BNLL CEWL Data Wrangling

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Contents

Packages

Background and Goals

This CEWL (cutaneous evaporative water loss) data was measured in 3-5 technical replicates on the mid-dorsum of Blunt-nosed Leopard Lizards (*Gambelia sila*) between April - July 2021. In this R script, I check the distribution of replicates, omit outliers, and average remaining replicates. The final values will be more precise and accurate estimates of the true CEWL for each lizard, and those values will be used in the analyses R script file. Please refer to **doi:** for the published scientific paper and full details.

Load Data

1. Compile a list of the filenames I need to read-in.

```
# make a list of file names of all data to load in
filenames <- list.files(path = "data/CEWL")
```

2. Make a function that will read in the data from each csv, name and organize the data correctly.

```r
read_CEWL_file <- function(filename) {

  dat <- read.csv(file.path("data/CEWL", filename),
                  na.strings=c("","NA"),
                 # each csv has headers
                 header = TRUE
                 ) %>%
    # select only the relevant values
    dplyr::select(date = Date,
                  time = Time,
                  status = Status,
                  ID_rep_no = Comments,
                  CEWL_g_m2h = 'TEWL..g..m2h..',
                  msmt_temp_C = 'AmbT..C.',
                  msmt_RH_percent = 'AmbRH....'
                  ) %>%
    # extract individual_ID and replicate number
    dplyr::mutate(ID_rep_no = as.character(ID_rep_no),
                  ID_len = as.factor(nchar(ID_rep_no)),

                  individual_ID = as.factor(case_when(
                    ID_len == 7 ~ as.character(paste(substr(ID_rep_no, 1, 1),
                                                     substr(ID_rep_no, 3, 5),
                                                     sep = "")),
                    ID_len == 6 & substr(ID_rep_no, 1, 1) == "W"
                        ~ as.character(substr(ID_rep_no, 1, 4)),
                    ID_len == 6 & substr(ID_rep_no, 1, 1) %in% c("M", "F")
                        ~ as.character(paste(substr(ID_rep_no, 1, 1),
                                                     substr(ID_rep_no, 3, 4),
                                                     sep = "")),
                    ID_len == 5 ~ as.character(substr(ID_rep_no, 1, 3))
                    )),

                  # works
                  replicate_no = as.factor(case_when(
                    ID_len == 7 ~ as.character(substr(ID_rep_no, 7, 7)),
                    ID_len == 6 ~ as.character(substr(ID_rep_no, 6, 6)),
                    ID_len == 5 ~ as.character(substr(ID_rep_no, 5, 5))
                    )))

  # return the dataframe for that single csv file
  dat
}
```

3. Apply the function I made to all of the filenames I compiled, then put all of those dataframes into one dataframe. This will print warnings saying that header and col.names are different lengths, because the data has extra notes cols that we read-in, but get rid of. Additionally, filter out failed measurements and properly format data classes.

```r
# apply function to get data from all csvs
all_CEWL_data <- lapply(filenames, read_CEWL_file) %>%
  # paste all data files together into one df by row
  reduce(rbind) %>%
  # filter out failed measurements
  dplyr::filter(status == "Normal") %>%
  # correctly format data classes
  mutate(date = as.Date(date, format = "%m/%d/%y"),
         time = as.POSIXct(time, format = "%H:%M"),
         status = as.factor(status)
         )

summary(all_CEWL_data)
```

```
##       date                 time                          status
##  Min.   :2021-04-23   Min.   :2022-07-03 01:00:00   Normal:456
##  1st Qu.:2021-04-24   1st Qu.:2022-07-03 02:24:45
##  Median :2021-05-07   Median :2022-07-03 03:46:00
##  Mean   :2021-05-12   Mean   :2022-07-03 04:22:43
##  3rd Qu.:2021-05-08   3rd Qu.:2022-07-03 05:02:15
##  Max.   :2021-07-14   Max.   :2022-07-03 12:59:00
##
##   ID_rep_no           CEWL_g_m2h     msmt_temp_C    msmt_RH_percent ID_len
##  Length:456         Min.   :-1.32   Min.   :18.90   Min.   :11.50   5:122
##  Class :character   1st Qu.: 7.74   1st Qu.:28.50   1st Qu.:14.50   6:244
##  Mode  :character   Median :10.21   Median :30.30   Median :16.95   7: 90
##                     Mean   :10.62   Mean   :29.55   Mean   :21.36
##                     3rd Qu.:12.89   3rd Qu.:31.50   3rd Qu.:24.30
##                     Max.   :65.31   Max.   :33.70   Max.   :41.60
##
##  individual_ID replicate_no
##  F12    : 13   1:117
##  M10    : 13   2:118
##  M11    : 13   3:118
##  M19    : 13   4: 52
##  M20    : 13   5: 51
##  M09    : 12
##  (Other):379
```

Check Data

Each lizard measured on each date should have 3-5 technical replicates, and those measurements should have been taken around the same time.

```
all_CEWL_data %>%
                group_by(individual_ID, date) %>%
                summarise(n = n(),
                          time_range = max(time) - min(time)) %>%
                arrange(n)
```

```
## `summarise()` regrouping output by 'individual_ID' (override with `.groups` argument)
```

```
## # A tibble: 118 x 4
## # Groups:   individual_ID [80]
##    individual_ID date           n time_range
##    <fct>         <date>     <int> <drtn>
##  1 F01           2021-04-23     3 120 secs
##  2 F02           2021-04-23     3 120 secs
##  3 F03           2021-04-23     3 120 secs
##   4 F04           2021-04-23     3  60 secs
##   5 F05           2021-04-24     3 120 secs
##   6 F06           2021-04-24     3 120 secs
##   7 F07           2021-04-24     3  60 secs
##   8 F08           2021-04-24     3  60 secs
##   9 F09           2021-04-24     3 120 secs
##  10 F10           2021-04-24     3 120 secs
## # ... with 108 more rows
```

The number of measurements taken is good! Almost always 3 or 5, with two lizards who only got 4 measurements, which is fine. But, M01 on April 23 and M03a on July 14 have abnormal time ranges of 43140 seconds (almost 12h), so we need to check that data.

```
all_CEWL_data %>% dplyr::filter(individual_ID %in% c("M01", "M03A"))
```

```
##          date                time status ID_rep_no CEWL_g_m2h msmt_temp_C
## 1  2021-04-23 2022-07-03 12:57:00 Normal     M01_1       0.69        31.0
## 2  2021-04-23 2022-07-03 12:59:00 Normal     M01_2       0.14        30.7
## 3  2021-04-23 2022-07-03 01:00:00 Normal     M01_3       1.12        30.5
## 4  2021-07-14 2022-07-03 12:58:00 Normal   M-03A-1       9.98        27.4
## 5  2021-07-14 2022-07-03 12:59:00 Normal   M-03A-2       9.16        27.8
## 6  2021-07-14 2022-07-03 01:00:00 Normal   M-03A-3      11.05        28.0
## 7  2021-07-14 2022-07-03 01:01:00 Normal   M-03A-4      13.29        28.1
## 8  2021-07-14 2022-07-03 01:02:00 Normal   M-03A-5       8.69        28.4
## 9  2021-07-14 2022-07-03 05:00:00 Normal    M-01-1      13.70        27.4
## 10 2021-07-14 2022-07-03 05:01:00 Normal    M-01-2      10.94        27.2
## 11 2021-07-14 2022-07-03 05:02:00 Normal    M-01-3      11.35        27.0
## 12 2021-07-14 2022-07-03 05:03:00 Normal    M-01-4       9.39        26.8
## 13 2021-07-14 2022-07-03 05:04:00 Normal    M-01-5       8.90        26.6
##    msmt_RH_percent ID_len individual_ID replicate_no
## 1             15.9      5           M01            1
## 2             16.3      5           M01            2
## 3             16.7      5           M01            3
## 4             37.1      7          M03A            1
## 5             36.8      7          M03A            2
## 6             37.1      7          M03A            3
## 7             35.9      7          M03A            4
## 8             35.2      7          M03A            5
## 9             39.7      6           M01            1
## 10            39.6      6           M01            2
## 11            39.5      6           M01            3
## 12            39.6      6           M01            4
## 13            39.6      6           M01            5
```

Aha, it seems the problem is that the time isn't perfectly formatted, so 1 pm is coded as 1 am –> the measurements in question went across hours of 12 noon to 1 pm, so when reformatted, it seems like 1 am to 12 pm. It's fine as-is, and nothing is amiss with the data.

Replicates

Assess Variation

We want the Coefficient of Variation (CV) among our technical replicates to be small. We need to calculate it to identify whether there may be outliers.

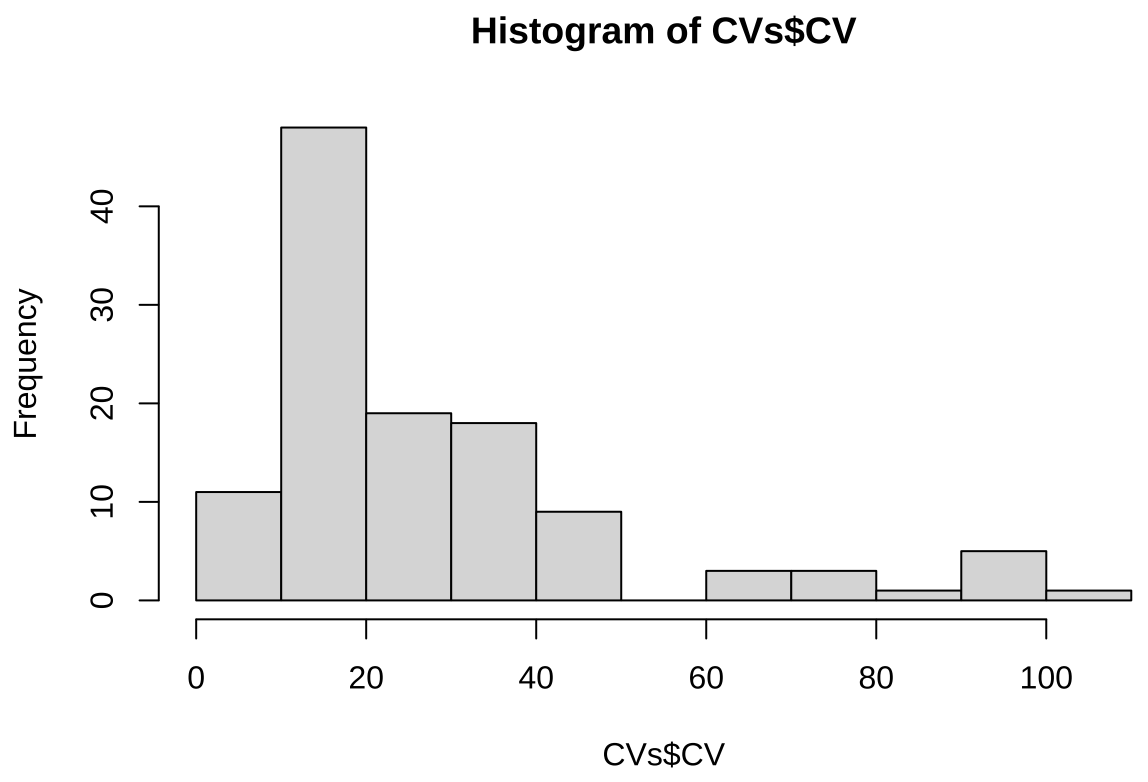
```
CVs <- all_CEWL_data %>%
  group_by(individual_ID, date) %>%
  summarise(mean = mean(CEWL_g_m2h),
            SD = sd(CEWL_g_m2h),
            CV = (SD/mean) *100,
            min = min(CEWL_g_m2h),
            max = max(CEWL_g_m2h),
            range = max - min
            )
```

```
## `summarise()` regrouping output by 'individual_ID' (override with `.groups` argument)
```

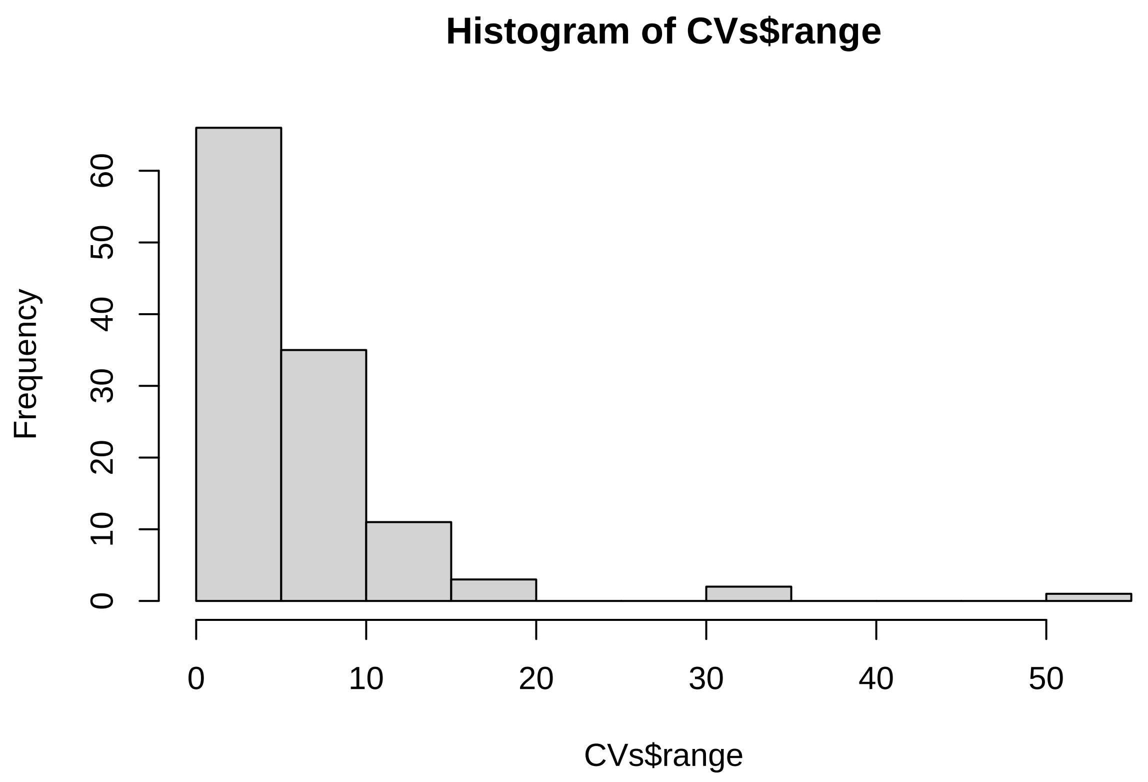
```
summary(CVs)
```

```
##  individual_ID      date                     mean                 SD
##  F12    :  3   Min.   :2021-04-23   Min.   : 0.650   Min.   : 0.1124
##  M09    :  3   1st Qu.:2021-04-24   1st Qu.: 8.486   1st Qu.: 1.4849
##  M10    :  3   Median :2021-04-24   Median :10.443   Median : 2.0290
##  M11    :  3   Mean   :2021-05-08   Mean   :10.823   Mean   : 2.9641
##  M19    :  3   3rd Qu.:2021-05-08   3rd Qu.:13.391   3rd Qu.: 3.1195
##  M20    :  3   Max.   :2021-07-14   Max.   :31.550   Max.   :29.3242
##  (Other):100
##        CV                min               max             range
##  Min.   :  1.956   Min.   :-1.320   Min.   : 1.12   Min.   : 0.220
##  1st Qu.: 15.021   1st Qu.: 6.723   1st Qu.:10.21   1st Qu.: 3.130
##  Median : 20.135   Median : 8.245   Median :13.32   Median : 4.600
##  Mean   : 28.713   Mean   : 8.159   Mean   :14.36   Mean   : 6.196
##  3rd Qu.: 35.639   3rd Qu.:10.500   3rd Qu.:16.37   3rd Qu.: 6.772
##  Max.   :105.713   Max.   :19.640   Max.   :65.31   Max.   :52.900
##
```

```
hist(CVs$CV)
```



```
hist(CVs$range)
```



We expect CV for technical replicates to be < 10-15%, so we must determine whether the CVs > 15% are due to outlier replicates. The range should also generally be within 5 units for these measurements. :(

Find Outliers

First, create a function to look at the replicates for each individual on each day. For each iteration, I will make a boxplot and extract any outliers, compiling a dataframe of outliers that I want to exclude from the final dataset. By printing the boxplots and compiling a dataframe of outliers, I can check the data against the plots to ensure confidence in the outliers quantified.

```r
# write function to find outliers for each individual on each date
find_outliers <- function(df) {

  # initiate dataframe to compile info and list to compile plots
  outliers <- data.frame()
  #boxplots <- list()

  # initiate a for loop to go through every who in df
  for(indiv_ch in unique(df$individual_ID)) {

    # select data for only the individual of interest
    df_sub <- df %>%
      dplyr::filter(individual_ID == (indiv_ch))

    # make a boxplot
    df_sub %>%
      ggplot(.) +
      geom_boxplot(aes(x = as.factor(date),
                       y = CEWL_g_m2h,
                       fill = as.factor(date))) +
      ggtitle(paste("Individual", indiv_ch)) +
      theme_classic() -> plot

    # print/save
    print(plot)
    #boxplots[[indiv_ch]] <- plot

    # extract outliers
    outs <- df_sub %>%
      group_by(individual_ID, date) %>%
      summarise(outs = boxplot.stats(CEWL_g_m2h)$out)

    # add to running dataframe of outliers
    outliers <- outliers %>%
      rbind(outs)
  }
  #return(boxplots)
  return(outliers)
}
```

