Aggregating anemone data analysis

Caitlin Bergman and Beth Blanchette

11/11/2021

Loading libraries and data

```
# loading libraries
library(rstatix)
library(fitdistrplus)
library(patchwork)
library(ordinal)
library(performance)
library(scales)
library(gamlss)
library(brms)
library(tidyverse)

# Loading data
pam <- read_delim("data/pam_data_clean.csv", delim = ",")
base <- read_delim("data/base_diameter_data_clean.csv", delim = ",")
food <- read_delim("data/feeding_time_data_clean.csv", delim = ",")
open_closed <- read_delim("data/open_closed_data_clean.csv",
    delim = ",")
hemocytometer <- read_delim("data/hemocytometer_data_clean.csv",
    delim = ",")
```

Cleaning data

```
# Creating a clean dataframe for each response variable,
# and a summarized dataframe with average #value for each
# treatment at each measurement time

# Function to calculate standard error for data summaries
standard_error <- function(x) sd(x)/sqrt(length(x))

# Cleaning photosynthetic efficiency data: Filtering to
# remove measurements that were not used during analysis,
# formatting columns, and selecting columns needed for
# model.
pam_clean <- pam %>%
    filter(Date != "10/25/2021 6:00:00", Date != "10/28/2021 6:00:00",
```

```r
        Date != "11/07/2021 6:00:00", Date != "11/07/2021 16:00:00") %>%
    select(Date, Event, Treatment, Bin, Site, Anemone_ID, Fv_Fm_av) %>%
    mutate(Date = as.POSIXct(as.character(Date), format = "%m/%d/%Y %H:%M:%S"),
        Anemone_ID = as.factor(Anemone_ID), Bin = as.factor(Bin),
        Site = as.factor(Site), Event = factor(Event, levels = c("Acclimation",
            "Pre-heat", "Post-heat", "After Heatwave", "Recovery ")),
        Treatment = fct_relevel(as.factor(Treatment), "Control",
            "25C", "30C"))

# Mean and standard error of photosynthetic efficiency for
# each treatment and measurement time
pam_summary <- pam_clean %>%
    group_by(Date, Treatment) %>%
    summarize(mean_FvFm = mean(Fv_Fm_av), se_FvFm = standard_error(Fv_Fm_av))

# Cleaning base measurement data: Filtering to remove
# measurements that were not used during analysis,
# formatting columns, and selecting columns needed for
# model.
base_clean <- base %>%
    filter(Treatment != "NA", Average_Diameter != "NA") %>%
    mutate(Date = factor(Date, levels = c("31-Oct", "05-Nov",
        "09-Nov", "13-Nov")), Event = fct_relevel(as.factor(Event),
        "Acclimation", "Before heatwave", "After heatwave", "Recovery"),
        Treatment = fct_relevel(as.factor(Treatment), "Control",
            "25C", "30C"), Anemone_ID = as.factor(Anemone_ID),
        Bin = as.factor(Bin), Site = as.factor(Site)) %>%
    select(Date, Event, Treatment, Bin, Site, Anemone_ID, Average_Diameter) %>%
    arrange_all()

# Mean and standard error of base measurement data for each
# treatment and measurement time
base_summary <- base_clean %>%
    group_by(Date, Treatment) %>%
    summarize(mean_base = mean(Average_Diameter), se_base = standard_error(Average_Diameter))

# Cleaning feeding time data: Filtering to remove
# measurements that were not used during analysis,
# formatting columns, and selecting columns needed for
# model.
food_clean <- food %>%
    filter(Date != "10/28/2021") %>%
    mutate(Feeding_Time_Min = as.numeric(Feeding_Time_Min), Event = fct_relevel(as.factor(Event),
        "Acclimation", "Before heatwave", "After heatwave", "Recovery"),
        Date = as.factor(Date), Site = as.factor(Site), Treatment = fct_relevel(as.factor(Treatment),
            "Control", "25C", "30C"), Anemone_ID = as.factor(Anemone_ID),
        Bin = as.factor(Bin)) %>%
    select(Date, Event, Treatment, Bin, Site, Anemone_ID, Feeding_Time_Min)

# Mean and standard error of feeding time data for each
# treatment and measurement time
food_summary <- food %>%
    group_by(Date, Treatment) %>%
```

```r
    summarize(mean_time = mean(Feeding_Time_Min), se_time = standard_error(Feeding_Time_Min))

# Cleaning heatwave response data: Formatting columns and
# selecting columns needed for model.
open_closed_clean <- open_closed %>%
    mutate(Date = as.factor(Date), Anemone_ID = as.factor(Anemone_ID),
        Time_Block = fct_relevel(as.factor(Time_Block), "0",
            "1", "2", "3", "4", "5", "6"), Treatment = as.factor(Treatment),
        Open_Closed = as.factor(Open_Closed), Open_Closed = factor(Open_Closed,
            levels = c("Open", "Partially open", "Closed"), ordered = TRUE),
        Treatment = fct_relevel(Treatment, "Control", "25C",
            "30C")) %>%
    select(Date, Event, Time_Block, Bin, Treatment, Open_Closed,
        Anemone_ID)

# Counts of heatwave response data for each treatment and
# measurement time
open_closed_summary <- open_closed_clean %>%
    group_by(Date, Event, Treatment, Time_Block) %>%
    count(Open_Closed)

# Cleaning hemocytometer data: Converting units for mass to
# mg, calculating cell densities and mitotic index,
# formatting columns, and selecting columns needed for
# model.
hemo_clean <- hemocytometer %>%
    mutate(Tentacle_Mass_mg = (Tentacle_Mass_g * 1000), Dino_Density = ((Number_Dino_Average *
        0.5)/(Tentacle_Mass_mg * 1e-04)), Green_Density = ((Number_Green_Average *
        0.5)/(Tentacle_Mass_mg * 1e-04)), Dino_MI = (Dividing_Dino_Average/Number_Dino_Average)) %>%
    mutate(Date = as.factor(Date), Treatment = as.factor(Treatment),
        Bin = as.factor(Bin), Site = as.factor(Site), Anemone_ID = as.factor(Anemone_ID)) %>%
    mutate(Date = as.POSIXct(as.character(Date), format = "%m/%d/%Y")) %>%
    select(Date, Treatment, Bin, Site, Anemone_ID, Tentacle_Mass_mg,
        Number_Dino_Average, Number_Green_Average, Dividing_Dino_Average,
        Dividing_Green_Average, Dino_Density, Green_Density,
        Dino_MI) %>%
    group_by(Date, Treatment)

# Mean and standard error of cell density and mitotic index
# for zooxanthellae and zoochlorellae at each treatment and
# measurement time
hemo_summary <- hemo_clean %>%
    group_by(Date, Treatment) %>%
    summarize(mean_Dino_Density = mean(Dino_Density), se_Dino_Density = standard_error(Dino_Density),
        mean_Green_Density = mean(Green_Density), se_Green_Density = standard_error(Green_Density),
        mean_Dino_MI = mean(Dino_MI), se_Dino_MI = standard_error(Dino_MI))

# Summarizing mean and standard error of temperature data
# from heatwave
temp_summary <- open_closed %>%
    select(Date, Time_Block, Event, Treatment, Bucket_Temp) %>%
    group_by(Date, Event, Treatment, Time_Block) %>%
    summarize(mean_temp = mean(Bucket_Temp), se_temp = standard_error(Bucket_Temp)) %>%
```

