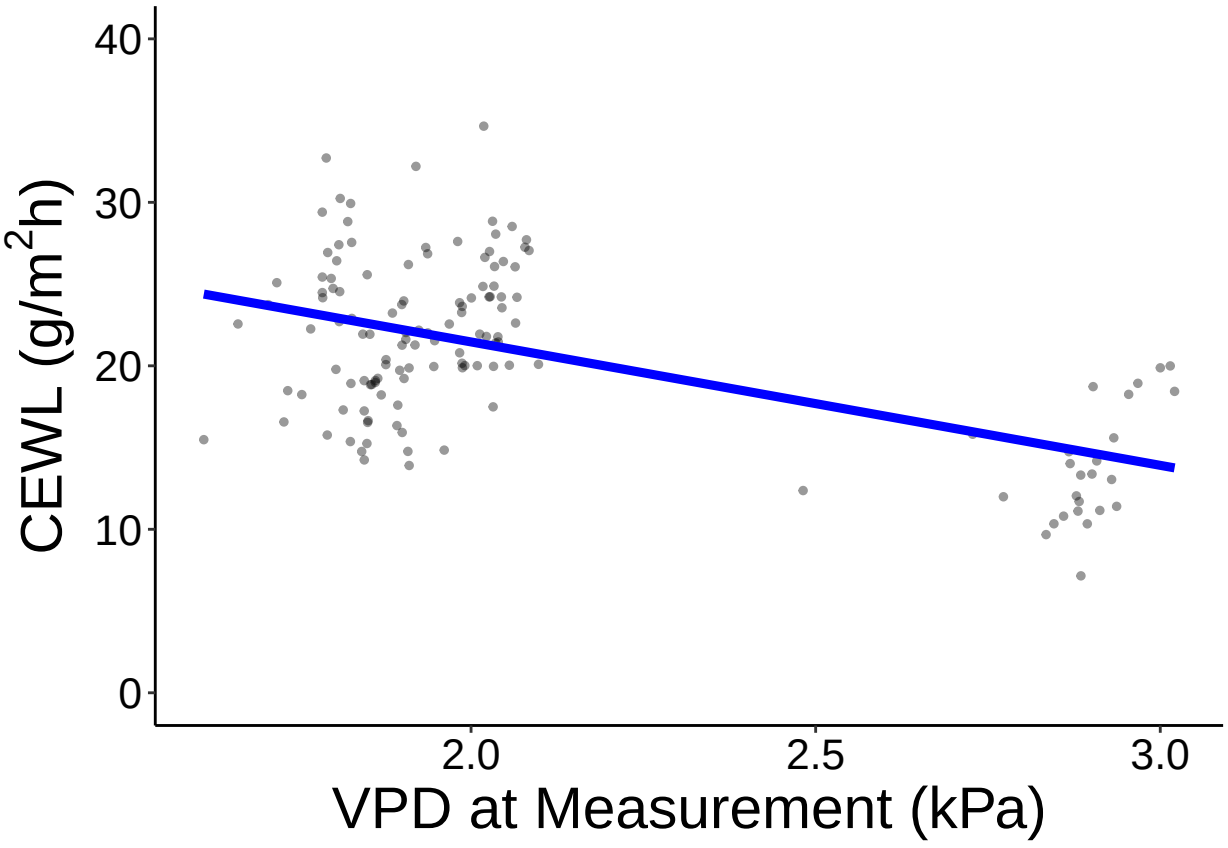
```
              color = temp_color,
              size = 1.6,
              alpha = 1) +
  theme_classic() +
  xlab("Temperature at Measurement (°C)") +
  ylab(bquote('CEWL (g/'*m^2*'h)')) +
  #ylab("") +
  #xlim() +
  ylim(0, 40) +
  theme(text = element_text(color = "black",
                            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
```



CEWL ~ VPD at Measurement

```
ggplot(dat) +
  aes(x = msmt_VPD_kPa,
      y = CEWL_g_m2h_mean) +
  geom_point(size = 1,
```

```
              alpha = 0.4) +
  stat_smooth(formula = y ~ x,
              method = "lm",
              se = F,
              color = VPD_color,
              size = 1.6,
              alpha = 1 ) +
  theme_classic() +
  xlab("VPD at Measurement (kPa)") +
  ylab(bquote('CEWL (g/'*m^2*'h)')) +
  #ylab("") +
  #xlim() +
  ylim(0, 40) +
  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_VPDm_fig
cap_CEWL_VPDm_fig
```