Now apply the function to the data:

```r
par(mfrow = c(71, 2))
outliers_found <- find_outliers(all_CEWL_data)
```

```
## `summarise()` regrouping output by 'individual_ID', 'date' (override with `.groups` argument)
## `summarise()` regrouping output by 'individual_ID', 'date' (override with `.groups` argument)
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## `summarise()` regrouping output by 'individual_ID', 'date' (override with `.groups` argument)

## `summarise()` regrouping output by 'individual_ID' (override with `.groups` argument)

## `summarise()` regrouping output by 'individual_ID', 'date' (override with `.groups` argument)

## `summarise()` regrouping output by 'individual_ID' (override with `.groups` argument)

## `summarise()` regrouping output by 'individual_ID', 'date' (override with `.groups` argument)

## `summarise()` regrouping output by 'individual_ID' (override with `.groups` argument)

## `summarise()` regrouping output by 'individual_ID', 'date' (override with `.groups` argument)

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## `summarise()` regrouping output by 'individual_ID', 'date' (override with `.groups` argument)
## `summarise()` regrouping output by 'individual_ID', 'date' (override with `.groups` argument)
## `summarise()` regrouping output by 'individual_ID', 'date' (override with `.groups` argument)
## `summarise()` regrouping output by 'individual_ID', 'date' (override with `.groups` argument)

## `summarise()` regrouping output by 'individual_ID' (override with `.groups` argument)
```
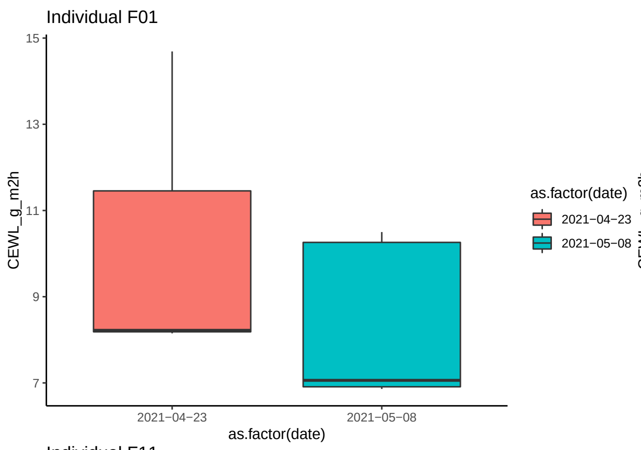
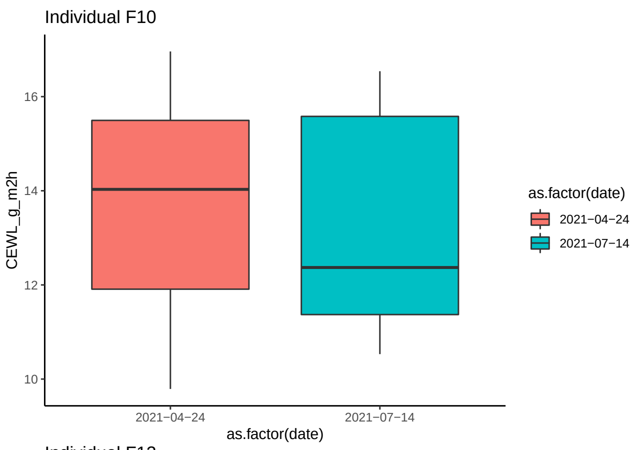
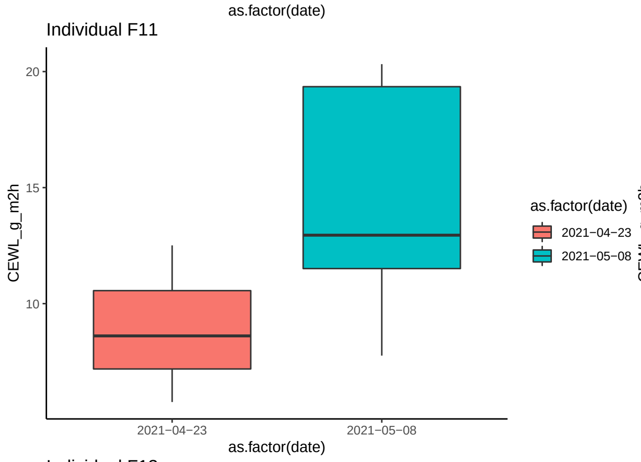
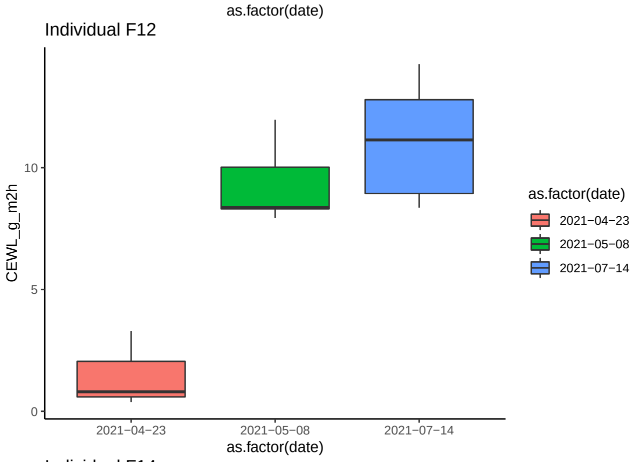
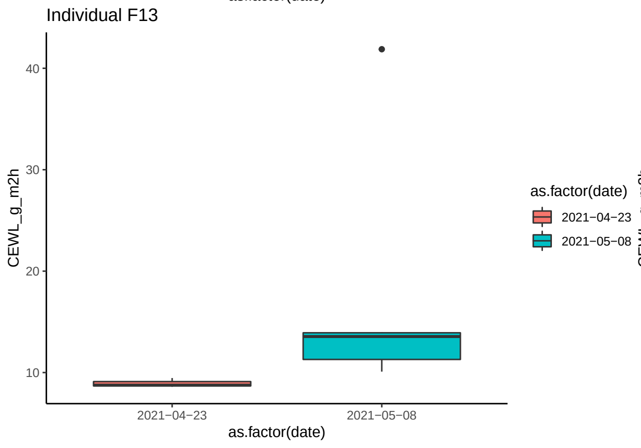
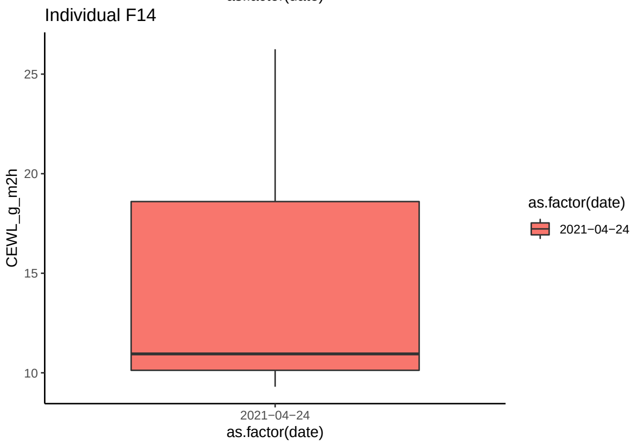
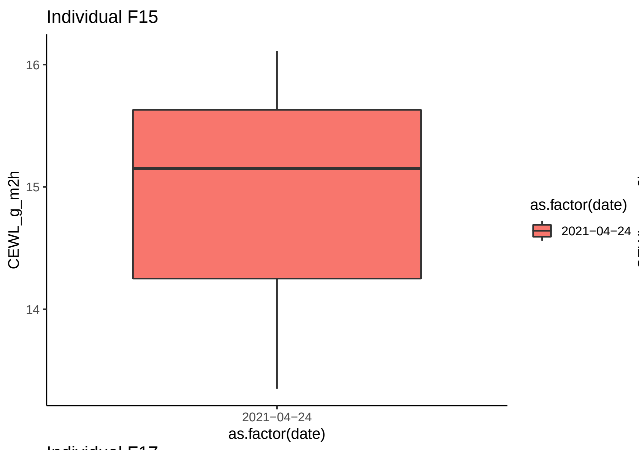

```
outliers_found
```

```
## # A tibble: 24 x 3
## # Groups:   individual_ID, date [18]
##    individual_ID date        outs
##    <fct>         <date>     <dbl>
##  1 F13           2021-05-08 41.9
##  2 F06           2021-05-08 13.8
##  3 M10           2021-05-07  7.17
##  4 M10           2021-05-07  2.79
##  5 M11           2021-05-07 13.5
##  6 M11           2021-07-14 11.5
##  7 M13           2021-07-14 17.1
##  8 M13           2021-07-14 11.3
##  9 M19           2021-07-14 17.9
## 10 M20           2021-07-14 11.3
## # ... with 14 more rows
```

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


Individual F01
CEWL_g_m2h
15
13
11
9
7
2021−04−23
2021−05−08
as.factor(date)
as.factor(date)
2021−04−23
2021−05−08

Individual F10
CEWL_g_m2h
16
14
12
10
2021−04−24
2021−07−14
as.factor(date)
as.factor(date)
2021−04−24
2021−07−14

Individual F11
CEWL_g_m2h
20
15
10
2021−04−23
2021−05−08
as.factor(date)
as.factor(date)
2021−04−23
2021−05−08

Individual F12
CEWL_g_m2h
10
5
0
2021−04−23
2021−05−08
2021−07−14
as.factor(date)
as.factor(date)
2021−04−23
2021−05−08
2021−07−14

Individual F13
CEWL_g_m2h
40
30
20
10
2021−04−23
2021−05−08
as.factor(date)
as.factor(date)
2021−04−23
2021−05−08

Individual F14
CEWL_g_m2h
25
20
15
10
2021−04−24
as.factor(date)
as.factor(date)
2021−04−24


Individual F15
CEWL_g_m2h
16
15
14
2021−04−24
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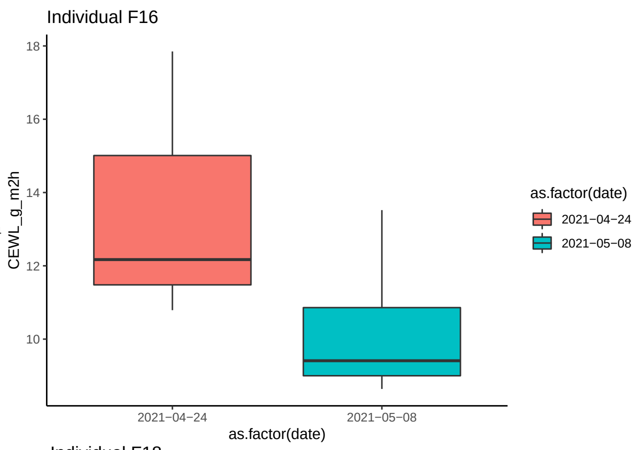
2021−04−24


Individual F16
CEWL_g_m2h
18
16
14
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2021−04−24
2021−05−08
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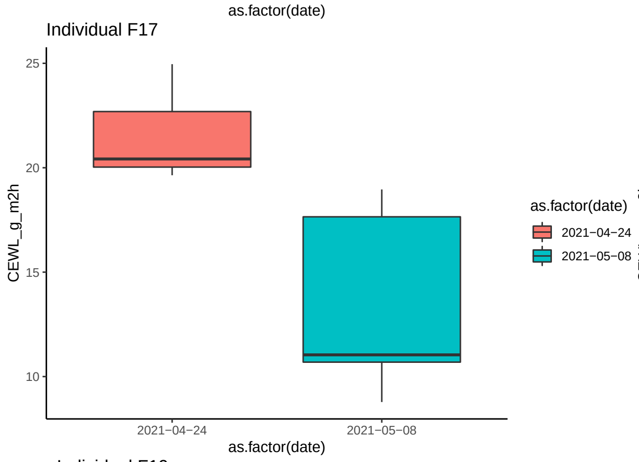
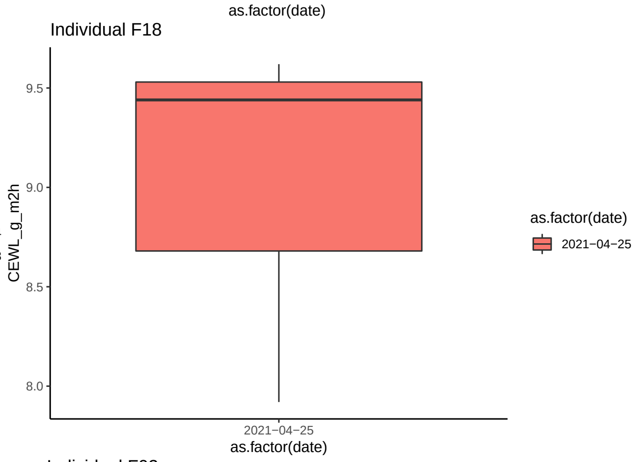
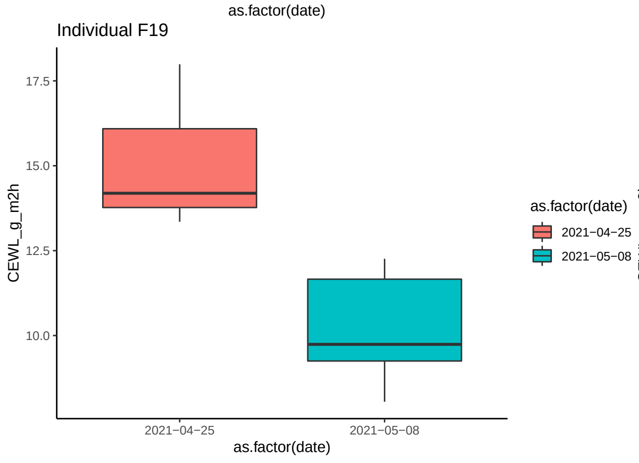
as.factor(date)
2021−04−24
2021−05−08


Individual F17
CEWL_g_m2h
25
20
15
10
2021−04−24
2021−05−08
as.factor(date)
as.factor(date)
2021−04−24
2021−05−08


Individual F18
CEWL_g_m2h
9.5
9.0
8.5
8.0
2021−04−25
as.factor(date)
as.factor(date)
2021−04−25


Individual F19
CEWL_g_m2h
17.5
15.0
12.5
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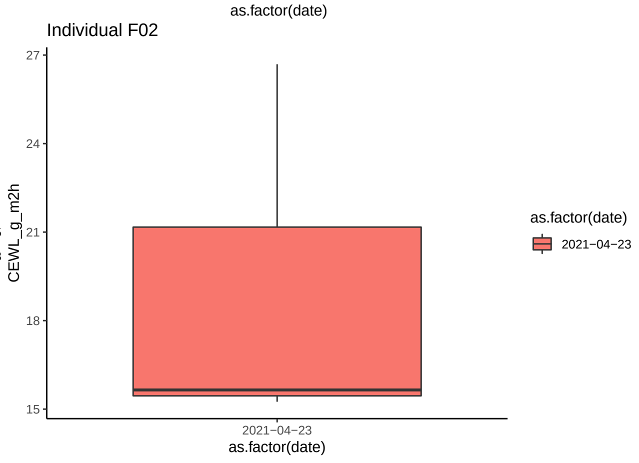
2021−04−25
2021−05−08
as.factor(date)
as.factor(date)
2021−04−25
2021−05−08


Individual F02
CEWL_g_m2h
27
24
21
18
15
2021−04−23
as.factor(date)
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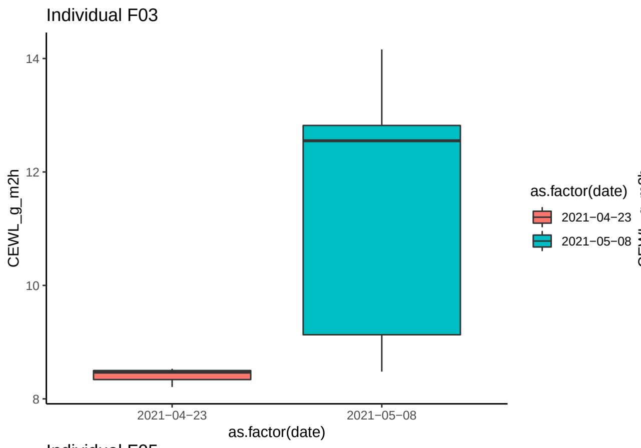
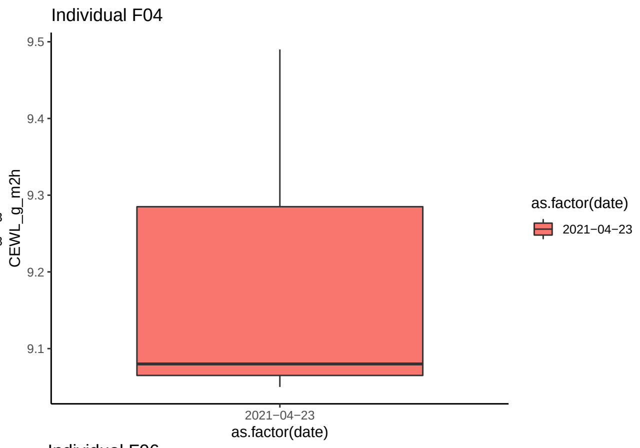
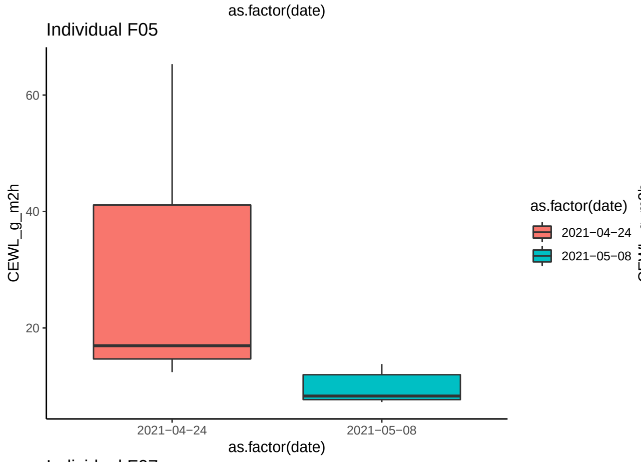
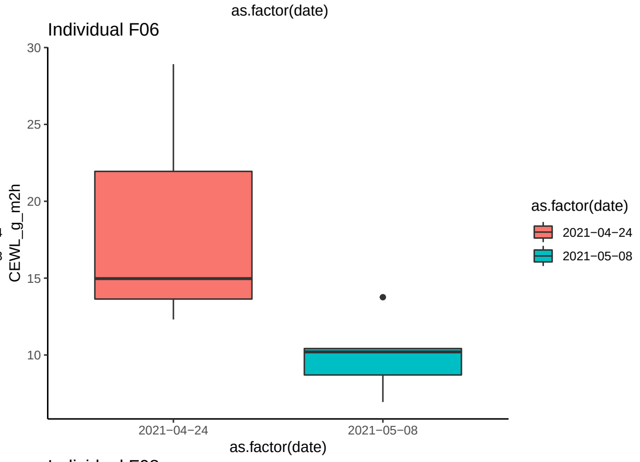
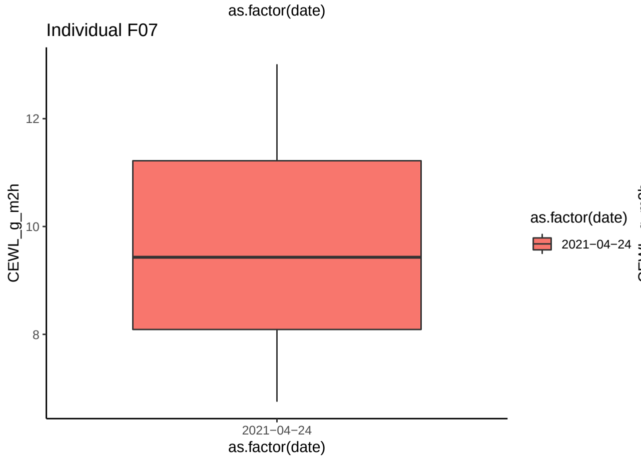
2021−04−23