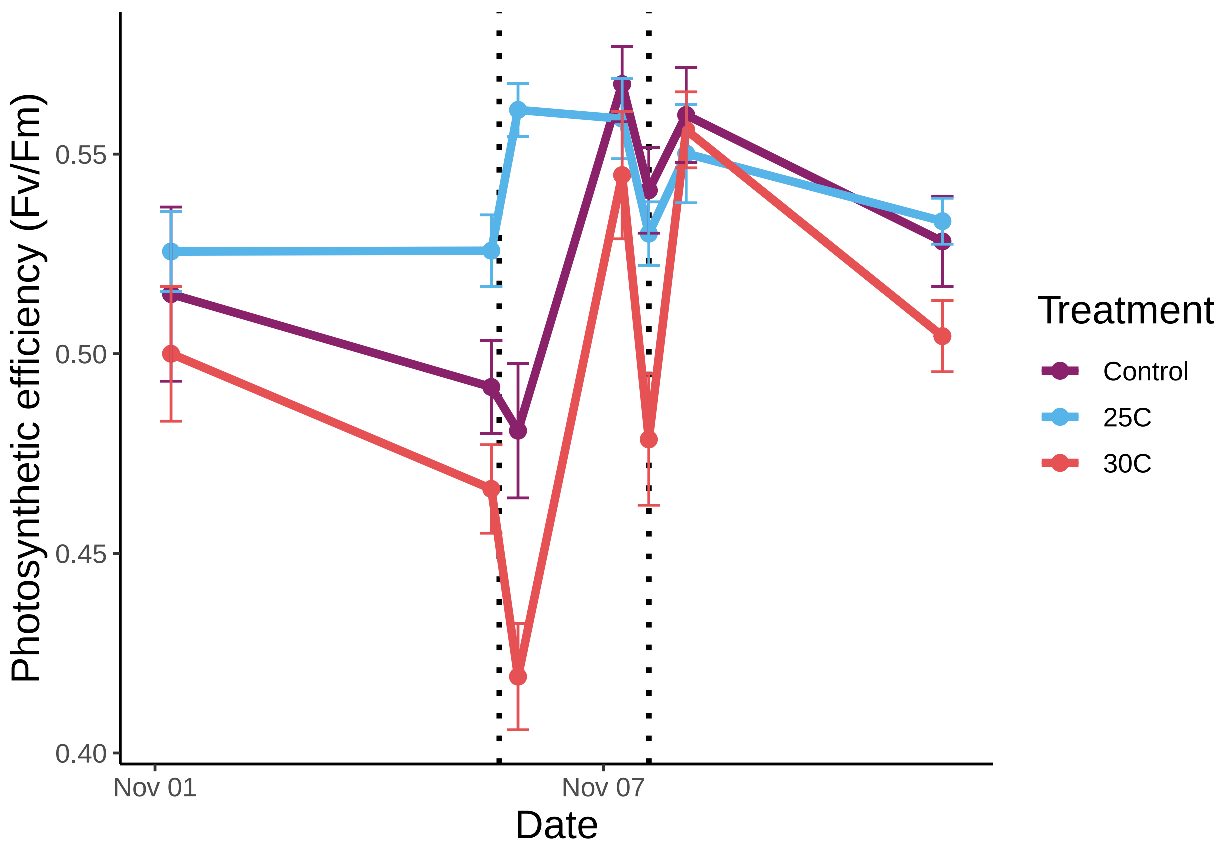
```
    mutate(Date = as.factor(Date), Treatment = as.factor(Treatment)) %>%
    mutate(Treatment = fct_relevel(Treatment, "Control", "25C",
        "30C"))
```

PAM data analysis

Plots

Plotting a timeseries including all photosynthetic efficiency measurement times

```
# Plotting measurements as a timeseries with standard error
# bars.
ggplot(data = pam_summary, aes(x = Date, y = mean_FvFm, group = Treatment,
    colour = Treatment)) + theme_classic() + geom_vline(xintercept = as.POSIXct("2021-11-06 09:00:00"),
    linetype = "dotted", size = 1) + geom_vline(xintercept = as.POSIXct("2021-11-08 16:00:00"),
    linetype = "dotted", size = 1) + geom_point(size = 2.5) +
    geom_line(lwd = 1.5) + geom_errorbar(aes(ymin = mean_FvFm -
    se_FvFm, ymax = mean_FvFm + se_FvFm), width = 30000) + labs(x = "Date",
    y = "Photosynthetic efficiency (Fv/Fm)") + scale_fill_manual(values = c("#89226AFF",
    "#56B4E9FF", "#E65154FF")) + scale_colour_manual(values = c("#89226AFF",
    "#56B4E9FF", "#E65154FF")) + theme(axis.text = element_text(size = 10),
    axis.title = element_text(size = 15), legend.text = element_text(size = 10),
    legend.title = element_text(size = 15))
```