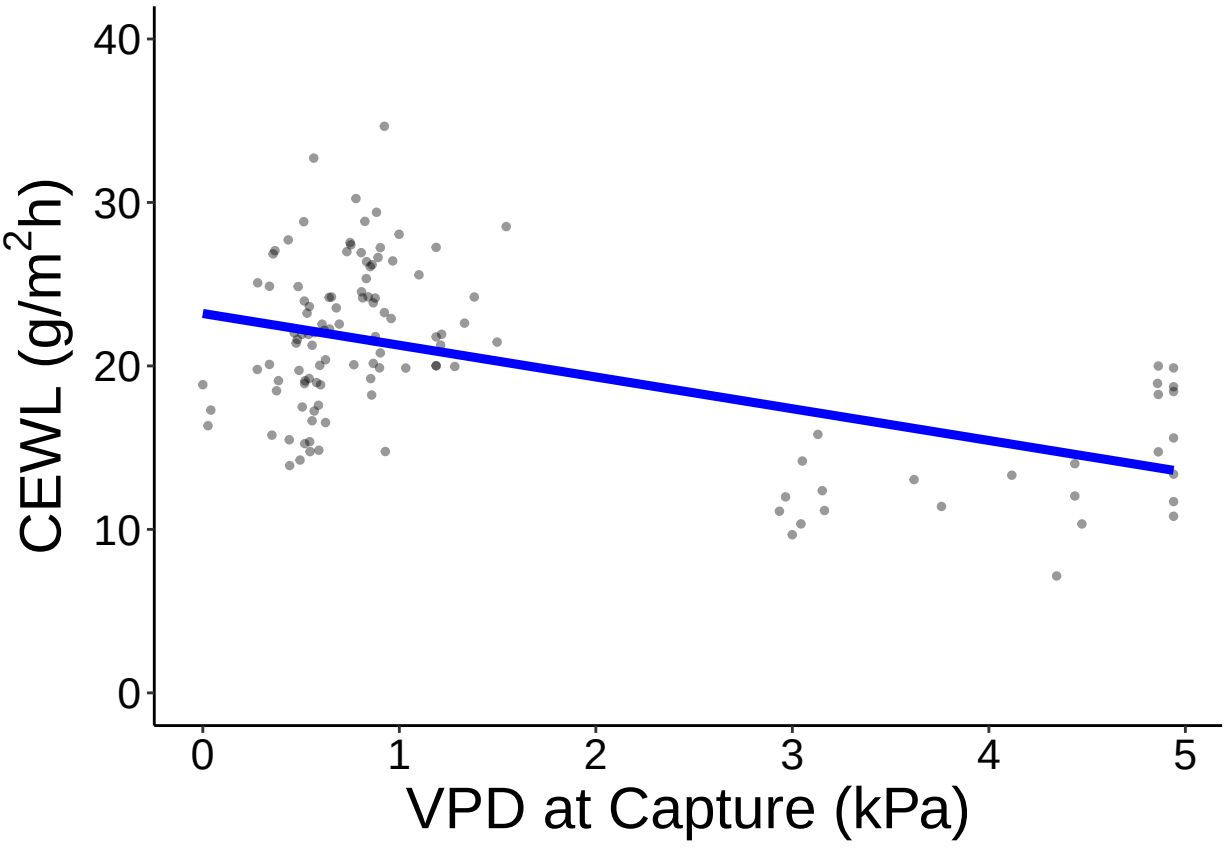


CEWL ~ VPD at Capture

```
ggplot(dat) +
  aes(x = VPD_kPa_int,
      y = CEWL_g_m2h_mean) +
  geom_point(size = 1,
             alpha = 0.4) +
  stat_smooth(formula = y ~ x,
              method = "lm",
              se = F,
              color = VPD_color,
              size = 1.6,
              alpha = 1 ) +
  theme_classic() +
  xlab("VPD at Capture (kPa)") +
  ylab(bquote('CEWL (g/'*m^2*'h)')) +
  #ylab("") +
  #xlim() +
  ylim(0, 40) +
  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_VPDc_fig
cap_CEWL_VPDc_fig
```