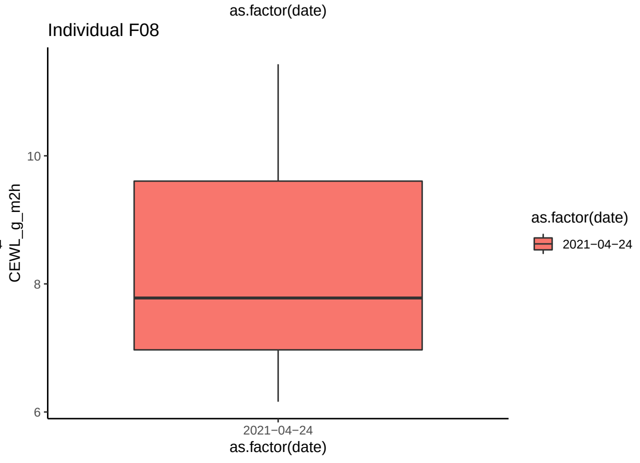

Individual F03
CEWL_g_m2h
14
12
10
8
2021−04−23
2021−05−08
as.factor(date)
as.factor(date)
2021−04−23
2021−05−08

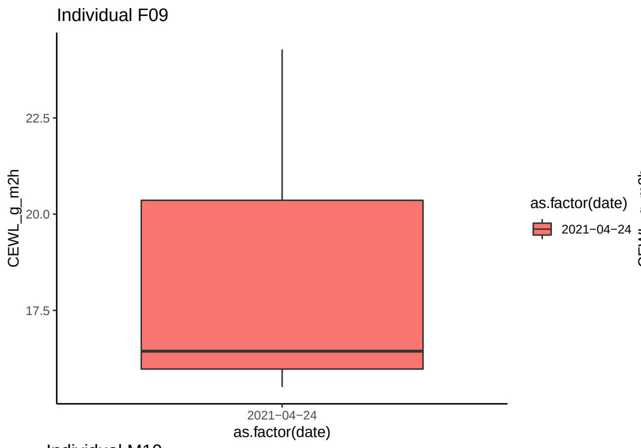

Individual F04
CEWL_g_m2h
9.5
9.4
9.3
9.2
9.1
2021−04−23
as.factor(date)
as.factor(date)
2021−04−23


Individual F05
CEWL_g_m2h
60
40
20
2021−04−24
2021−05−08
as.factor(date)
as.factor(date)
2021−04−24
2021−05−08


Individual F06
CEWL_g_m2h
30
25
20
15
10
2021−04−24
2021−05−08
as.factor(date)
as.factor(date)
2021−04−24
2021−05−08


Individual F07
CEWL_g_m2h
12
10
8
2021−04−24
as.factor(date)
as.factor(date)
2021−04−24


Individual F08
CEWL_g_m2h
10
8
6
2021−04−24
as.factor(date)
as.factor(date)
2021−04−24


Individual F09
CEWL_g_m2h
22.5
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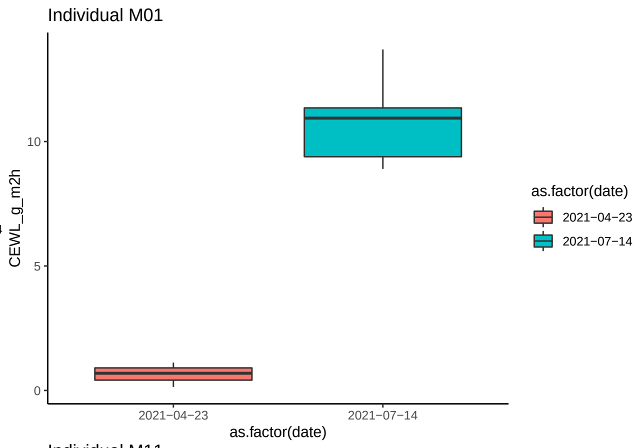
17.5
2021−04−24
as.factor(date)
as.factor(date)
2021−04−24


Individual M01
CEWL_g_m2h
10
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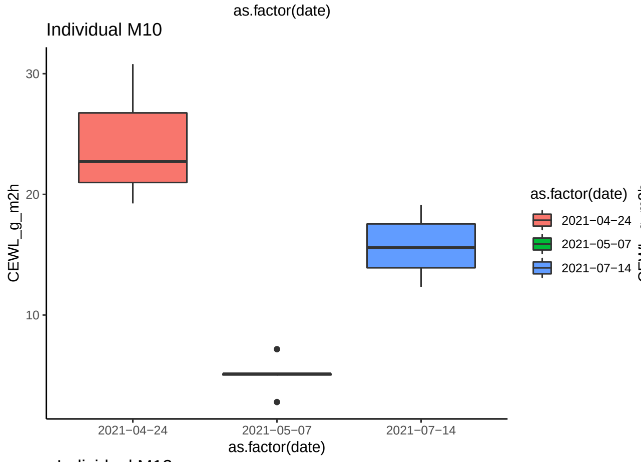
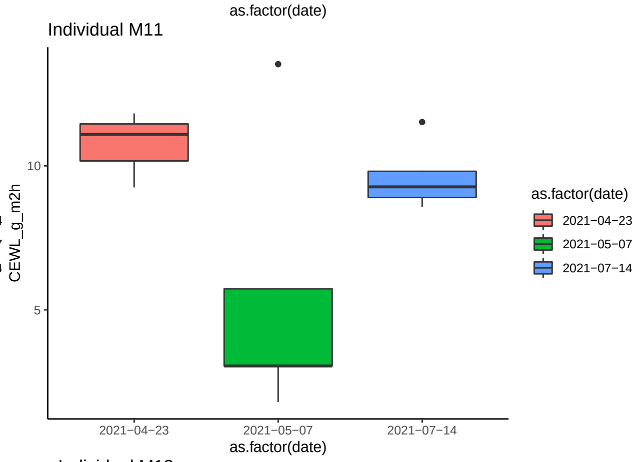
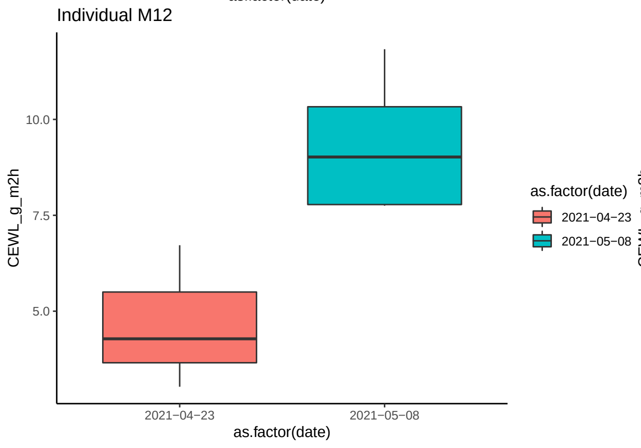
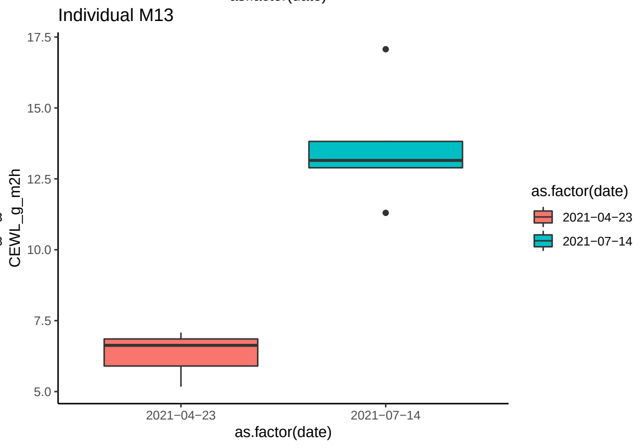
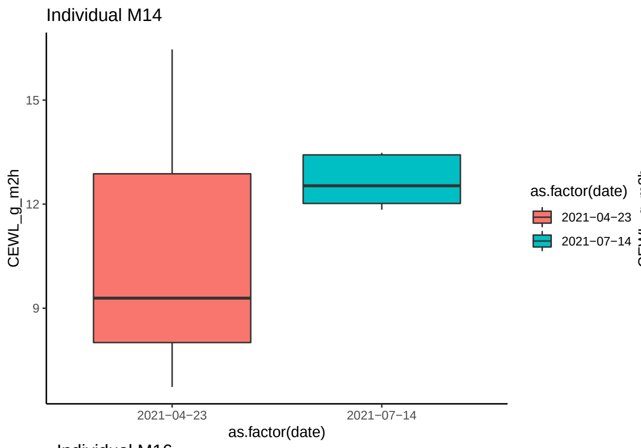
2021−04−23
2021−07−14
as.factor(date)
as.factor(date)
2021−04−23
2021−07−14

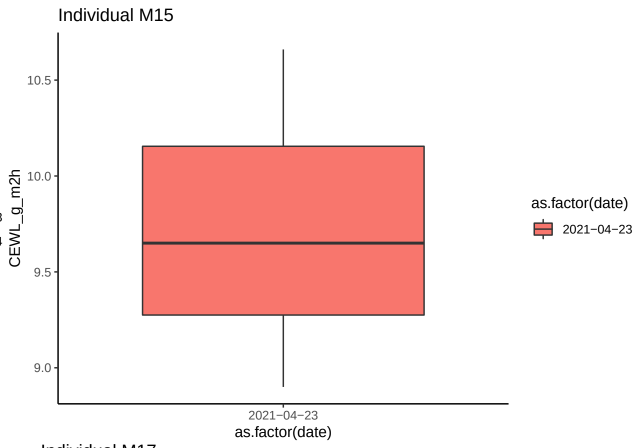

Individual M10
CEWL_g_m2h
30
20
10
2021−04−24
2021−05−07
2021−07−14
as.factor(date)
as.factor(date)
2021−04−24
2021−05−07
2021−07−14


Individual M11
CEWL_g_m2h
10
5
2021−04−23
2021−05−07
2021−07−14
as.factor(date)
as.factor(date)
2021−04−23
2021−05−07
2021−07−14


Individual M12
CEWL_g_m2h
10.0
7.5
5.0
2021−04−23
2021−05−08
as.factor(date)
as.factor(date)
2021−04−23
2021−05−08


Individual M13
CEWL_g_m2h
17.5
15.0
12.5
10.0
7.5
5.0
2021−04−23
2021−07−14
as.factor(date)
as.factor(date)
2021−04−23
2021−07−14


Individual M14
CEWL_g_m2h
15
12
9
2021−04−23
2021−07−14
as.factor(date)
as.factor(date)
2021−04−23
2021−07−14


Individual M15
CEWL_g_m2h
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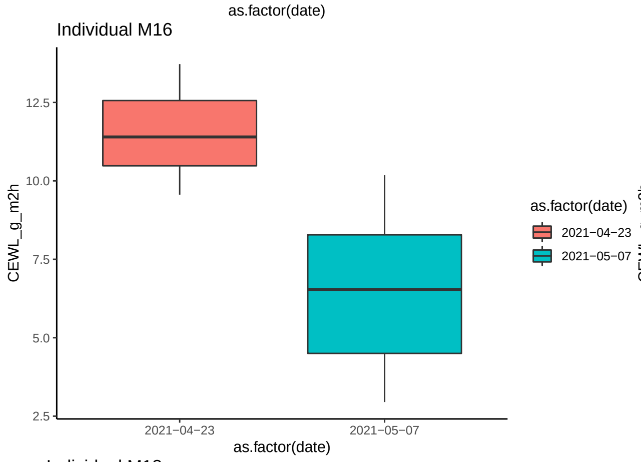
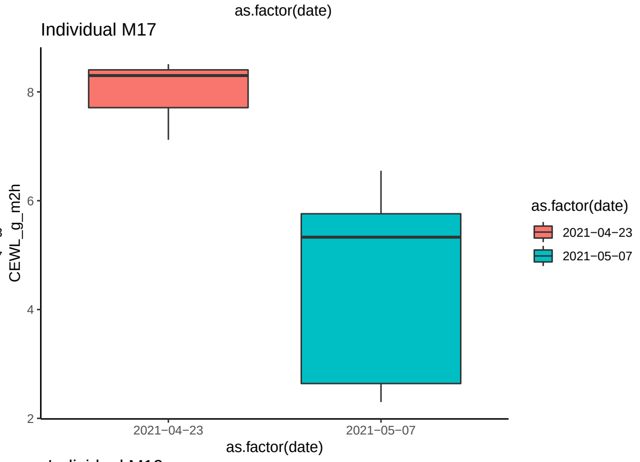
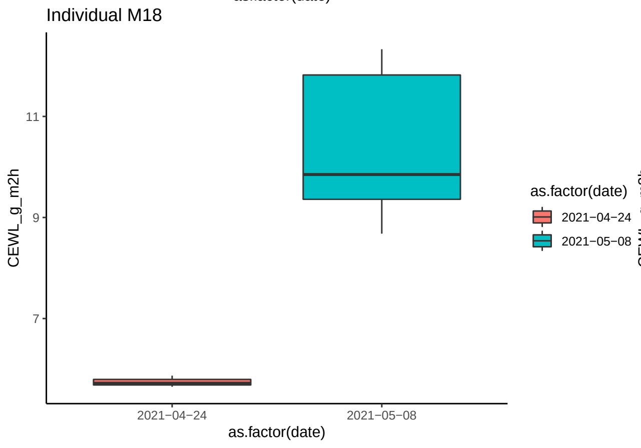
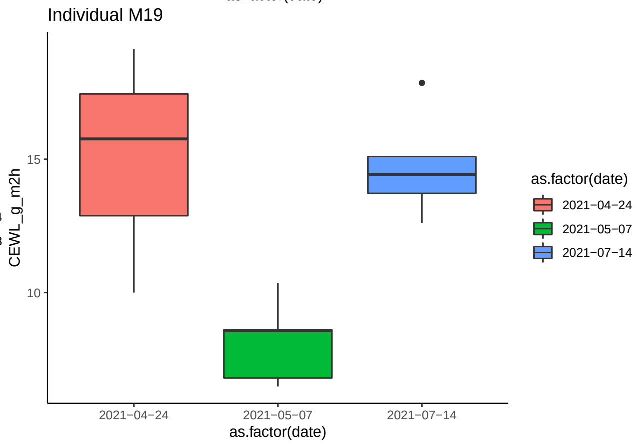
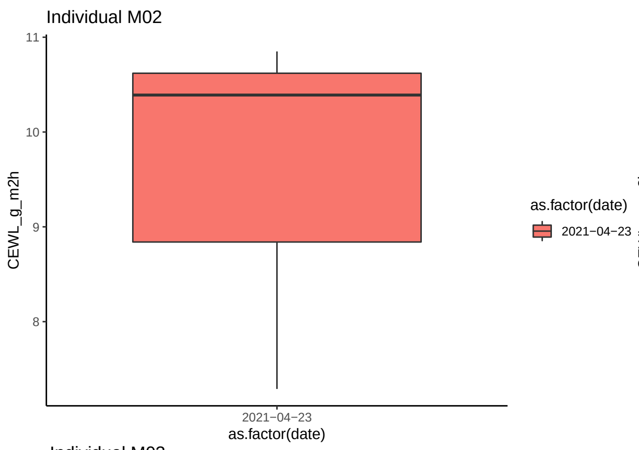
9.5
9.0
2021−04−23
as.factor(date)
as.factor(date)
2021−04−23


Individual M16
CEWL_g_m2h
12.5
10.0
7.5
5.0
2.5
2021−04−23
2021−05−07
as.factor(date)
as.factor(date)
2021−04−23
2021−05−07


Individual M17
CEWL_g_m2h
8
6
4
2
2021−04−23
2021−05−07
as.factor(date)
as.factor(date)
2021−04−23
2021−05−07


Individual M18
CEWL_g_m2h
11
9
7
2021−04−24
2021−05−08
as.factor(date)
as.factor(date)
2021−04−24
2021−05−08


Individual M19
CEWL_g_m2h
15
10
2021−04−24
2021−05−07
2021−07−14
as.factor(date)
as.factor(date)
2021−04−24
2021−05−07
2021−07−14


Individual M02
CEWL_g_m2h
11
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8
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as.factor(date)
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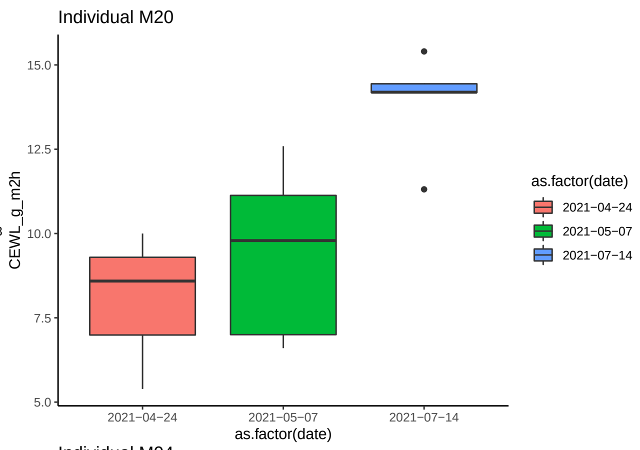
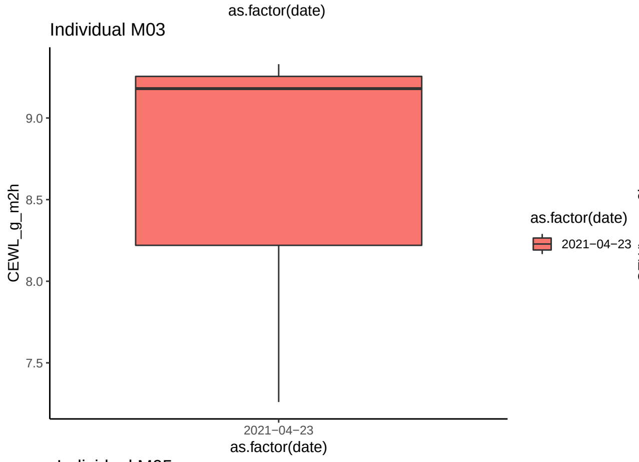
🟥 2021−04−23