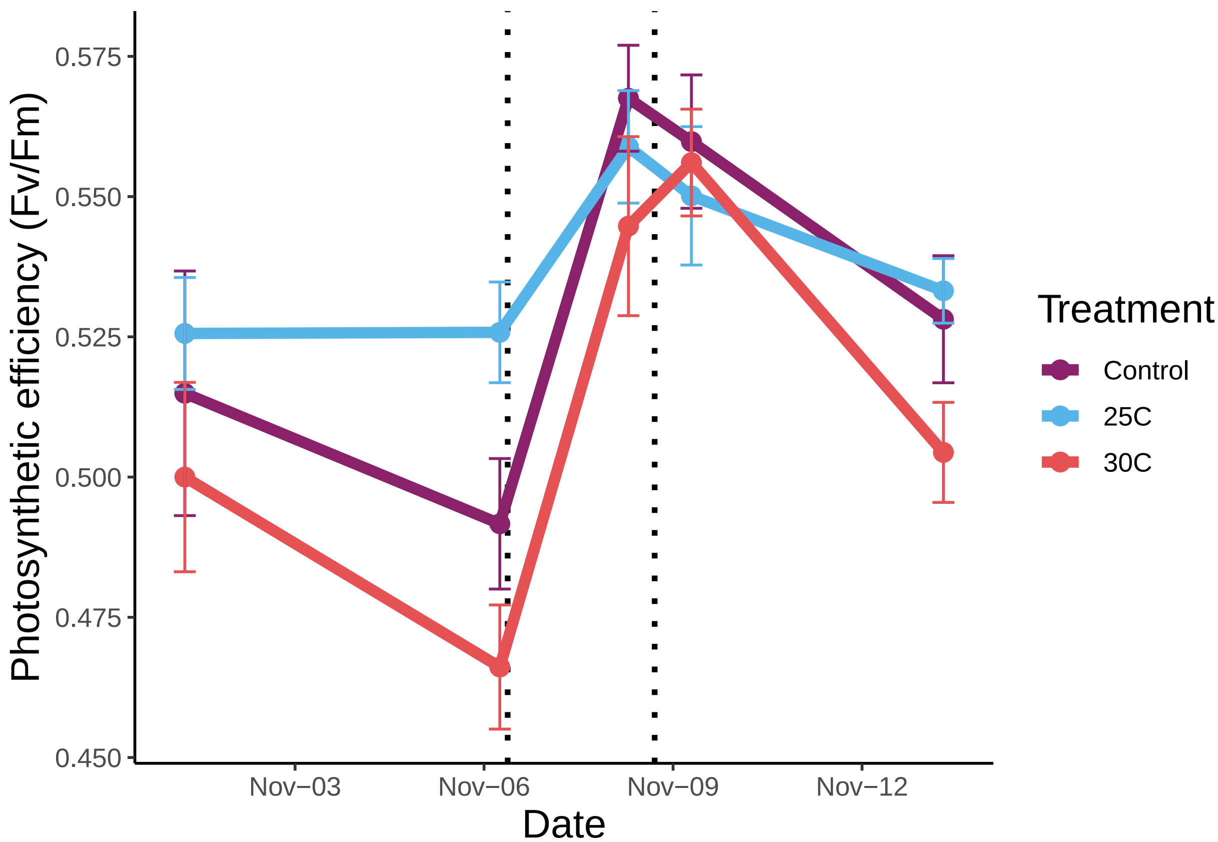



```
ggsave(path = "plots", filename = "pam_overall_line.png", width = 10,
    height = 7)
```

Plotting a timeseries of all morning photosynthetic efficiency measurements (5 timepoints)

```r
# Selecting all morning PAM measurements
pam_morning <- pam_summary %>%
    filter(Date == "2021-11-01 06:00:00" | Date == "2021-11-06 06:00:00" |
        Date == "2021-11-08 06:00:00" | Date == "2021-11-09 06:00:00" |
        Date == "2021-11-13 06:00:00")

# Plotting measurements as a timeseries with standard error
# bars.
ggplot(data = pam_morning, aes(x = Date, y = mean_FvFm, group = Treatment,
    colour = Treatment)) + theme_classic() + geom_vline(xintercept = as.POSIXct("2021-11-06 09:00:00"),
    linetype = "dotted", size = 1) + geom_vline(xintercept = as.POSIXct("2021-11-08 16:00:00"),
    linetype = "dotted", size = 1) + geom_point(size = 3) + geom_line(lwd = 2) +
    scale_x_datetime(breaks = date_breaks("3 days"), labels = date_format("%b-%d")) +
    geom_errorbar(aes(ymin = mean_FvFm - se_FvFm, ymax = mean_FvFm +
        se_FvFm), width = 30000) + labs(x = "Date", y = "Photosynthetic efficiency (Fv/Fm)") +
    scale_fill_manual(values = c("#89226AFF", "#56B4E9FF", "#E65154FF")) +
    scale_colour_manual(values = c("#89226AFF", "#56B4E9FF",
        "#E65154FF")) + theme(axis.text = element_text(size = 10),
    axis.title = element_text(size = 15), legend.text = element_text(size = 10),
    legend.title = element_text(size = 15))
```



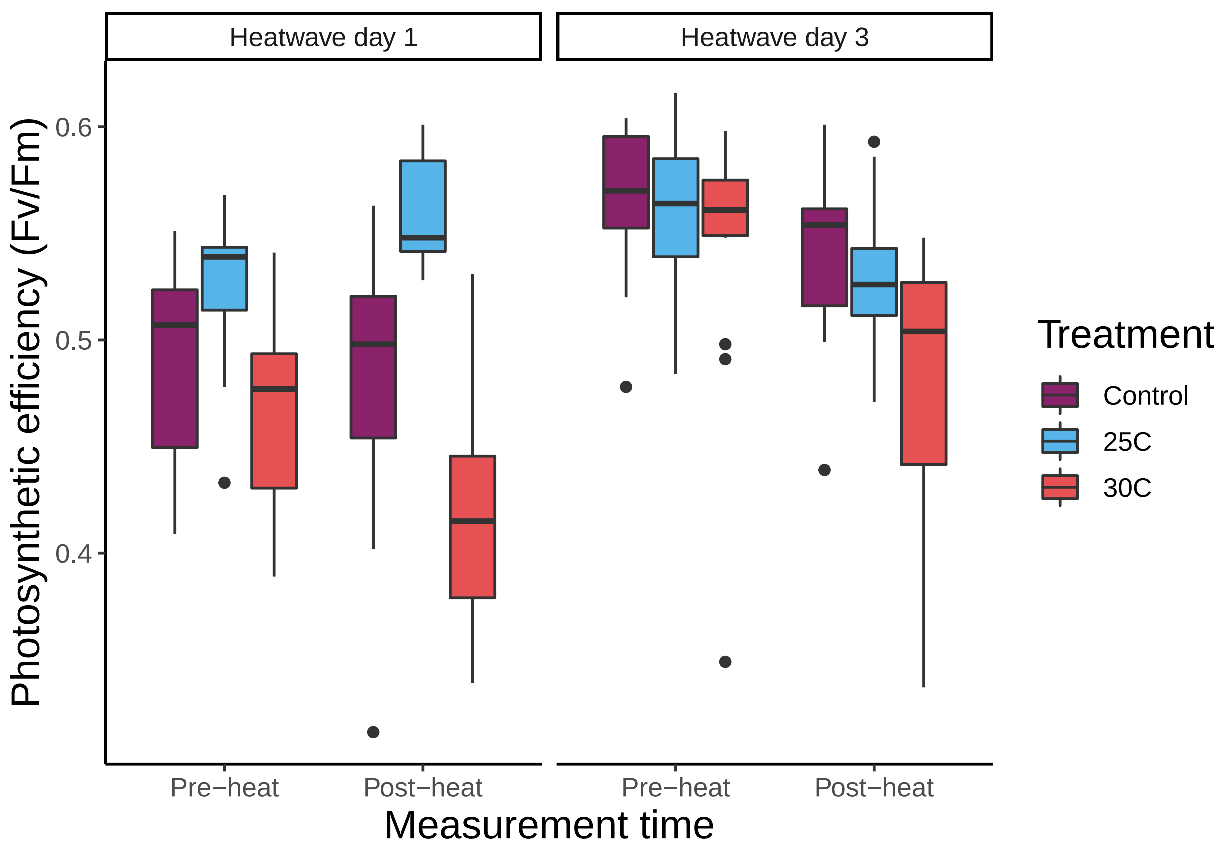

```r
ggsave(path = "plots", filename = "pam_timeseries.jpg", width = 15,
    height = 7)
```