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

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



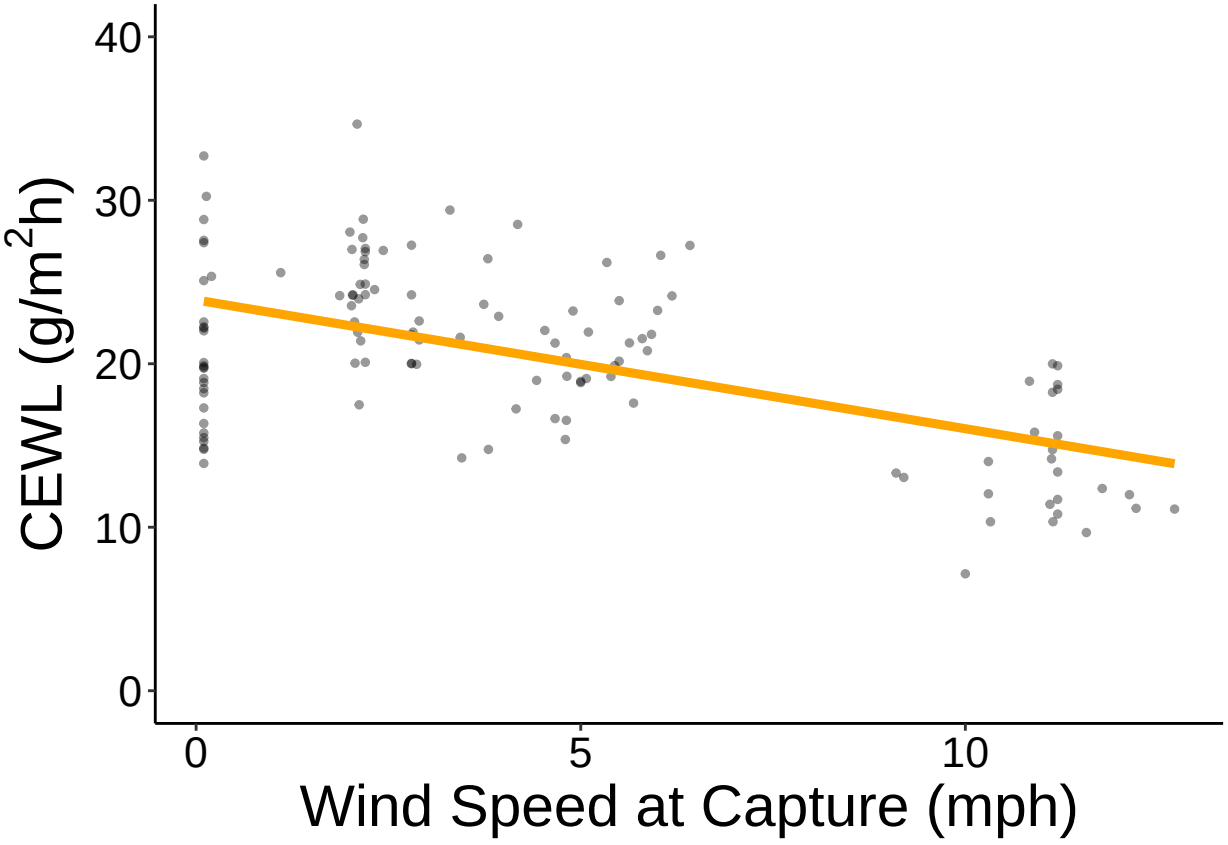
CEWL ~ Wind at Capture

```
ggplot(dat) +
  aes(x = wind_mph_interpol,
      y = CEWL_g_m2h_mean)+
  geom_point(size = 1,
             alpha = 0.4) +
  stat_smooth(formula = y ~ x,
              method = "lm",
              se = F,
              color = wind_color,
              size = 1.6,
              alpha = 1 ) +
  theme_classic() +
  xlab("Wind Speed at Capture (mph)") +
  ylab(bquote('CEWL (g/'*m^2*'h)')) +
  #ylab("") +
  #xlim() +
  ylim(0, 40) +
  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_wind_fig
cap_CEWL_wind_fig
```

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

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



CEWL ~ Date

```
ggplot(dat) +
  aes(x = as.factor(capture_date),
      y = CEWL_g_m2h_mean,
      group = as.factor(capture_date)) +
  geom_boxplot() +
  geom_jitter(size = 1,
              alpha = 0.4) +
  theme_classic() +
  xlab("Date") +
  ylab(bquote('CEWL (g/'*m^2*'h)')) +
  #ylab("") +
  #xlim() +
  ylim(0, 40) +
  #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
```