Individual M20
CEWL_g_m2h
15.0
12.5
10.0
7.5
5.0
2021−04−24
2021−05−07
2021−07−14
as.factor(date)
as.factor(date)
🟥 2021−04−24
🟩 2021−05−07
🟦 2021−07−14


Individual M03
CEWL_g_m2h
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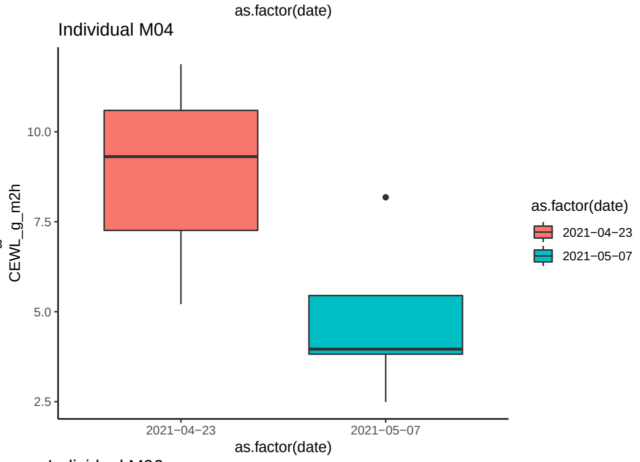
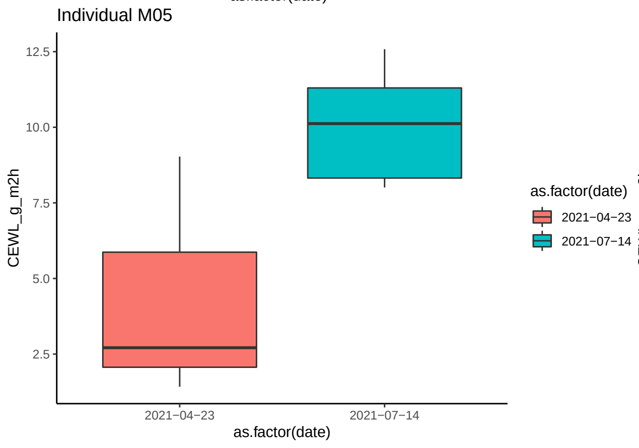
8.5
8.0
7.5
2021−04−23
as.factor(date)
as.factor(date)
🟥 2021−04−23


Individual M04
CEWL_g_m2h
10.0
7.5
5.0
2.5
2021−04−23
2021−05−07
as.factor(date)
as.factor(date)
🟥 2021−04−23
🟦 2021−05−07


Individual M05
CEWL_g_m2h
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10.0
7.5
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2.5
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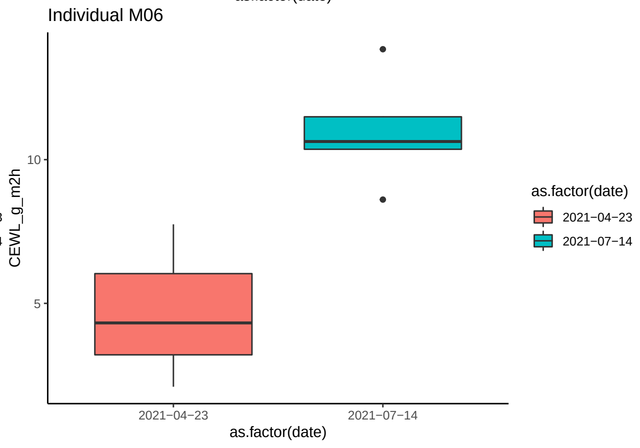
2021−07−14
as.factor(date)
as.factor(date)
🟥 2021−04−23
🟦 2021−07−14


Individual M06
CEWL_g_m2h
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2021−07−14
as.factor(date)
as.factor(date)
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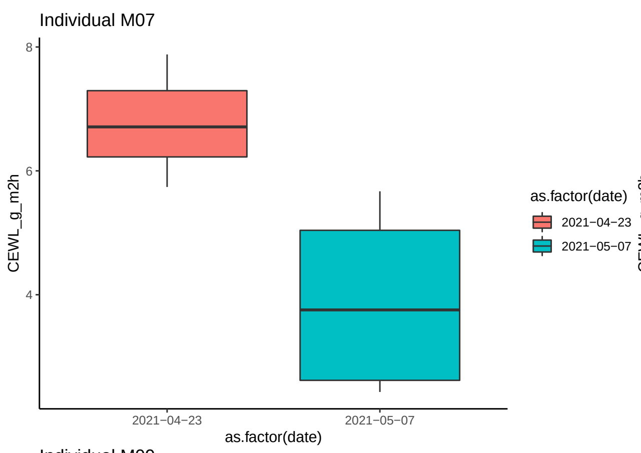
🟦 2021−07−14


Individual M07
CEWL_g_m2h
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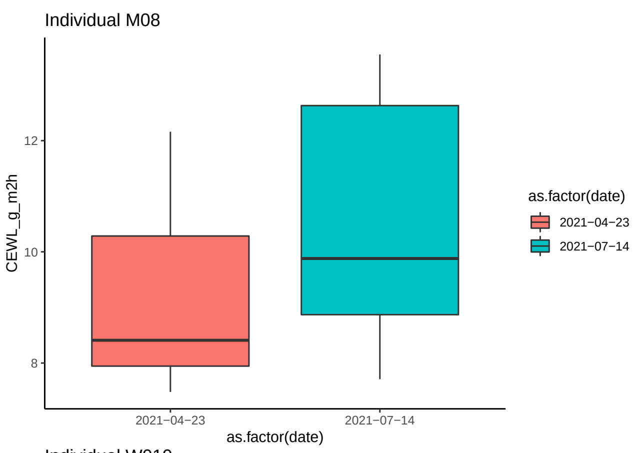
2021−04−23
2021−05−07
as.factor(date)
2021−04−23
2021−05−07


Individual M08
CEWL_g_m2h
12
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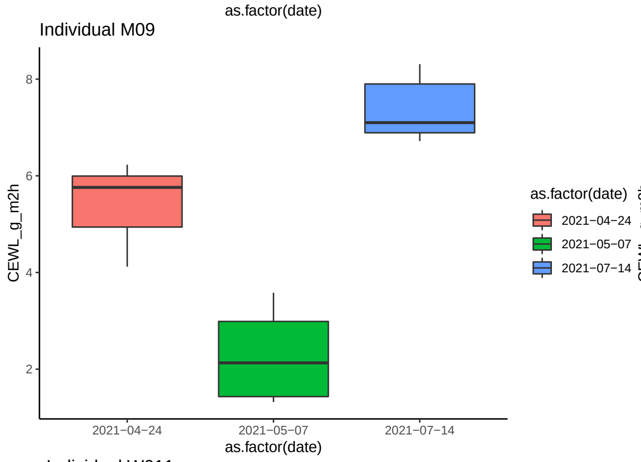
8
2021−04−23
2021−07−14
as.factor(date)
2021−04−23
2021−07−14


Individual M09
CEWL_g_m2h
8
6
4
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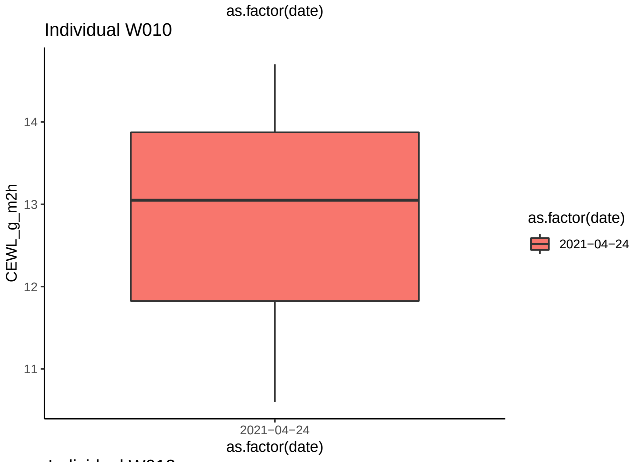
2021−04−24
2021−05−07
2021−07−14
as.factor(date)
2021−04−24
2021−05−07
2021−07−14


Individual W010
CEWL_g_m2h
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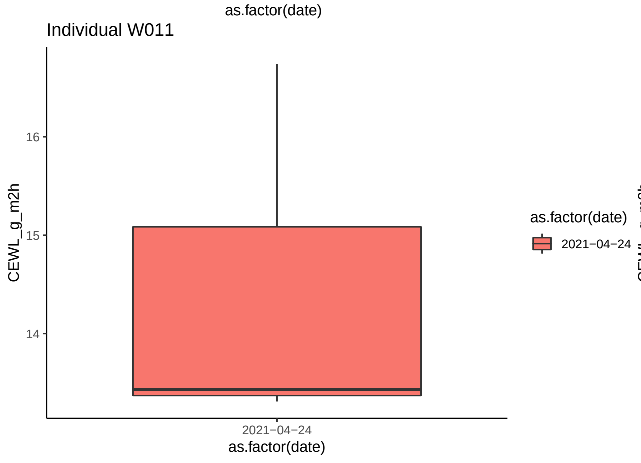
2021−04−24
as.factor(date)
2021−04−24


Individual W011
CEWL_g_m2h
16
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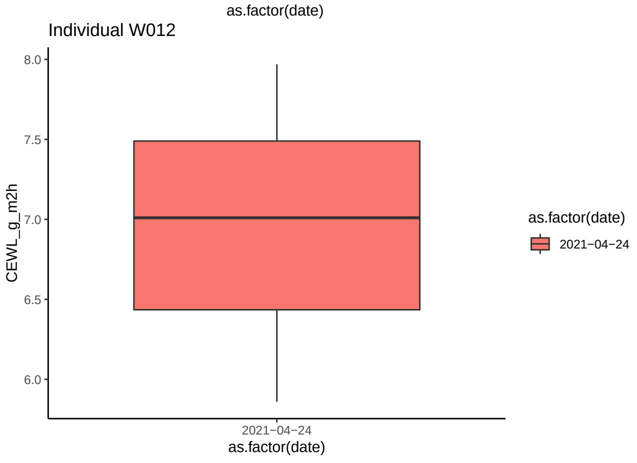
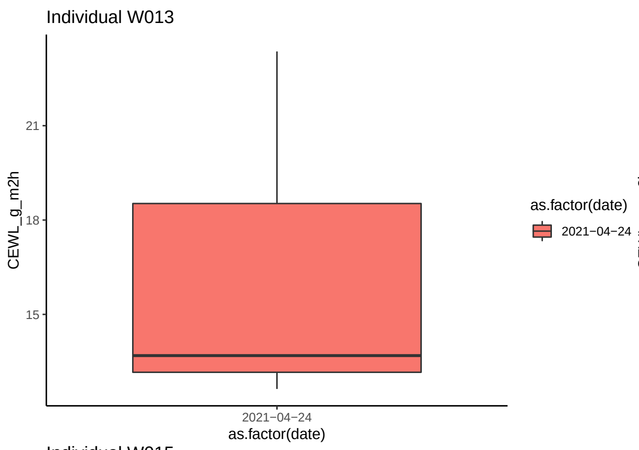
2021−04−24
as.factor(date)
2021−04−24


Individual W012
CEWL_g_m2h
8.0
7.5
7.0
6.5
6.0
2021−04−24
as.factor(date)
2021−04−24


Individual W013
CEWL_g_m2h
21
18
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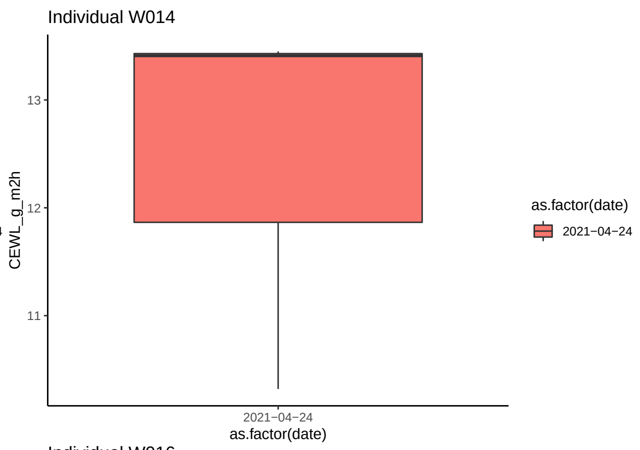
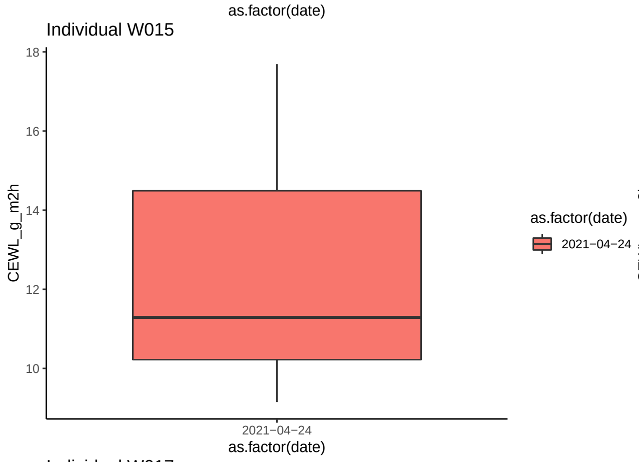
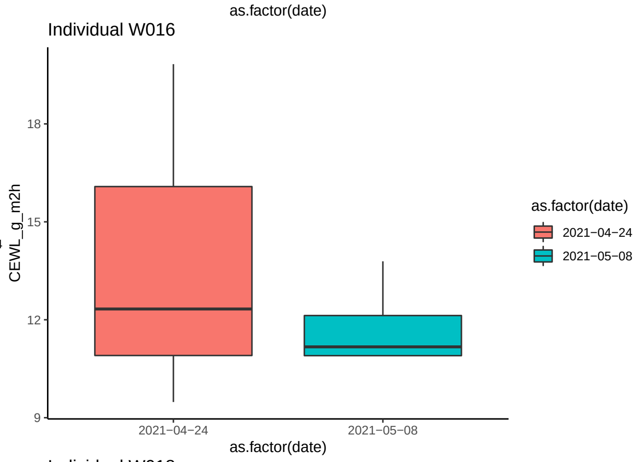
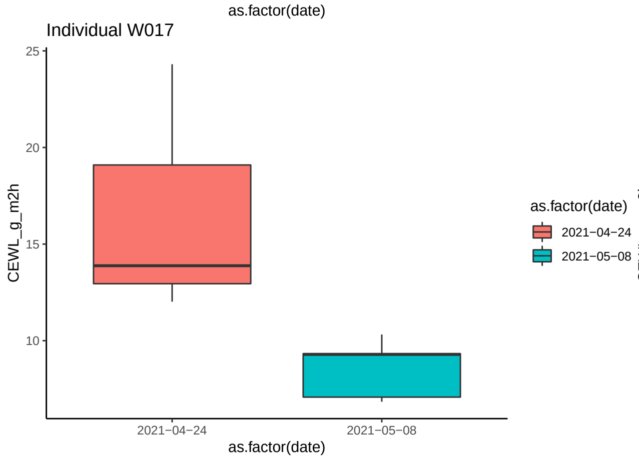
2021−04−24
as.factor(date)
as.factor(date)
2021−04−24


Individual W014
CEWL_g_m2h
13
12
11
2021−04−24
as.factor(date)
as.factor(date)
2021−04−24


Individual W015
CEWL_g_m2h
18
16
14
12
10
2021−04−24
as.factor(date)
as.factor(date)
2021−04−24


Individual W016
CEWL_g_m2h
18
15
12
9
2021−04−24
2021−05−08
as.factor(date)
as.factor(date)
2021−04−24
2021−05−08


Individual W017
CEWL_g_m2h
25
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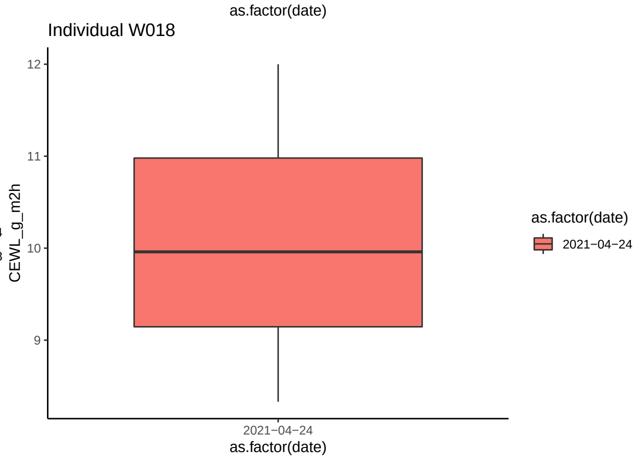
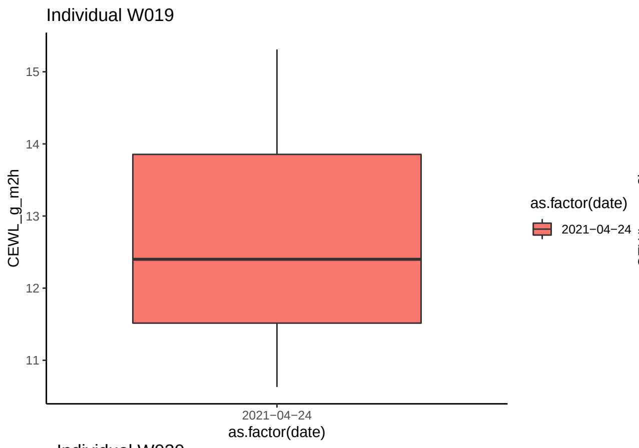
2021−04−24
2021−05−08
as.factor(date)
as.factor(date)
2021−04−24
2021−05−08


Individual W018
CEWL_g_m2h
12
11
10
9
2021−04−24
as.factor(date)
as.factor(date)
2021−04−24