Plot comparing morning and afternoon photosynthetic efficiency measurements on first and third days of heatwave:

```
# Selecting only PAM measurements taken on first and third
# heatwave days (Nov. 6 and Nov. 8)
pam_heatwave <- pam_clean %>%
    filter(Date == "2021-11-06 06:00:00" | Date == "2021-11-06 16:00:00" |
        Date == "2021-11-08 06:00:00" | Date == "2021-11-08 16:00:00") %>%
    separate(Date, c("Day", "Hour"), sep = " ", remove = T) %>%
    mutate(Day = fct_relevel(Day, "2021-11-06", "2021-11-08"))

# Changing names of heatwave days for x-axis of graph
levels(pam_heatwave$Day) <- c("Heatwave day 1", "Heatwave day 3")

# Plotting data as two boxplots, separated by day. Each
# boxplot is separated by time (before/after heatwave) and
# treatment.
ggplot(pam_heatwave, aes(fill = Treatment, y = Fv_Fm_av, x = Event)) +
    geom_boxplot() + scale_fill_manual(values = c("#89226AFF",
    "#56B4E9FF", "#E65154FF")) + labs(x = "Measurement time",
    y = "Photosynthetic efficiency (Fv/Fm)") + facet_grid(. ~
    Day) + theme_classic() + theme(strip.text.x = element_text(size = 10),
    axis.text = element_text(size = 10), axis.title = element_text(size = 15),
    legend.text = element_text(size = 10), legend.title = element_text(size = 15))
```



```
ggsave(path = "plots", filename = "pam_heatwave_boxplot.png",
    width = 15, height = 7)
```

Analysis of photosynthetic efficiency data

Model 1: includes all morning measurement times

Testing assumptions of ANOVA:

```
## # A tibble: 1 x 3
##   variable                        statistic  p.value
##   <chr>                               <dbl>    <dbl>
## 1 pam_morning_timeseries$Fv_Fm_av     0.911 2.38e-10
```

```
##
##  Bartlett test of homogeneity of variances
##
## data:  Fv_Fm_av by Treatment
## Bartlett's K-squared = 15.536, df = 2, p-value = 0.0004231
```

```
## # A tibble: 1 x 3
##   variable                         statistic  p.value
##   <chr>                                <dbl>    <dbl>
## 1 pam_morning_timeseries$log_Fv_Fm     0.836 1.08e-14
```

```
## # A tibble: 1 x 3
##   variable                          statistic  p.value
##   <chr>                                 <dbl>    <dbl>
## 1 pam_morning_timeseries$sqrt_Fv_Fm     0.878 1.74e-12
```

```
## # A tibble: 1 x 3
##   variable                         statistic  p.value
##   <chr>                                <dbl>    <dbl>
## 1 pam_morning_timeseries$arc_Fv_Fm     0.907 1.30e-10
```

Since the data does not fit the assumptions of an ANOVA, we will use a gamlss model:

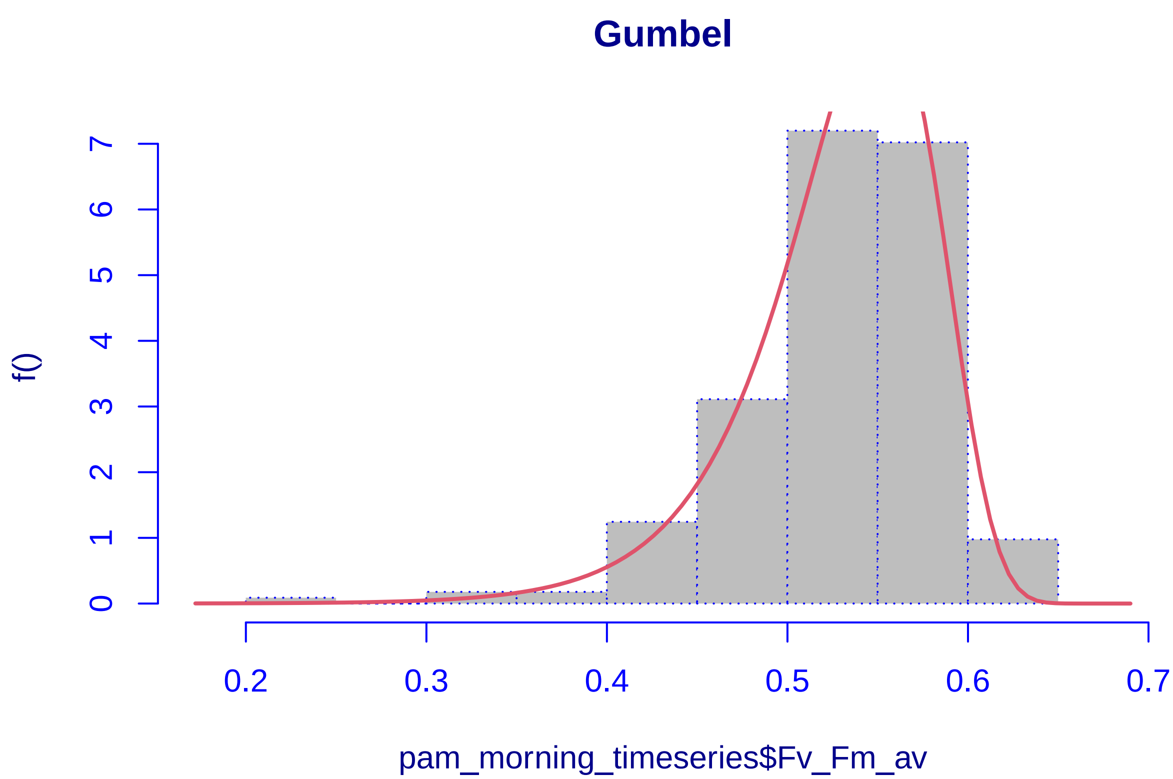
```
# Finding distribution that best fits data
fitDist(Fv_Fm_av, data = pam_morning_timeseries, type = "realAll",
    try.gamlss = T)
```

```
##   |                                                                              |
```

```
## Sigma Coefficients:
## [1]  -3.212
##
##  Degrees of Freedom for the fit: 2 Residual Deg. of Freedom   223
## Global Deviance:     -731.337
##             AIC:     -727.337
##             SBC:     -720.504
```

```
# Results: Gumbel is the best fit

# Visualizing distribution
histDist(pam_morning_timeseries$Fv_Fm_av, "GU", density = F,
    main = "Gumbel")
```




```
##
## Family:  c("GU", "Gumbel")
## Fitting method: "nlminb"
##
## Call:  gamlssML(formula = pam_morning_timeseries$Fv_Fm_av,      family = "GU")
##
##
## Mu Coefficients:
## [1]  0.5521
## Sigma Coefficients:
## [1]  -3.212
```

```
##
##  Degrees of Freedom for the fit: 2 Residual Deg. of Freedom   223
## Global Deviance:     -731.337
##             AIC:     -727.337
##             SBC:     -720.504
```

```
# Testing fit of full and reduced models using AIC
AIC(pam_morning_mod_full, pam_morning_mod_step)
```

```
##                            df       AIC
## pam_morning_mod_step 55.42874 -887.1672
## pam_morning_mod_full 54.34304 -884.1726
```

```
formula(pam_morning_mod_step)
```

```
## Fv_Fm_av ~ Treatment + Date + random(Anemone_ID) + Treatment:Date
```

```
summary(pam_morning_mod_step)
```

```
## ******************************************************************
## Family:  c("GU", "Gumbel")
##
## Call:  gamlss(formula = Fv_Fm_av ~ Treatment + Date + random(Anemone_ID) +
##     Treatment:Date, family = GU(), data = pam_morning_timeseries,
##     control = gamlss.control(n.cyc = 200), trace = FALSE)
##
## Fitting method: RS()
##
## ------------------------------------------------------------------
## Mu link function:  identity
## Mu Coefficients:
##                                        Estimate Std. Error t value Pr(>|t|)
## (Intercept)                            0.536333   0.005459  98.240  < 2e-16 ***
## Treatment25C                           0.001645   0.007697   0.214  0.83099
## Treatment30C                          -0.010478   0.007699  -1.361  0.17536
## Date2021-11-06 06:00:00               -0.035279   0.007697  -4.583 8.84e-06 ***
## Date2021-11-08 06:00:00                0.035240   0.007701   4.576 9.13e-06 ***
## Date2021-11-09 06:00:00                0.034688   0.007697   4.507 1.22e-05 ***
## Date2021-11-13 06:00:00                0.000565   0.007698   0.073  0.94157
## Treatment25C:Date2021-11-06 06:00:00  0.035787   0.010886   3.288  0.00123 **
## Treatment30C:Date2021-11-06 06:00:00 -0.010158   0.010886  -0.933  0.35208
## Treatment25C:Date2021-11-08 06:00:00  0.001552   0.010892   0.142  0.88688
## Treatment30C:Date2021-11-08 06:00:00  0.004408   0.010886   0.405  0.68604
## Treatment25C:Date2021-11-09 06:00:00 -0.006848   0.010886  -0.629  0.53016
## Treatment30C:Date2021-11-09 06:00:00  0.006413   0.010889   0.589  0.55666
## Treatment25C:Date2021-11-13 06:00:00  0.004169   0.010886   0.383  0.70222
## Treatment30C:Date2021-11-13 06:00:00 -0.011996   0.010887  -1.102  0.27212
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## ------------------------------------------------------------------
## Sigma link function:  log
```

```
## Sigma Coefficients:
##             Estimate Std. Error t value Pr(>|t|)
## (Intercept) -3.85902    0.05489  -70.31   <2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## -------------------------------------------------------------------
## NOTE: Additive smoothing terms exist in the formulas:
##  i) Std. Error for smoothers are for the linear effect only.
## ii) Std. Error for the linear terms maybe are not accurate.
## -------------------------------------------------------------------
## No. of observations in the fit:  225
## Degrees of Freedom for the fit:  55.42874
##       Residual Deg. of Freedom:  169.5713
##                       at cycle:  5
##
## Global Deviance:     -998.0247
##             AIC:     -887.1672
##             SBC:     -697.8171
## *******************************************************************
```

```
# Final model includes Treatment, Date, Treatment * Date,
# and random(Anemone_ID)
```

Model 2: includes morning/afternoon measurements on first and third days of heatwave

Testing assumptions of ANOVA:

```
## # A tibble: 1 x 3
##   variable                         statistic     p.value
##   <chr>                                <dbl>       <dbl>
## 1 pam_heatwave_timeseries$Fv_Fm_av     0.939 0.000000620
```

```
##
##  Bartlett test of homogeneity of variances
##
## data:  Fv_Fm_av by Treatment
## Bartlett's K-squared = 25.172, df = 2, p-value = 3.42e-06
```

```
## # A tibble: 1 x 3
##   variable                          statistic       p.value
##   <chr>                                 <dbl>         <dbl>
## 1 pam_heatwave_timeseries$log_Fv_Fm     0.902 0.00000000155
```

```
## # A tibble: 1 x 3
##   variable                           statistic      p.value
##   <chr>                                  <dbl>        <dbl>
## 1 pam_heatwave_timeseries$sqrt_Fv_Fm     0.922 0.0000000321
```

```
## # A tibble: 1 x 3
##   variable                          statistic     p.value
##   <chr>                                 <dbl>       <dbl>
## 1 pam_heatwave_timeseries$arc_Fv_Fm     0.939 0.000000583
```