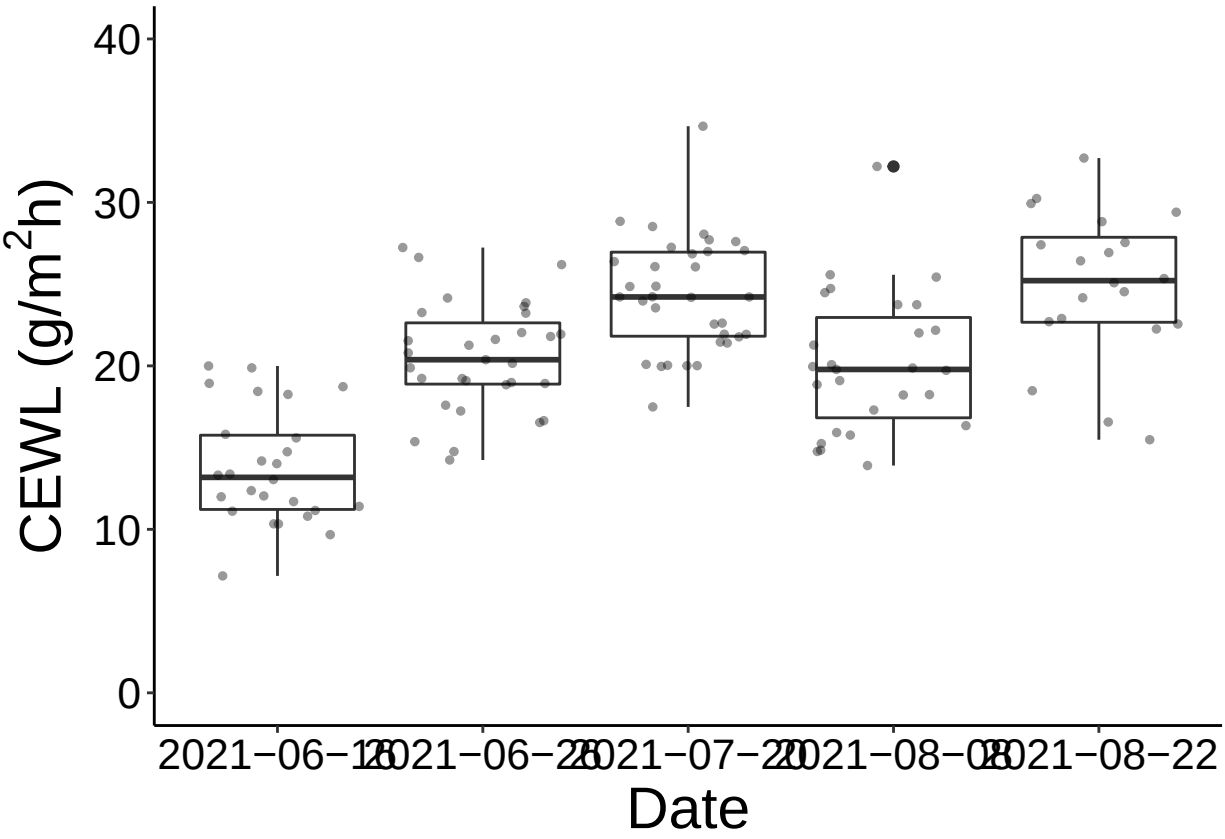


Figure Arrangements

```
# hematocrit
ggarrange(cap_hct_sorad_fig, cap_hct_VPD_fig,
          cap_hct_SMI_fig, cap_hct_wind_fig,
          ncol = 2, nrow = 2,
          legend = "none"
          ) -> cap_hct_multi_fig
```

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

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

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

```
#cap_hct_multi_fig
# export figure
#ggsave(filename = "cap_hct_multi_fig.jpeg",
 #      plot = cap_hct_multi_fig,
  #     path = "./results_figures",
   #    device = "jpeg",
    #   dpi = 1200,
     #  width = 12, height = 8)


# osmolality
ggarrange(cap_osml_sorad_fig, cap_osml_VPD_fig,
          cap_osml_SMI_fig, cap_osml_SVL_fig,
          ncol = 2, nrow = 2,
          legend = "none"
          ) -> cap_osml_multi_fig
```

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

```
#cap_osml_multi_fig
# export figure
#ggsave(filename = "cap_osml_multi_fig.jpeg",
 #      plot = cap_osml_multi_fig,
  #     path = "./results_figures",
   #    device = "jpeg",
    #   dpi = 1200,
     #  width = 12, height = 8)



# CEWL
ggarrange(cap_CEWL_VPDm_fig, cap_CEWL_VPDc_fig,
          cap_CEWL_temp_fig, cap_CEWL_wind_fig,
          cap_CEWL_osml_fig, cap_CEWL_clotemp_fig,
          ncol = 2, nrow = 3,
          legend = "none"
          ) -> cap_CEWL_multi_fig
```

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

```
#cap_CEWL_multi_fig
# export figure
#ggsave(filename = "cap_CEWL_multi_fig",
 #      plot = cap_CEWL_multi_fig,
  #     path = "./results_figures",
   #    device = "jpeg",
    #   dpi = 1200,
     #  width = 12, height = 16)



# date differences
ggarrange(cap_osml_date_fig, cap_CEWL_date_fig,
          ncol = 1, nrow = 2,
          legend = "none"
          ) -> cap_date_diffs_multi_fig
##cap_date_diffs_multi_fig
# export figure
#ggsave(filename = "cap_date_diffs_multi_fig.jpeg",
 #      plot = cap_date_diffs_multi_fig,
  #     path = "./results_figures",
   #    device = "jpeg",
    #   dpi = 1200,
     #  width = 6, height = 8)
```