Individual W019
CEWL_g_m2h
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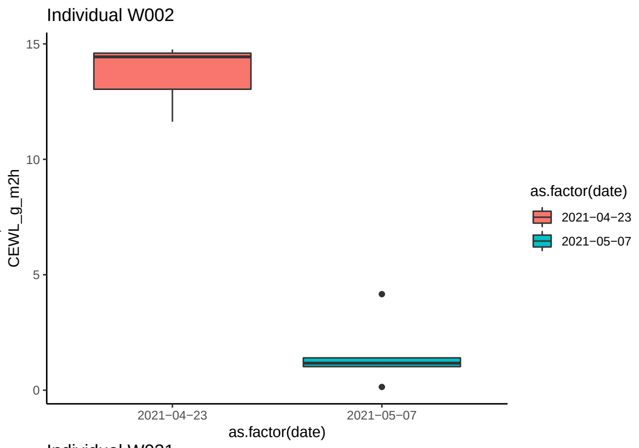
12
11
2021−04−24
as.factor(date)
as.factor(date)
2021−04−24

Individual W002
CEWL_g_m2h
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10
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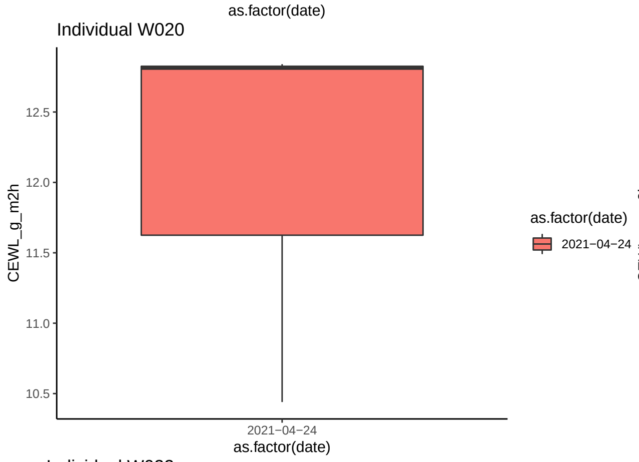
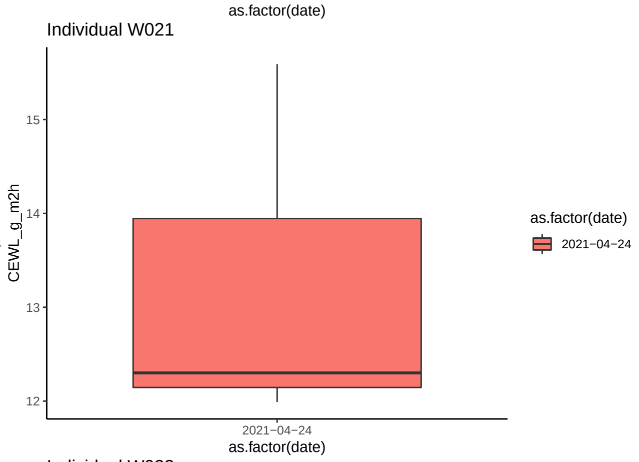
2021−04−23
2021−05−07
as.factor(date)
as.factor(date)
2021−04−23
2021−05−07

Individual W020
CEWL_g_m2h
12.5
12.0
11.5
11.0
10.5
2021−04−24
as.factor(date)
as.factor(date)
2021−04−24

Individual W021
CEWL_g_m2h
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14
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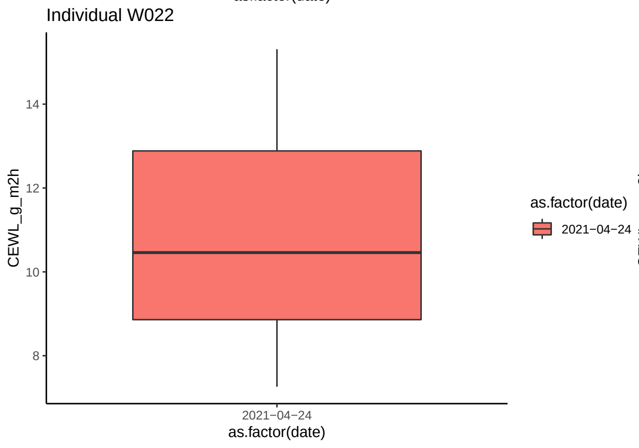
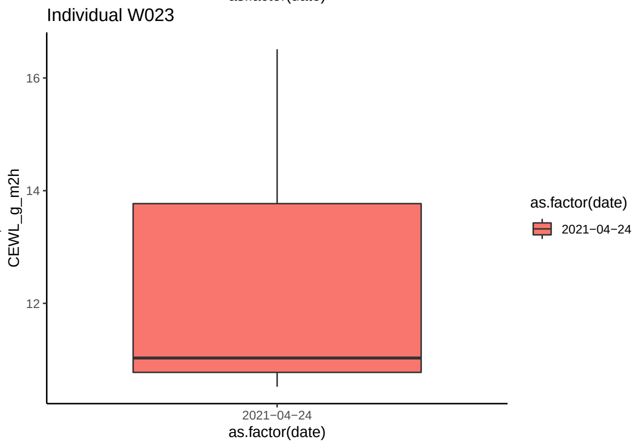
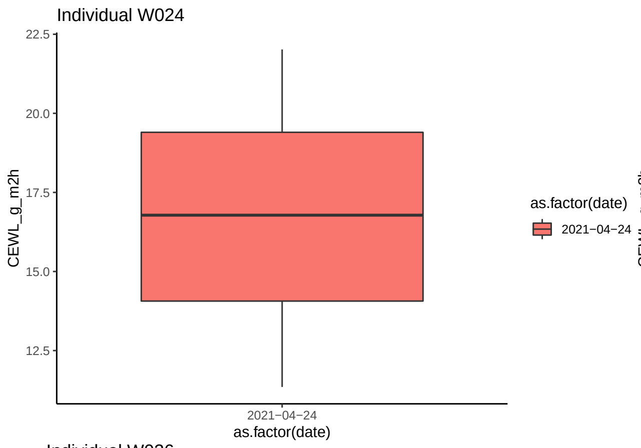
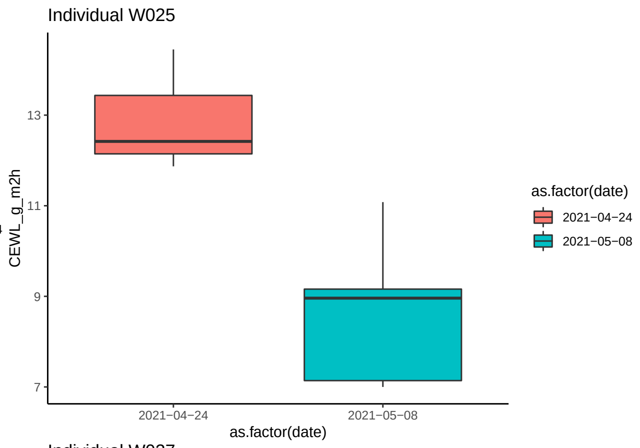
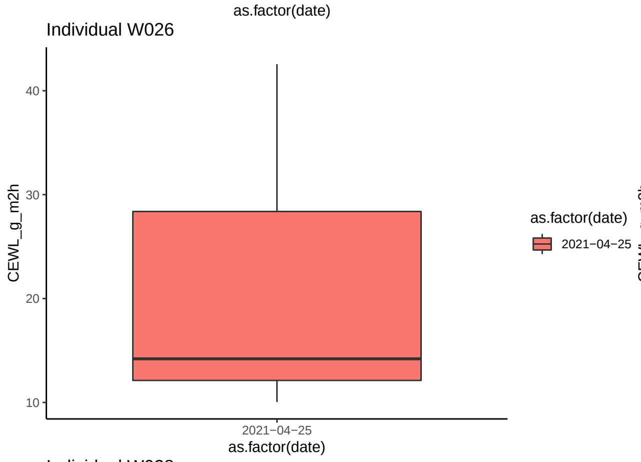
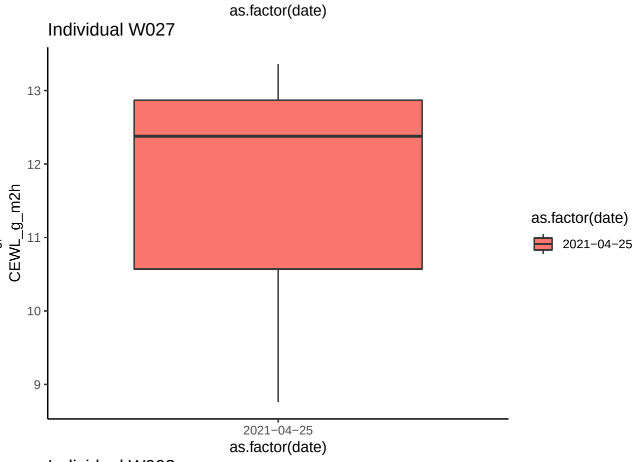
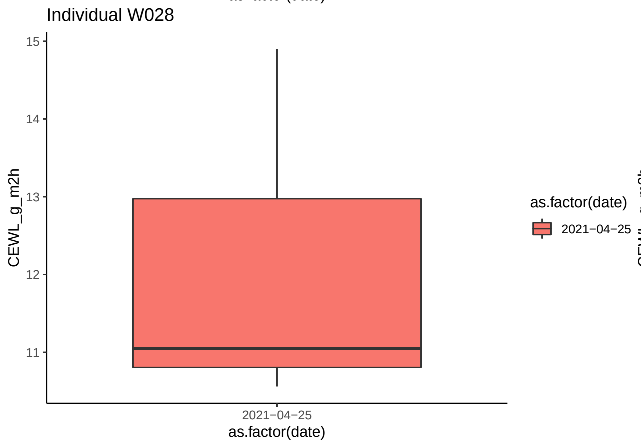
12
2021−04−24
as.factor(date)
as.factor(date)
2021−04−24

Individual W022
CEWL_g_m2h
14
12
10
8
2021−04−24
as.factor(date)
as.factor(date)
2021−04−24

Individual W023
CEWL_g_m2h
16
14
12
2021−04−24
as.factor(date)
as.factor(date)
2021−04−24

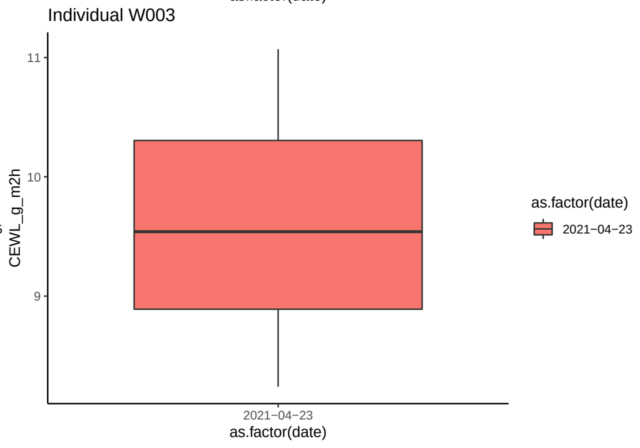

Individual W024
CEWL_g_m2h
22.5
20.0
17.5
15.0
12.5
2021−04−24
as.factor(date)
as.factor(date)
2021−04−24

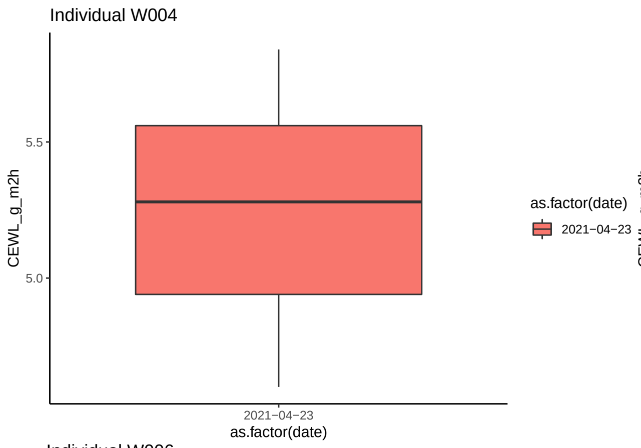

Individual W025
CEWL_g_m2h
13
11
9
7
2021−04−24
2021−05−08
as.factor(date)
as.factor(date)
2021−04−24
2021−05−08

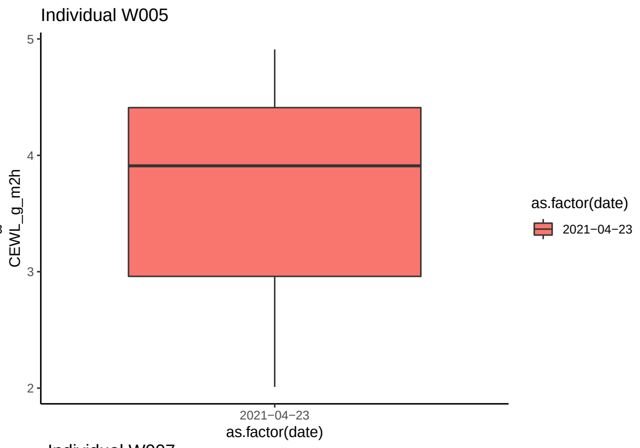

Individual W026
CEWL_g_m2h
40
30
20
10
2021−04−25
as.factor(date)
as.factor(date)
2021−04−25

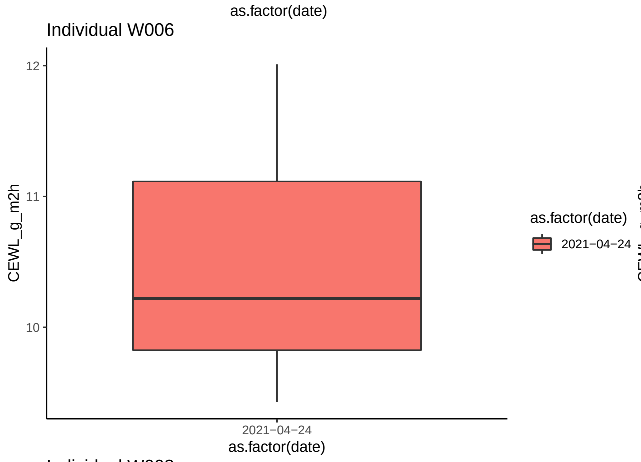

Individual W027
CEWL_g_m2h
13
12
11
10
9
2021−04−25
as.factor(date)
as.factor(date)
2021−04−25

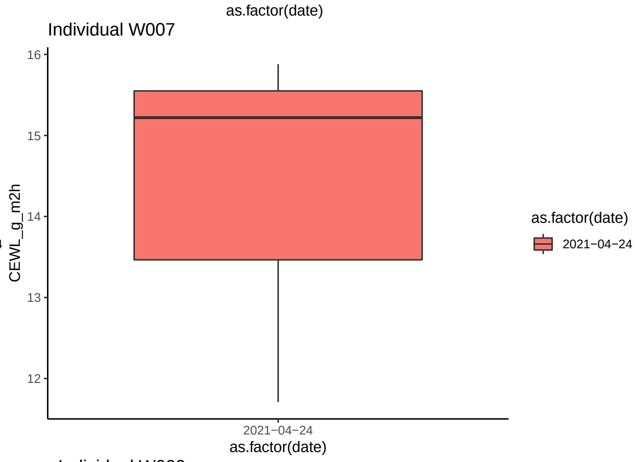

Individual W028
CEWL_g_m2h
15
14
13
12
11
2021−04−25
as.factor(date)
as.factor(date)
2021−04−25

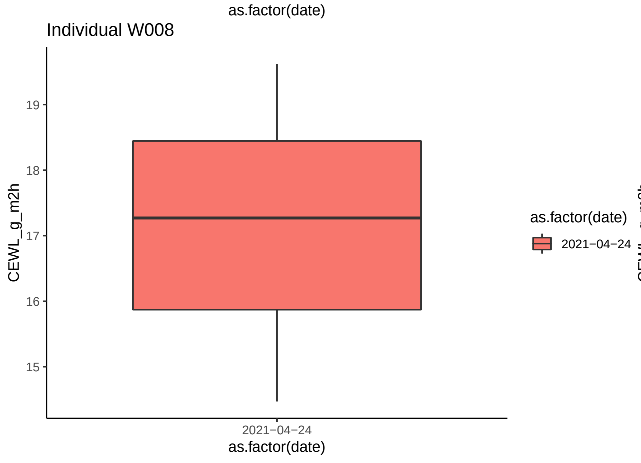

Individual W003
CEWL_g_m2h
11
10
9
2021−04−23
as.factor(date)
as.factor(date)
2021−04−23

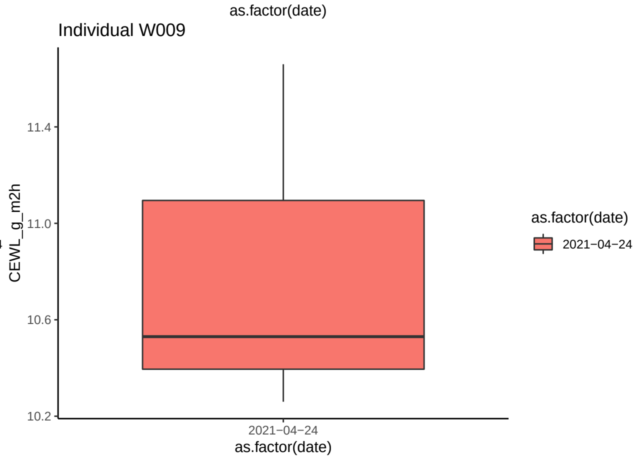

Individual W004
5.5
5.0
CEWL_g_m2h
2021−04−23
as.factor(date)
as.factor(date)
2021−04−23

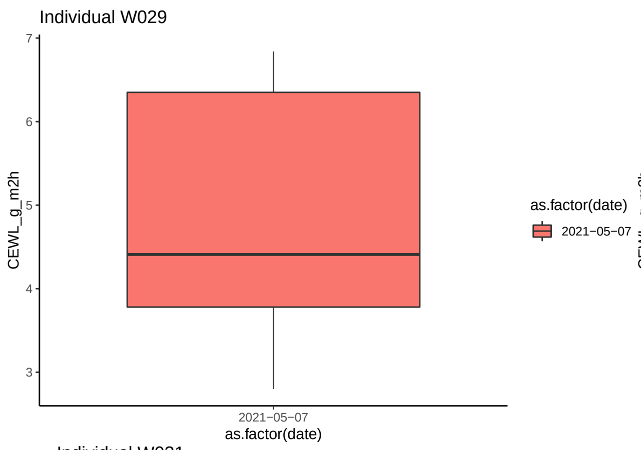

Individual W005
5
4
3
2
CEWL_g_m2h
2021−04−23
as.factor(date)
as.factor(date)
2021−04−23