Since the data does not fit the assumptions of an ANOVA, we will use a gamlss model:

```
# Finding distribution that fits data
fitDist(Fv_Fm_av, data = pam_heatwave_timeseries, type = "realAll",
    try.gamlss = T)
```

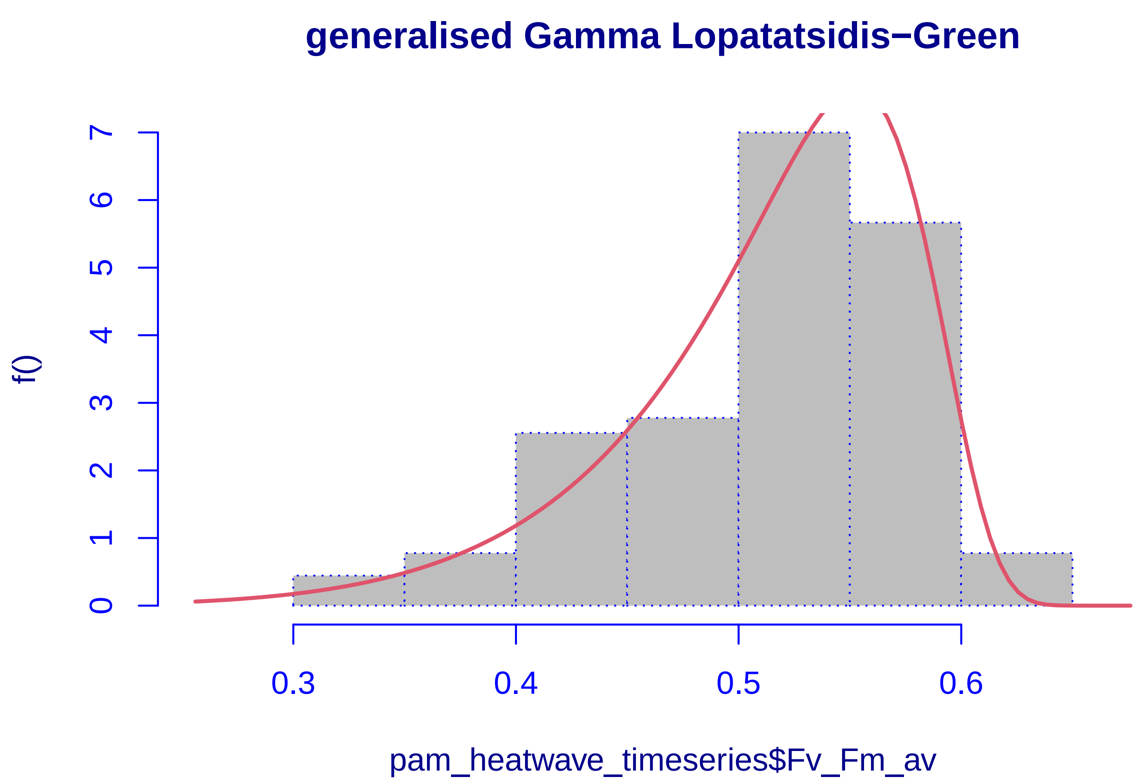
```
##   |                                                                      |
##   Lapack routine dgesv: system is exactly singular: U[4,4] = 0
##   |                                                                      |===================
##   Lapack routine dgesv: system is exactly singular: U[4,4] = 0
##   |                                                                      |===================
##   Lapack routine dgesv: system is exactly singular: U[4,4] = 0
##   |                                                                      |===================
##   Lapack routine dgesv: system is exactly singular: U[4,4] = 0
##   |                                                                      |===================
```

```
##
## Family:  c("GG", "generalised Gamma Lopatatsidis-Green")
## Fitting method: "nlminb"
##
## Call:  gamlssML(formula = y, family = DIST[i])
##
```

```
## Mu Coefficients:
## [1]  -0.5865
## Sigma Coefficients:
## [1]  -2.575
## Nu Coefficients:
## [1]  22.43
##
##  Degrees of Freedom for the fit: 3 Residual Deg. of Freedom   177
## Global Deviance:     -519.642
##             AIC:     -513.642
##             SBC:     -504.063
```

```r
# Best fit: generalized Gamma Loptatsidis-Green

# Visualizing distribution:
histDist(pam_heatwave_timeseries$Fv_Fm_av, "GG", density = F,
    main = "generalised Gamma Lopatatsidis-Green")
```




```
##
## Family:  c("GG", "generalised Gamma Lopatatsidis-Green")
## Fitting method: "nlminb"
##
## Call:  gamlssML(formula = pam_heatwave_timeseries$Fv_Fm_av,
##     family = "GG")
##
```

```
## Mu Coefficients:
## [1]  -0.5865
## Sigma Coefficients:
## [1]  -2.575
## Nu Coefficients:
## [1]  22.43
##
##  Degrees of Freedom for the fit: 3 Residual Deg. of Freedom   177
## Global Deviance:     -519.642
##             AIC:     -513.642
##             SBC:     -504.063
```

```
formula(pam_heatwave_mod_final)
```

```
## Fv_Fm_av ~ Treatment + Date + Treatment * Date + random(as.factor(Bin)) +
##     random(as.factor(Site))
```

```
summary(pam_heatwave_mod_final)
```

```
## ******************************************************************
## Family:  c("GG", "generalised Gamma Lopatatsidis-Green")
##
## Call:  gamlss(formula = Fv_Fm_av ~ Treatment + Date + Treatment *
##     Date + random(as.factor(Bin)) + random(as.factor(Site)),
##     family = GG(), data = pam_heatwave_timeseries,
##     control = gamlss.control(n.cyc = 200))
##
## Fitting method: RS()
##
## ------------------------------------------------------------------
## Mu link function:  log
## Mu Coefficients:
##                                     Estimate Std. Error t value Pr(>|t|)
## (Intercept)                        -0.672441   0.012799 -52.538  < 2e-16 ***
## Treatment25C                        0.060676   0.016433   3.692 0.000309 ***
## Treatment30C                       -0.043454   0.016573  -2.622 0.009634 **
## Date2021-11-06 16:00:00             0.007481   0.016762   0.446 0.656002
## Date2021-11-08 06:00:00             0.112915   0.016587   6.807 2.17e-10 ***
## Date2021-11-08 16:00:00             0.088817   0.016426   5.407 2.44e-07 ***
## Treatment25C:Date2021-11-06 16:00:00  0.051082   0.023259   2.196 0.029595 *
## Treatment30C:Date2021-11-06 16:00:00 -0.061675   0.023227  -2.655 0.008771 **
## Treatment25C:Date2021-11-08 06:00:00 -0.031651   0.023559  -1.343 0.181124
## Treatment30C:Date2021-11-08 06:00:00  0.047600   0.023216   2.050 0.042058 *
## Treatment25C:Date2021-11-08 16:00:00 -0.086546   0.023218  -3.727 0.000272 ***
## Treatment30C:Date2021-11-08 16:00:00 -0.038508   0.023216  -1.659 0.099247 .
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## ------------------------------------------------------------------
## Sigma link function:  log
## Sigma Coefficients:
##             Estimate Std. Error t value Pr(>|t|)
## (Intercept)  -3.1017     0.1117  -27.76   <2e-16 ***
```

```
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## ------------------------------------------------------------------
## Nu link function:  identity
## Nu Coefficients:
##             Estimate Std. Error t value Pr(>|t|)
## (Intercept)    39.83      11.07   3.598 0.000434 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## ------------------------------------------------------------------
## NOTE: Additive smoothing terms exist in the formulas:
##  i) Std. Error for smoothers are for the linear effect only.
## ii) Std. Error for the linear terms maybe are not accurate.
## ------------------------------------------------------------------
## No. of observations in the fit:  180
## Degrees of Freedom for the fit:  28.28158
##       Residual Deg. of Freedom:  151.7184
##                       at cycle:  74
##
## Global Deviance:     -699.4709
##             AIC:     -642.9078
##             SBC:     -552.6059
## ******************************************************************
```

```
# Final model includes Treatment, Date, Treatment * Date,
# random(Bin), and random(Site)

# Testing fit of full and reduced models using AIC
AIC(pam_heatwave_mod_full, pam_heatwave_mod_final)
```