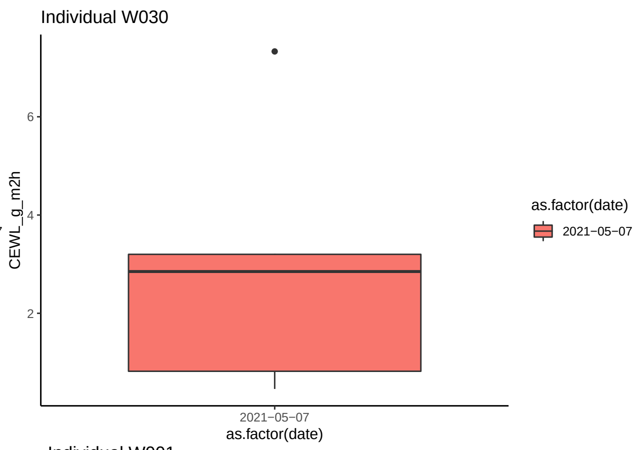

Individual W006
12
11
10
CEWL_g_m2h
2021−04−24
as.factor(date)
as.factor(date)
2021−04−24

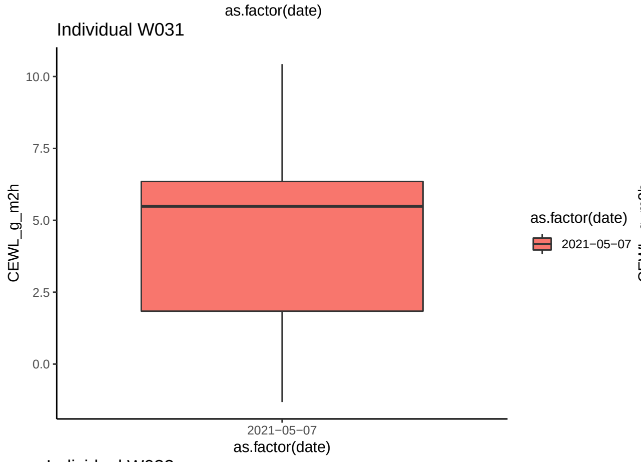

Individual W007
16
15
14
13
12
CEWL_g_m2h
2021−04−24
as.factor(date)
as.factor(date)
2021−04−24

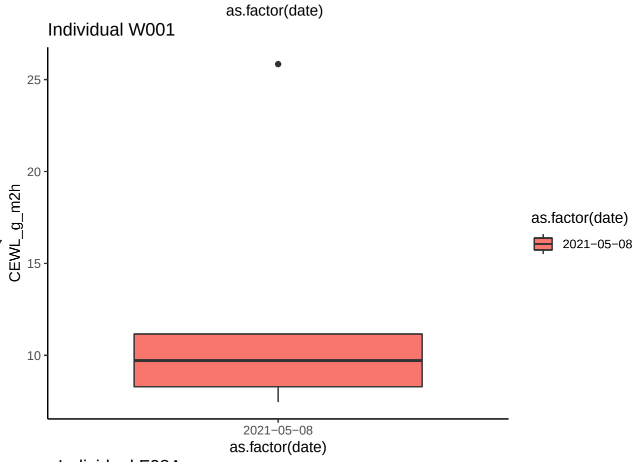

Individual W008
19
18
17
16
15
CEWL_g_m2h
2021−04−24
as.factor(date)
as.factor(date)
2021−04−24

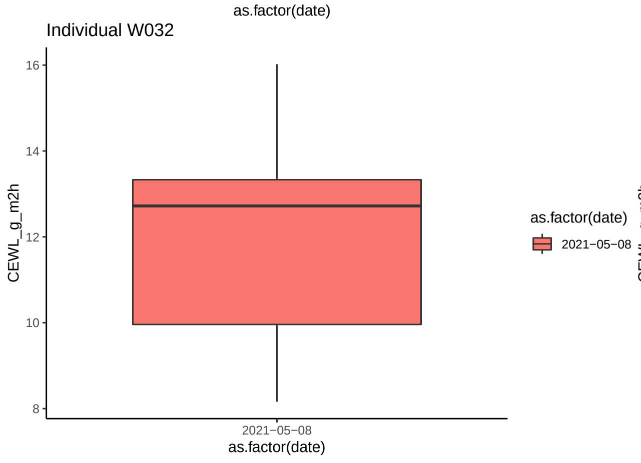

Individual W009
11.4
11.0
10.6
10.2
CEWL_g_m2h
2021−04−24
as.factor(date)
as.factor(date)
2021−04−24

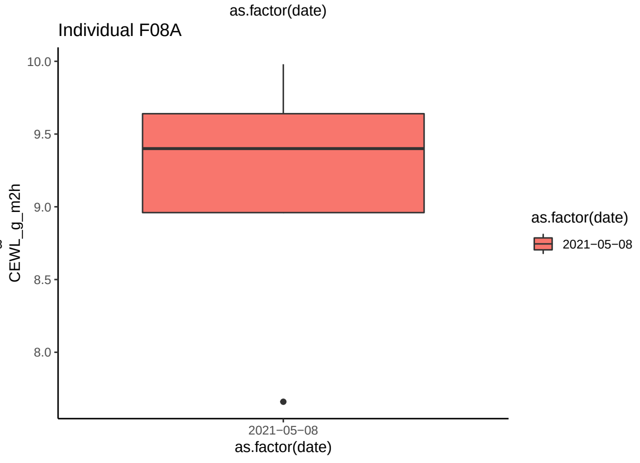

Individual W029
CEWL_g_m2h
7
6
5
4
3
2021−05−07
as.factor(date)
as.factor(date)
2021−05−07

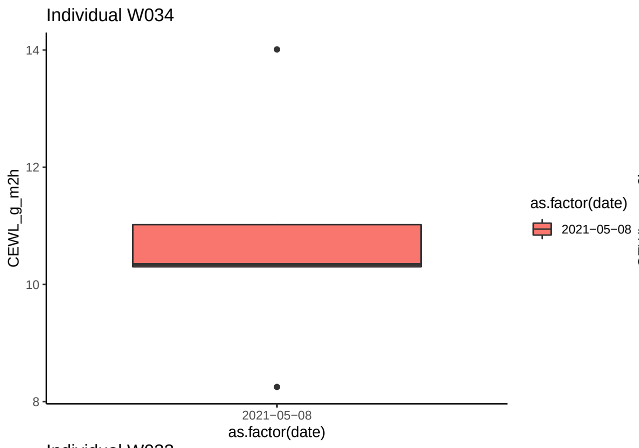

Individual W030
CEWL_g_m2h
6
4
2
2021−05−07
as.factor(date)
as.factor(date)
2021−05−07

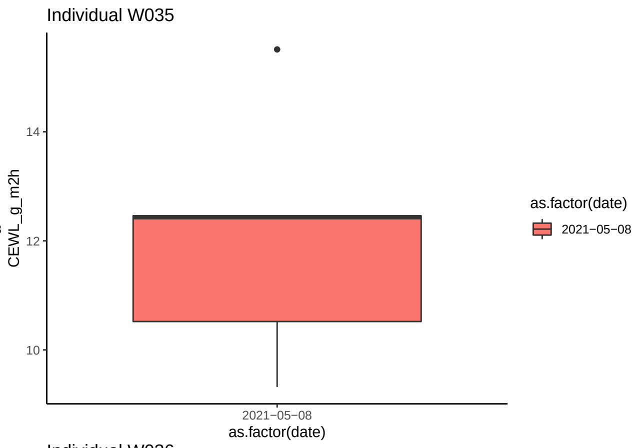

Individual W031
CEWL_g_m2h
10.0
7.5
5.0
2.5
0.0
2021−05−07
as.factor(date)
as.factor(date)
2021−05−07

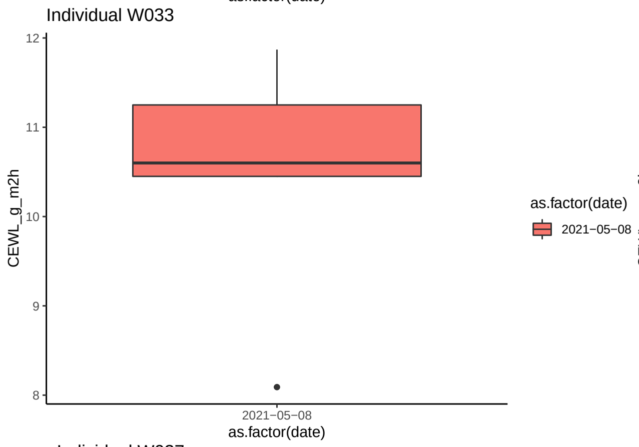

Individual W001
CEWL_g_m2h
25
20
15
10
2021−05−08
as.factor(date)
as.factor(date)
2021−05−08

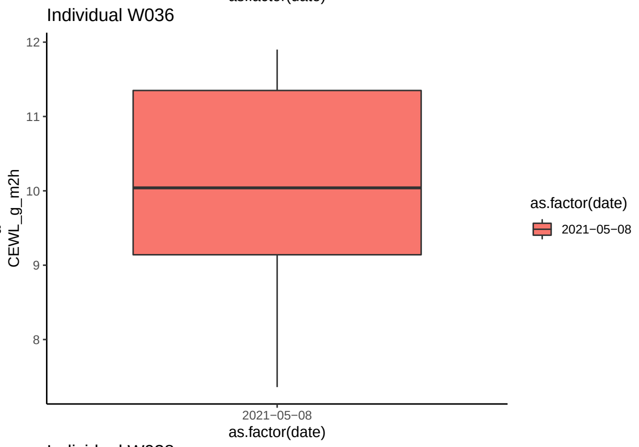

Individual W032
CEWL_g_m2h
16
14
12
10
8
2021−05−08
as.factor(date)
as.factor(date)
2021−05−08

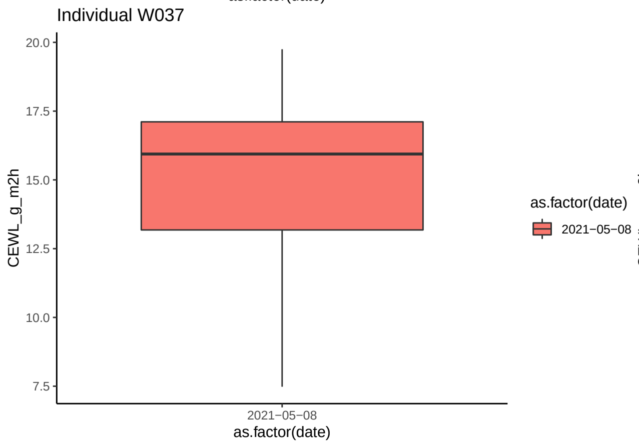

Individual F08A
CEWL_g_m2h
10.0
9.5
9.0
8.5
8.0
2021−05−08
as.factor(date)
as.factor(date)
2021−05−08

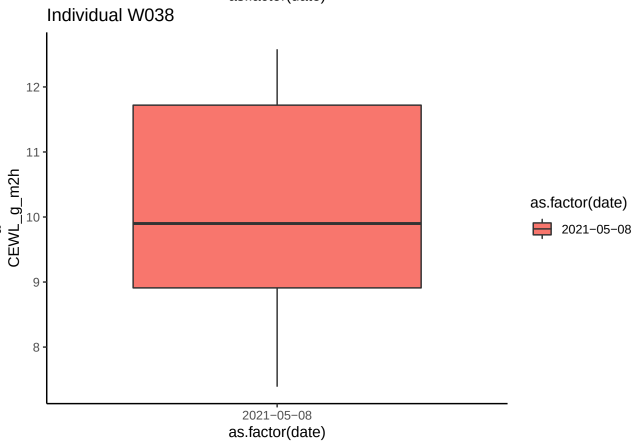

Individual W034
CEWL_g_m2h
14
12
10
8
2021−05−08
as.factor(date)
as.factor(date)
2021−05−08

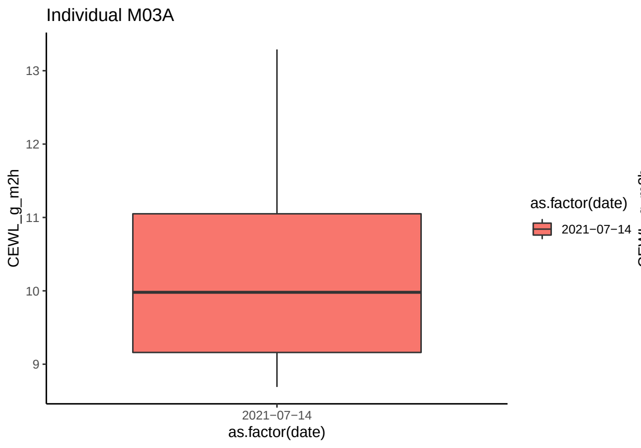

Individual W035
CEWL_g_m2h
14
12
10
2021−05−08
as.factor(date)
as.factor(date)
2021−05−08

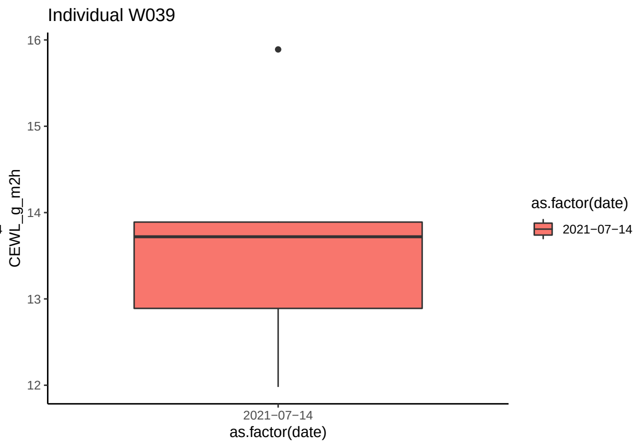

Individual W033
CEWL_g_m2h
12
11
10
9
8
2021−05−08
as.factor(date)
as.factor(date)
2021−05−08


Individual W036
CEWL_g_m2h
12
11
10
9
8
2021−05−08
as.factor(date)
as.factor(date)
2021−05−08


Individual W037
CEWL_g_m2h
20.0
17.5
15.0
12.5
10.0
7.5
2021−05−08
as.factor(date)
as.factor(date)
2021−05−08


Individual W038
CEWL_g_m2h
12
11
10
9
8
2021−05−08
as.factor(date)
as.factor(date)
2021−05−08





Based on the plots, the dataframe of outliers I compiled is correct. (yay!)

Remove Outliers

Now I will create a secondary version of the same function, but instead of compiling outliers, I will omit them from the dataset.

```r
# write function to find and exclude outliers
omit_outliers <- function(df) {

  # initiate dataframe to compile info and list to compile plots
  cleaned <- data.frame()

  # initiate a for loop to go through every who in df
  for(indiv_ch in unique(df$individual_ID)) {

    # select data for only the individual of interest
    df_sub <- df %>%
      dplyr::filter(individual_ID == (indiv_ch))

    # extract outliers
    outs <- df_sub %>%
      group_by(individual_ID, date) %>%
      summarise(outs = boxplot.stats(CEWL_g_m2h)$out)

    # filter outliers from data subset for this individual
    filtered <- df_sub %>%
      dplyr::filter(CEWL_g_m2h %nin% outs$outs)

    # add to running dataframe of cleaned data
    cleaned <- cleaned %>%
      rbind(filtered)
  }
  return(cleaned)
}
```

Apply function to data and check that the new data subsets still contain the right amount of data:

```r
outliers_omitted <- omit_outliers(all_CEWL_data)
nrow(all_CEWL_data) == nrow(outliers_omitted) + nrow(outliers_found)
```

```
## [1] TRUE
```

Re-Assess Variation

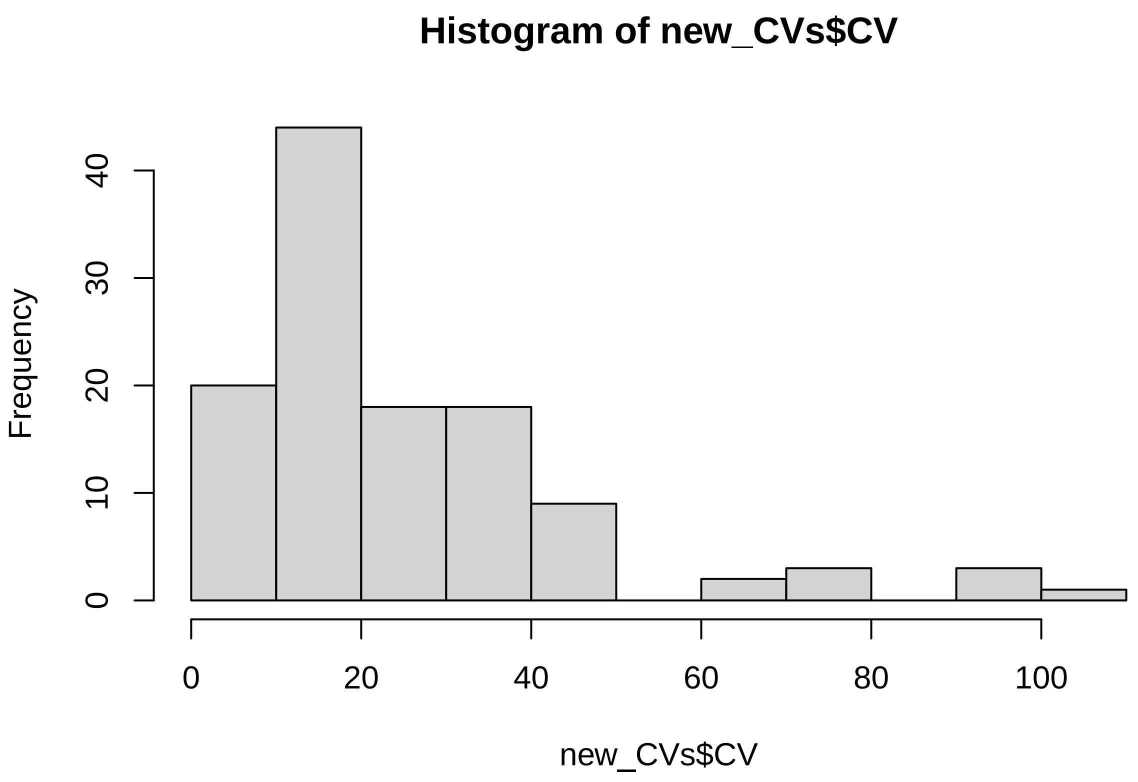
```
new_CVs <- outliers_omitted %>%
  group_by(individual_ID, date) %>%
  summarise(mean = mean(CEWL_g_m2h),
            SD = sd(CEWL_g_m2h),
            CV = (SD/mean) *100,
            min = min(CEWL_g_m2h),
            max = max(CEWL_g_m2h),
            range = max - min)
```

```
## `summarise()` regrouping output by 'individual_ID' (override with `.groups` argument)
```