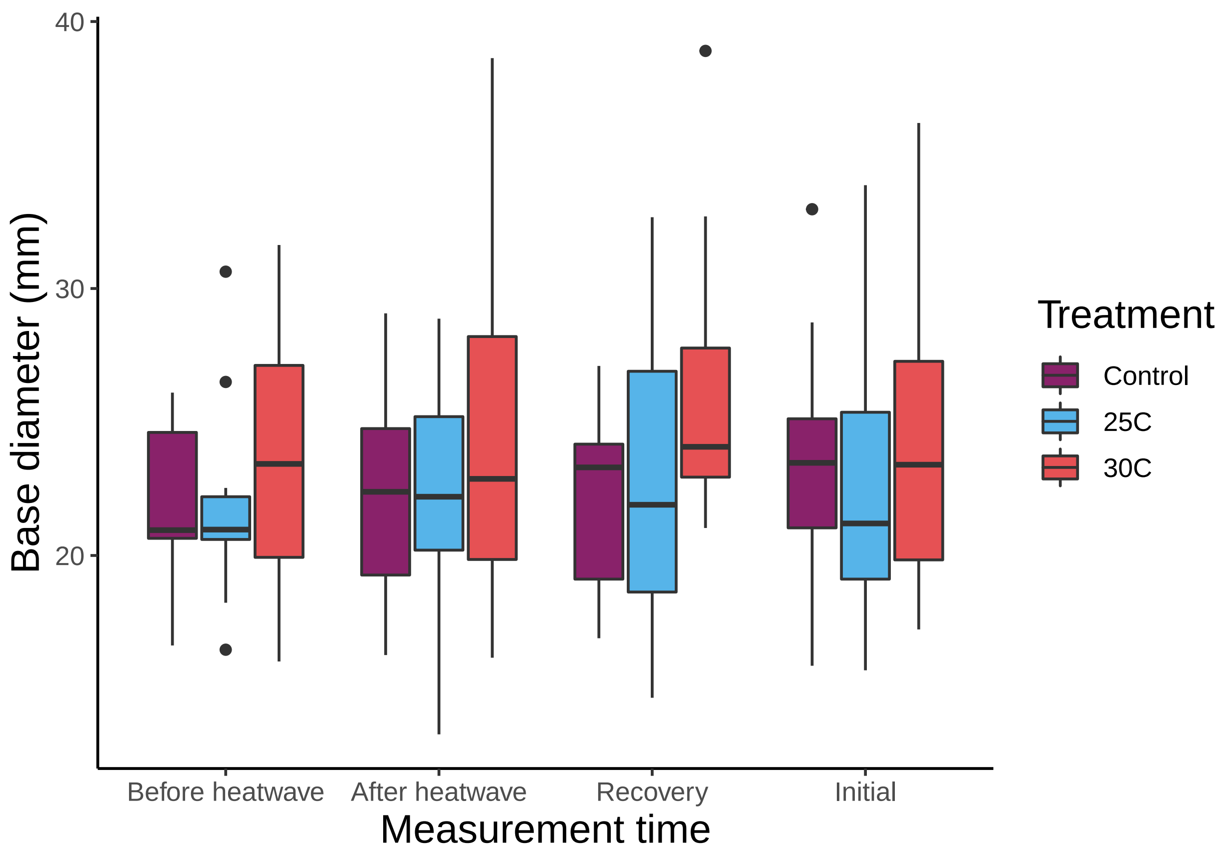
```
##                              df       AIC
## pam_heatwave_mod_full  28.28158 -642.9078
## pam_heatwave_mod_final 28.28158 -642.9078
```

Base measurement analysis

Plots

Boxplot of base measurements for each treatment and measurement time:

```
ggplot(base_clean, aes(fill = Treatment, x = Event, y = Average_Diameter)) +
    theme_classic() + geom_boxplot() + labs(x = "Measurement time",
    y = "Base diameter (mm)") + scale_fill_manual(values = c("#89226AFF",
    "#56B4E9FF", "#E65154FF")) + theme(axis.text = element_text(size = 10),
    axis.title = element_text(size = 15), legend.text = element_text(size = 10),
    legend.title = element_text(size = 15))
```




```
ggsave(path = "plots", filename = "base_boxplot.png", width = 10,
    height = 7)
```