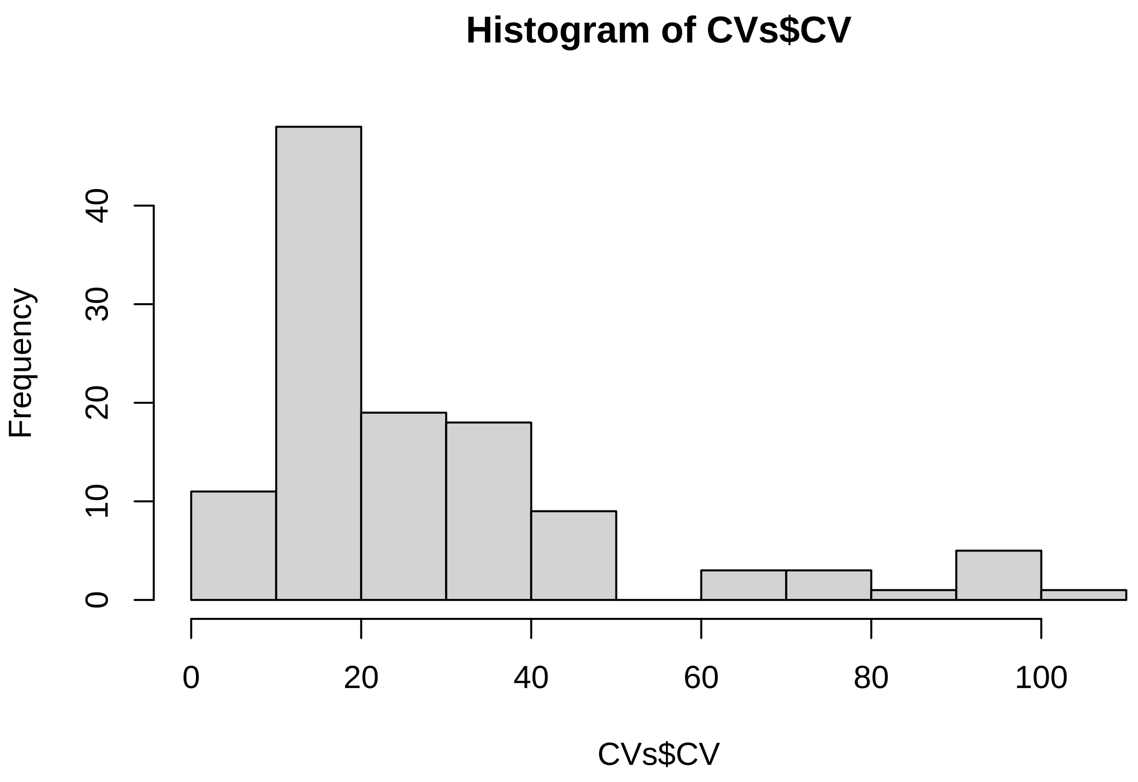
```
summary(new_CVs)
```

```
##  individual_ID      date                  mean              SD          
##  F12    :  3   Min.   :2021-04-23   Min.   : 0.650   Min.   : 0.05508  
##  M09    :  3   1st Qu.:2021-04-24   1st Qu.: 8.486   1st Qu.: 1.21719  
##  M10    :  3   Median :2021-04-24   Median :10.421   Median : 1.85776  
##  M11    :  3   Mean   :2021-05-08   Mean   :10.682   Mean   : 2.65196  
##  M19    :  3   3rd Qu.:2021-05-08   3rd Qu.:13.239   3rd Qu.: 2.88268  
##  M20    :  3   Max.   :2021-07-14   Max.   :31.550   Max.   :29.32424  
##  (Other):100                                                          
##        CV                min               max              range       
##  Min.   :  1.032   Min.   :-1.320   Min.   : 1.120   Min.   : 0.100  
##  1st Qu.: 13.433   1st Qu.: 6.723   1st Qu.: 9.985   1st Qu.: 2.518  
##  Median : 19.265   Median : 8.420   Median :12.545   Median : 4.060  
##  Mean   : 25.543   Mean   : 8.287   Mean   :13.639   Mean   : 5.352  
##  3rd Qu.: 33.436   3rd Qu.:10.502   3rd Qu.:15.520   3rd Qu.: 6.197  
##  Max.   :105.713   Max.   :19.640   Max.   :65.310   Max.   :52.900  
## 
```

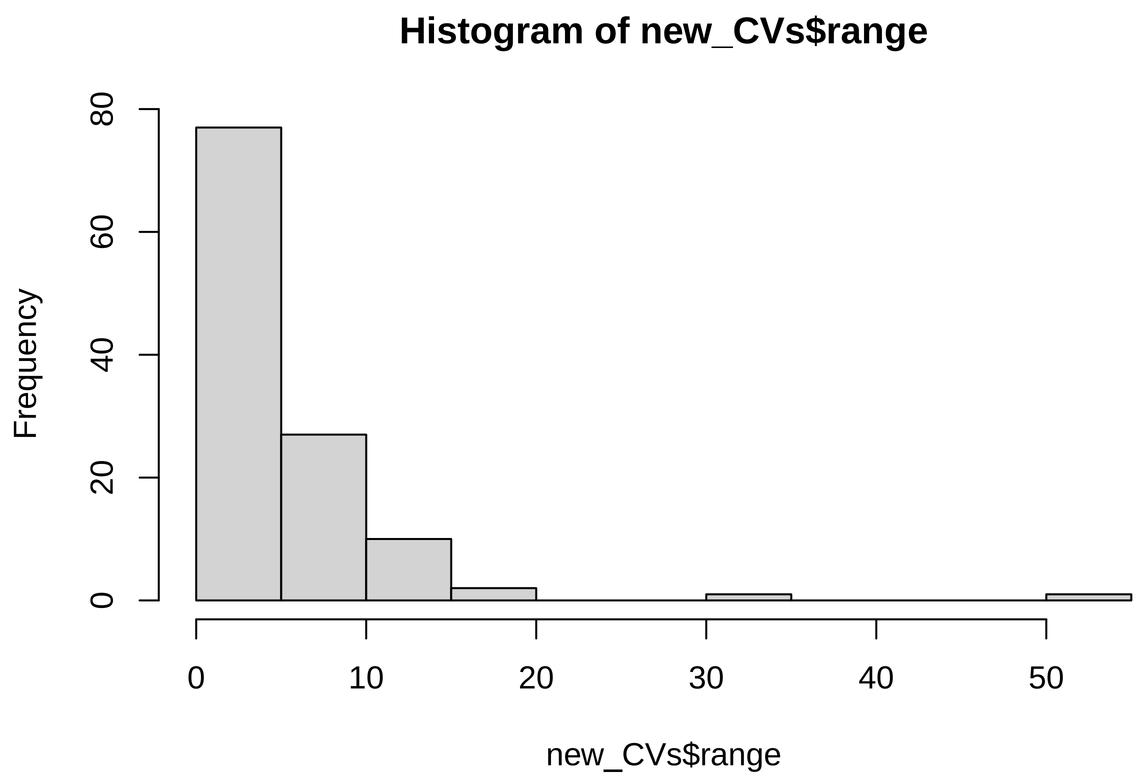
```
hist(new_CVs$CV)
```



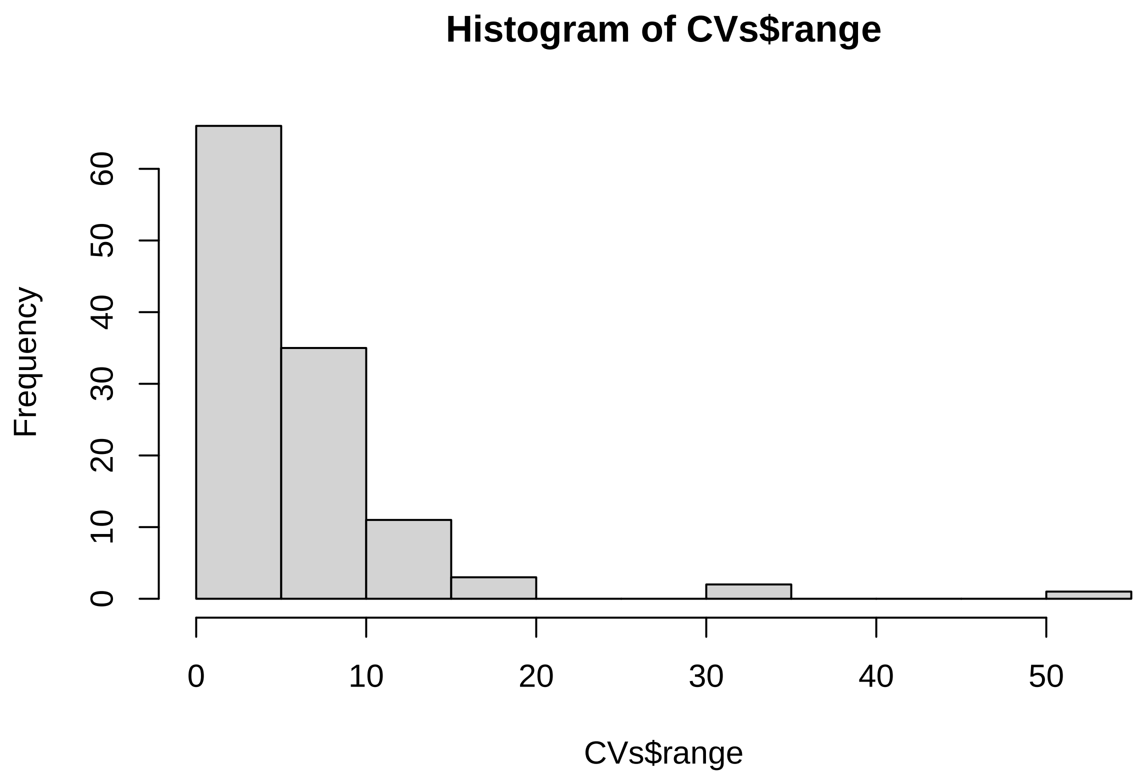
```
hist(CVs$CV)
```



```
hist(new_CVs$range)
```



```
hist(CVs$range)
```



This definitely improved things, but unfortunately, CVs are still skewed to the right. I think the replicate groups with only 3 replicates are harder to find outliers in, so let's compute pairwise CVs and see if we can still minimze the larger range/CV values.

Find "Outliers"

Determine which replicates lead to an increased CV…

```r
# which individuals have how many reps
n_reps <- outliers_omitted %>%
  group_by(individual_ID, date) %>%
  summarise(n = (n()))
```

```
## `summarise()` regrouping output by 'individual_ID' (override with `.groups` argument)
```

```r
# prep dfs for computing CVs
oo_small_345 <- outliers_omitted %>%
  dplyr::select(individual_ID, date, CEWL_g_m2h, replicate_no)

oo_small_45 <- oo_small_345 %>%
  left_join(n_reps, by = c('individual_ID', 'date')) %>%
  dplyr::filter(n %in% c(4, 5))

oo_small_5 <- oo_small_45 %>%
  dplyr::filter(n == 5)

# test excluding different replicates
CV_excl1 <- oo_small_345 %>%
    dplyr::filter(replicate_no != 1) %>%
    group_by(individual_ID, date) %>%
    summarise(mean = mean(CEWL_g_m2h),
              SD = sd(CEWL_g_m2h),
              CV = (SD/mean) *100) %>%
    mutate(rep_excluded = "1")
```

```
## `summarise()` regrouping output by 'individual_ID' (override with `.groups` argument)
```

```r
CV_excl2 <- oo_small_345 %>%
    dplyr::filter(replicate_no != 2) %>%
    group_by(individual_ID, date) %>%
    summarise(mean = mean(CEWL_g_m2h),
              SD = sd(CEWL_g_m2h),
              CV = (SD/mean) *100) %>%
    mutate(rep_excluded = "2")
```

```
## `summarise()` regrouping output by 'individual_ID' (override with `.groups` argument)
```

```r
CV_excl3 <- oo_small_345 %>%
    dplyr::filter(replicate_no != 3) %>%
    group_by(individual_ID, date) %>%
    summarise(mean = mean(CEWL_g_m2h),
              SD = sd(CEWL_g_m2h),
              CV = (SD/mean) *100) %>%
    mutate(rep_excluded = "3")
```

```
## `summarise()` regrouping output by 'individual_ID' (override with `.groups` argument)
```

```r
CV_excl4 <- oo_small_45 %>%
    dplyr::filter(replicate_no != 4) %>%
    group_by(individual_ID, date) %>%
    summarise(mean = mean(CEWL_g_m2h),
              SD = sd(CEWL_g_m2h),
              CV = (SD/mean) *100) %>%
    mutate(rep_excluded = "4")
```

```
## `summarise()` regrouping output by 'individual_ID' (override with `.groups` argument)
```

```
CV_excl5 <- oo_small_5 %>%
    dplyr::filter(replicate_no != 5) %>%
    group_by(individual_ID, date) %>%
    summarise(mean = mean(CEWL_g_m2h),
              SD = sd(CEWL_g_m2h),
              CV = (SD/mean) *100) %>%
    mutate(rep_excluded = "5")
```

```
## `summarise()` regrouping output by 'individual_ID' (override with `.groups` argument)
```

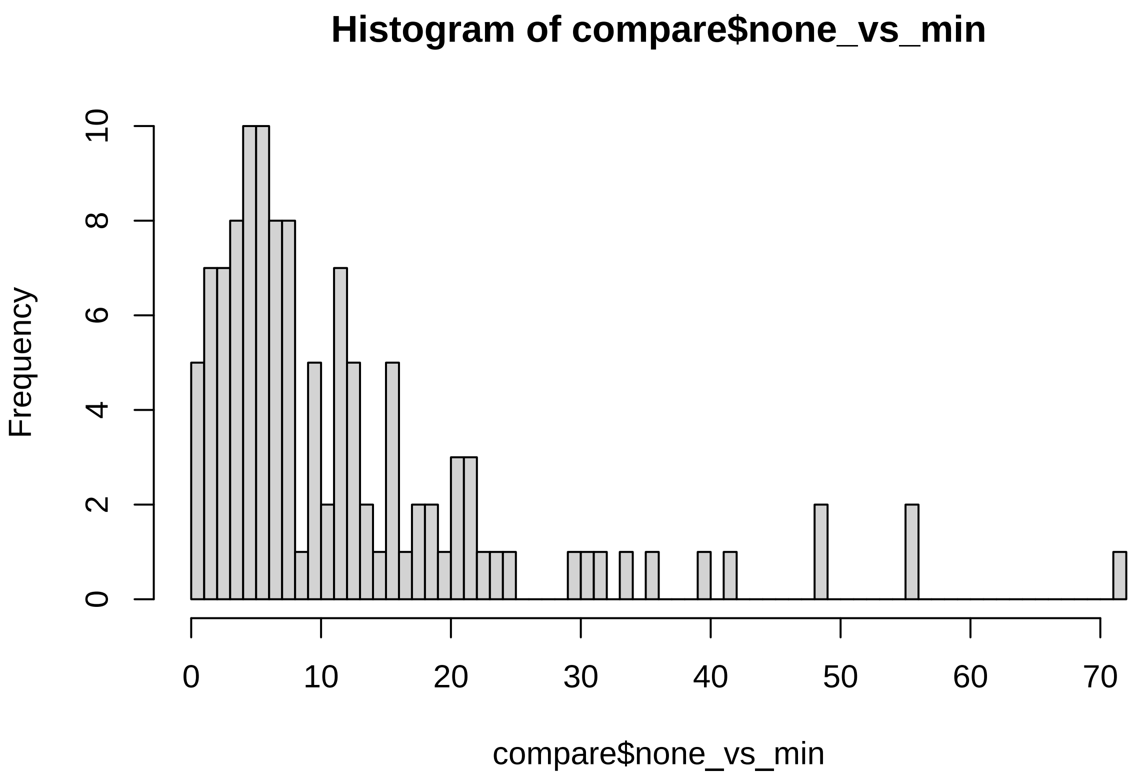
```
# figure out what replicate inflates CV (and range)
compare <- oo_small_345 %>%
    # first compute CV again with ALL replicates
    group_by(individual_ID, date) %>%
    summarise(mean = mean(CEWL_g_m2h),
              SD = sd(CEWL_g_m2h),
              CV = (SD/mean) *100) %>%
    mutate(rep_excluded = "none") %>%
    # attach other CVs with sub-setted rep numbers
    rbind(CV_excl1) %>%
    rbind(CV_excl2) %>%
    rbind(CV_excl3) %>%
    rbind(CV_excl4) %>%
    rbind(CV_excl5) %>%
    # compare which group of reps gives the lowest CV for each individual
    group_by(individual_ID, date) %>%
    dplyr::mutate(none_CV = case_when(rep_excluded == "none" ~ CV,
                                      rep_excluded != "none" ~ NA_real_),
                  min_CV = min(CV),
                  none_vs_min = none_CV - min_CV,
                  rep_excluded = as.factor(rep_excluded))
```

```
## `summarise()` regrouping output by 'individual_ID' (override with `.groups` argument)
```

```
summary(compare)
```

```
##  individual_ID      date                 mean              SD
##  F12     : 16   Min.   :2021-04-23   Min.   : 0.415   Min.   : 0.00707
##  M09     : 15   1st Qu.:2021-04-24   1st Qu.: 8.385   1st Qu.: 1.00698
##  M19     : 15   Median :2021-05-07   Median :10.396   Median : 1.79953
##  M10     : 14   Mean   :2021-05-10   Mean   :10.527   Mean   : 2.42046
##  M11     : 14   3rd Qu.:2021-05-08   3rd Qu.:12.891   3rd Qu.: 2.69628
##  M20     : 14   Max.   :2021-07-14   Max.   :38.860   Max.   :37.40595
##  (Other):462
##        CV              rep_excluded    none_CV            min_CV
##  Min.   :  0.04985   1    :118     Min.   :  1.032   Min.   : 0.04985
##  1st Qu.: 11.40235   2    :118     1st Qu.: 13.432   1st Qu.: 4.64184
##  Median : 19.11119   3    :118     Median : 19.265   Median :11.66153
##  Mean   : 24.07846   none:118     Mean   : 25.543   Mean   :14.13556
##  3rd Qu.: 31.21640   4    : 46     3rd Qu.: 33.435   3rd Qu.:19.11642
##  Max.   :122.85266   5    : 32     Max.   :105.713   Max.   :68.71924
##                                    NA's   :432
##   none_vs_min
##  Min.   : 0.000
##  1st Qu.: 4.295
##  Median : 7.624
##  Mean   :12.132
##  3rd Qu.:15.433
##  Max.   :71.159
##  NA's   :432
```

```
hist(compare$none_vs_min, breaks = 100)
```



Remove Outliers

```
# take the "none" removed rep avg when none_vs_min <5
no_cleaning_needed <- compare %>%
  dplyr::filter(none_vs_min <= 5) %>%
  dplyr::select(individual_ID, date, rep_excluded)

# get rest
needs_cleaning_IDs <- compare %>%
  dplyr::filter(none_vs_min > 5) %>%
  dplyr::mutate(keep = "KEEP") %>%
  dplyr::select(individual_ID, date, keep)

# check number of data obs
test_n <- outliers_omitted %>%
  group_by(individual_ID, date) %>%
  summarise(n = n())
```

```
## `summarise()` regrouping output by 'individual_ID' (override with `.groups` argument)
```

```
nrow(test_n) == (nrow(no_cleaning_needed) + nrow(needs_cleaning_IDs))
```

```
## [1] TRUE
```

```
# designate what to remove / not
how_cleaning <- compare %>%
  left_join(needs_cleaning_IDs) %>%
  dplyr::filter(keep == "KEEP") %>%
  dplyr::filter(CV == min_CV) %>%
  dplyr::select(individual_ID, date, rep_excluded) %>%
  rbind(no_cleaning_needed)
```

```
## Joining, by = c("individual_ID", "date")
```

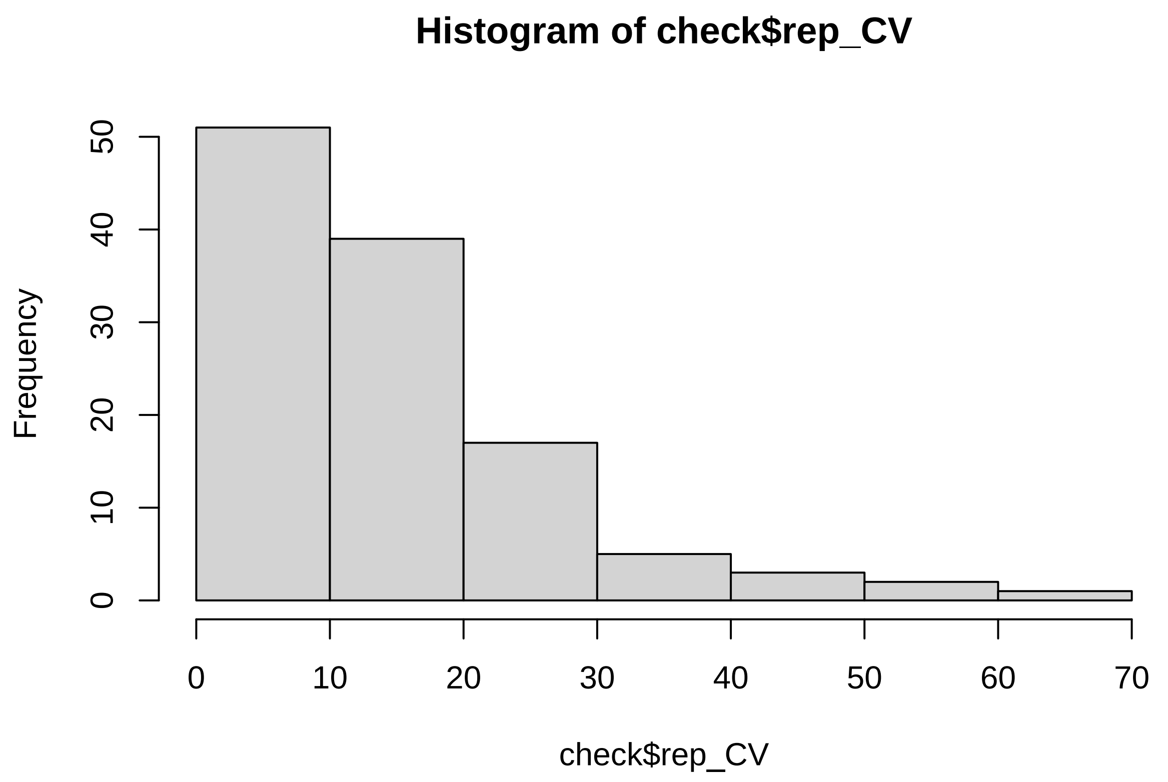
```
# check
nrow(test_n) == (nrow(how_cleaning))
```

```
## [1] TRUE
```

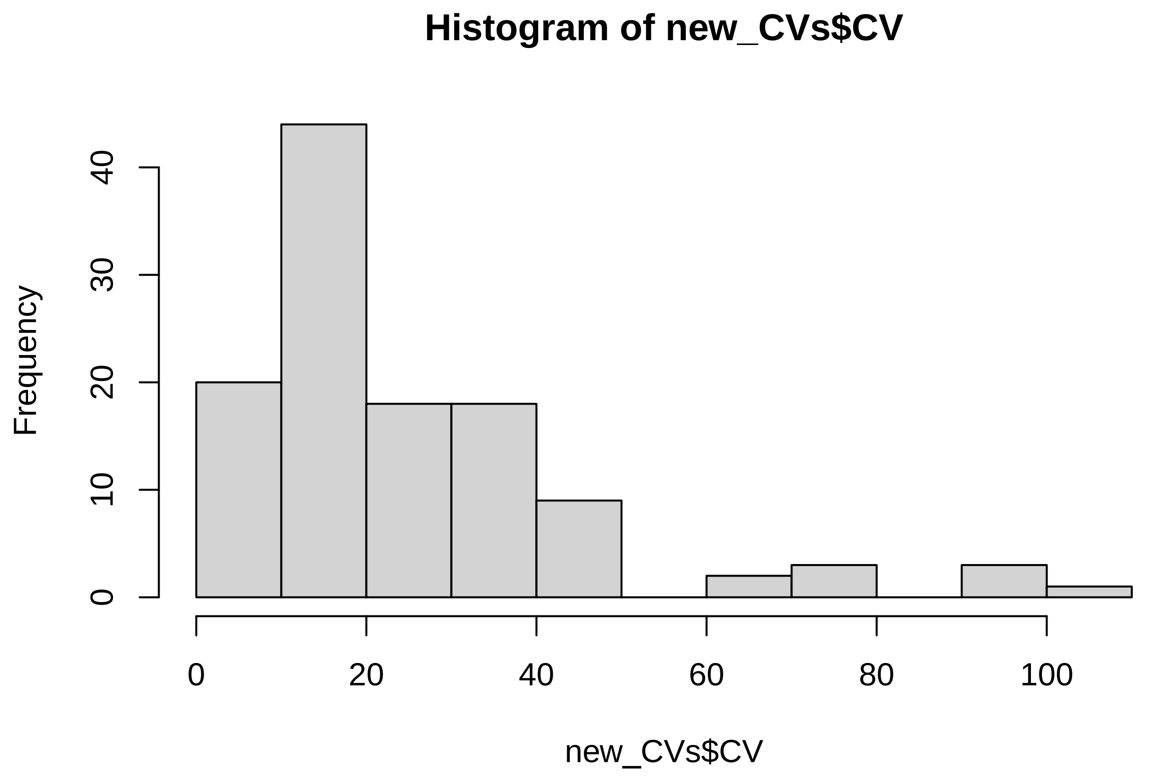
```
# remove!! :D
cleaned_using_CVs <- outliers_omitted %>%
  left_join(how_cleaning, by = c("individual_ID", "date")) %>%
  dplyr::filter(replicate_no != as.character(rep_excluded))

# check that we improved things
check <- cleaned_using_CVs %>%
  group_by(individual_ID, date) %>%
  summarise(CEWL_g_m2h_mean = mean(CEWL_g_m2h),
            rep_SD = sd(CEWL_g_m2h),
            rep_CV = (rep_SD/CEWL_g_m2h_mean) *100,
            rep_min = min(CEWL_g_m2h),
            rep_max = max(CEWL_g_m2h),
            rep_range = rep_max - rep_min
            )
```

```
## `summarise()` regrouping output by 'individual_ID' (override with `.groups` argument)
```

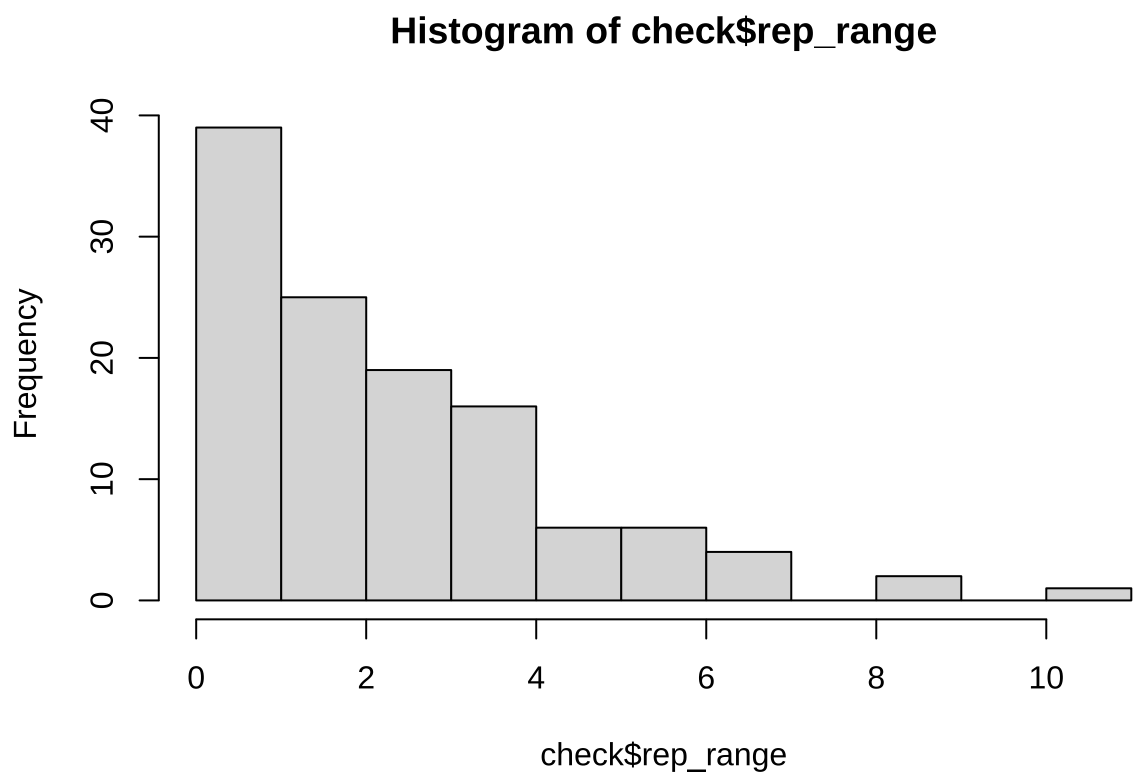
```
hist(check$rep_CV)
```



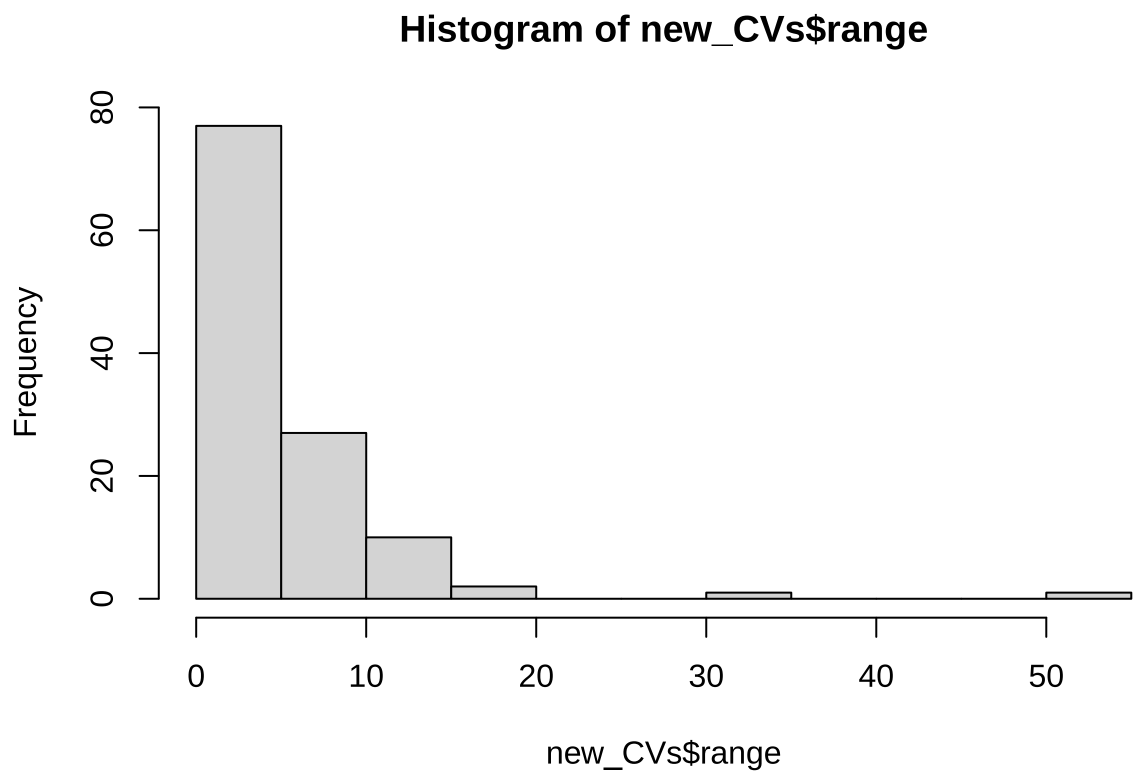
```
hist(new_CVs$CV)
```



```
hist(check$rep_range)
```



```
hist(new_CVs$range)
```



Yes, we decreased the CVs and ranges even more, so I think worth the data scrubbing.

Average Replicates (outliers removed)

```
CEWL_final <- cleaned_using_CVs %>%
  group_by(date, individual_ID) %>%
  summarise(CEWL_g_m2h = mean(CEWL_g_m2h),
            msmt_temp_C = mean(msmt_temp_C),
            msmt_RH_percent = mean(msmt_RH_percent))
```

```
## `summarise()` regrouping output by 'date' (override with `.groups` argument)
```

```
head(CEWL_final)
```

```
## # A tibble: 6 x 5
## # Groups:   date [1]
##   date       individual_ID CEWL_g_m2h msmt_temp_C msmt_RH_percent
##   <date>     <fct>              <dbl>       <dbl>           <dbl>
## 1 2021-04-23 F01                 8.18        31.6            11.8
## 2 2021-04-23 F02                15.4         33.6            16.8
## 3 2021-04-23 F03                 8.40        32.0            14.2
## 4 2021-04-23 F04                 9.21        25.0            26.0
## 5 2021-04-23 F11                10.6         32.3            13.8
## 6 2021-04-23 F12                 0.59        32.3            13.5
```

Final Synthesis

Re-Check Data

Check that we still have data for every individual.

I can check this by comparing original individual IDs to the individual IDs in our final dataset, then selecting/printing the IDs used that are in one but not the other.

```
unique(CEWL_final$individual_ID) %in% unique(all_CEWL_data$individual_ID)
```

```
##  [1] TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE
## [16] TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE
## [31] TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE
## [46] TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE
## [61] TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE
## [76] TRUE TRUE TRUE TRUE TRUE
```

```
unique(all_CEWL_data$individual_ID) %in% unique(CEWL_final$individual_ID)
```

```
##  [1] TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE
## [16] TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE
## [31] TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE
## [46] TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE
## [61] TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE TRUE
## [76] TRUE TRUE TRUE TRUE TRUE
```

All is as expected. :)

Check how many observations were used to calculate mean CEWL for each individual on each date:

```
cleaned_using_CVs %>%
  group_by(individual_ID, date) %>%
  summarise(n = n()) %>%
  arrange(n)
```

```
## `summarise()` regrouping output by 'individual_ID' (override with `.groups` argument)
```

```
## # A tibble: 118 x 3
## # Groups:   individual_ID [80]
##    individual_ID date           n
##    <fct>         <date>     <int>
##  1 F01           2021-04-23     2
##  2 F02           2021-04-23     2
##  3 F05           2021-04-24     2
##  4 F06           2021-04-24     2
##  5 F07           2021-04-24     2
##  6 F08           2021-04-24     2
##  7 F09           2021-04-24     2
##  8 F10           2021-04-24     2
##  9 F11           2021-04-23     2
## 10 F12           2021-04-23     2
## # ... with 108 more rows
```

Between 2-5. So, We were able to delete a point if it was off from the other two in a group of 3.

Export

Save the cleaned data for models and figures.

```
write.csv(CEWL_final, "./data/CEWL_dat_all_clean.csv")
```

Reporting

We omitted a total of 105 measurements from our CEWL dataset (465 - 351): 1 replicate was removed for most individuals. We used the boxplot.stats function in R to extract outliers from each set of technical replicates, and 24 points were removed this way. The remaining 81 removed replicates were taken out because they increased the CV for their replicate group by >5% compared to the CV without that point. After data cleaning, every individual still had 2-5 technical replicates for each of their measurement dates. The distribution of coefficient of variation values was much better after both data cleaning steps than before.