Analyzing base diameter data

Testing assumptions for ANOVA:

```
shapiro_test(base_clean$Average_Diameter)
```

```
## # A tibble: 1 x 3
```

```
##   variable                      statistic p.value
##   <chr>                             <dbl>   <dbl>
## 1 base_clean$Average_Diameter     0.973 0.00172
```

```r
bartlett.test(Average_Diameter ~ Treatment, data = base_clean)
```

```
##
##  Bartlett test of homogeneity of variances
##
## data:  Average_Diameter by Treatment
## Bartlett's K-squared = 8.3712, df = 2, p-value = 0.01521
```

```r
# Data is non-normal and does not have equal variances

# Trying log transformation:
base_clean <- base_clean %>%
    mutate(log_diameter = log(Average_Diameter))

# Testing assumptions for log transformed data:
shapiro_test(base_clean$log_diameter)
```

```
## # A tibble: 1 x 3
##   variable                  statistic p.value
##   <chr>                         <dbl>   <dbl>
## 1 base_clean$log_diameter     0.996   0.932
```

```r
bartlett.test(log_diameter ~ Treatment, data = base_clean)
```

```
##
##  Bartlett test of homogeneity of variances
##
## data:  log_diameter by Treatment
## Bartlett's K-squared = 5.2511, df = 2, p-value = 0.0724
```

```r
base_clean %>%
    group_by(Date, Treatment) %>%
    identify_outliers(log_diameter)
```

```
## # A tibble: 8 x 10
##   Date   Treatment Event    Bin   Site  Anemone_ID Average_Diameter log_diameter
##   <fct>  <fct>     <fct>    <fct> <fct> <fct>                 <dbl>        <dbl>
## 1 31-Oct Control   Initial  M     Blue~ A43B                   15.9         2.76
## 2 31-Oct Control   Initial  O     Fore~ A21F                   33.0         3.50
## 3 05-Nov 25C       Before ~ A     Blue~ A47B                   16.5         2.80
## 4 05-Nov 25C       Before ~ C     Blue~ A46B                   30.6         3.42
## 5 05-Nov 25C       Before ~ D     Scot~ A41S                   26.5         3.28
## 6 05-Nov 25C       Before ~ E     Scot~ A35S                   18.2         2.90
## 7 09-Nov 25C       After h~ D     Fore~ A16F                   13.3         2.59
## 8 13-Nov 30C       Recovery G     Blue~ A56B                   38.9         3.66
## # ... with 2 more variables: is.outlier <lgl>, is.extreme <lgl>
```

```r
# Results: Log transformed data is normal and has equal
# variances. The data has one extreme outlier, but this
# will not have a major effect on the results. We will use
# an two-way ANOVA on the log transformed data.
```

Performing two-way ANOVA test:

```r
# Two-way ANOVA on base diameter data with treatment and
# date as fixed effects, and anemone ID as a random effect:
base_aov <- aov(log_diameter ~ Treatment * Date + random(Anemone_ID),
    data = base_clean)
summary(base_aov)
```

```
##                 Df Sum Sq Mean Sq F value Pr(>F)
## Treatment        2  0.318 0.15877   4.166 0.0172 *
## Date             3  0.049 0.01627   0.427 0.7340
## Treatment:Date   6  0.079 0.01316   0.345 0.9117
## Residuals      161  6.136 0.03811
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```r
TukeyHSD(base_aov)
```

```
##   Tukey multiple comparisons of means
##     95% family-wise confidence level
##
## Fit: aov(formula = log_diameter ~ Treatment * Date + random(Anemone_ID), data = base_clean)
##
## $Treatment
##                    diff          lwr       upr     p adj
## 25C-Control -0.01848219 -0.105003074 0.0680387 0.8688497
## 30C-Control  0.07990056 -0.005493861 0.1652950 0.0719460
## 30C-25C      0.09838274  0.012222789 0.1845427 0.0207832
##
## $Date
##                      diff         lwr        upr     p adj
## 05-Nov-31-Oct -0.0288092676 -0.13814215 0.08052362 0.9030454
## 09-Nov-31-Oct -0.0280812771 -0.13613537 0.07997282 0.9065491
## 13-Nov-31-Oct  0.0091336008 -0.09954690 0.11781410 0.9963199
## 09-Nov-05-Nov  0.0007279904 -0.10860489 0.11006088 0.9999981
## 13-Nov-05-Nov  0.0379428683 -0.07200914 0.14789487 0.8069998
## 13-Nov-09-Nov  0.0372148779 -0.07146562 0.14589538 0.8106017
##
## $`Treatment:Date`
##                                     diff         lwr       upr     p adj
## 25C:31-Oct-Control:31-Oct     -0.0553837601 -0.29182575 0.1810582 0.9997642
## 30C:31-Oct-Control:31-Oct      0.0176877774 -0.22293935 0.2583149 1.0000000
## Control:05-Nov-Control:31-Oct -0.0549051428 -0.29553227 0.1857220 0.9998172
## 25C:05-Nov-Control:31-Oct     -0.0699836856 -0.31535114 0.1753838 0.9984954
## 30C:05-Nov-Control:31-Oct      0.0044638799 -0.23197811 0.2409059 1.0000000
## Control:09-Nov-Control:31-Oct -0.0698213213 -0.31044845 0.1708058 0.9982417
## 25C:09-Nov-Control:31-Oct     -0.0711685735 -0.30761056 0.1652734 0.9975571
```

```
## 30C:09-Nov-Control:31-Oct       0.0204149297 -0.21602706 0.2568569 1.0000000
## Control:13-Nov-Control:31-Oct -0.0546541127 -0.29109610 0.1817879 0.9997926
## 25C:13-Nov-Control:31-Oct     -0.0541868888 -0.29955434 0.1911806 0.9998673
## 30C:13-Nov-Control:31-Oct      0.0988732365 -0.13756875 0.3353152 0.9645061
## 30C:31-Oct-25C:31-Oct          0.0730715375 -0.16755559 0.3136987 0.9973575
## Control:05-Nov-25C:31-Oct      0.0004786174 -0.24014851 0.2411057 1.0000000
## 25C:05-Nov-25C:31-Oct         -0.0145999254 -0.25996738 0.2307675 1.0000000
## 30C:05-Nov-25C:31-Oct          0.0598476400 -0.17659435 0.2962896 0.9995042
## Control:09-Nov-25C:31-Oct     -0.0144375612 -0.25506469 0.2261896 1.0000000
## 25C:09-Nov-25C:31-Oct         -0.0157848134 -0.25222680 0.2206572 1.0000000
## 30C:09-Nov-25C:31-Oct          0.0757986899 -0.16064330 0.3122407 0.9957529
## Control:13-Nov-25C:31-Oct      0.0007296474 -0.23571234 0.2371716 1.0000000
## 25C:13-Nov-25C:31-Oct          0.0011968713 -0.24417058 0.2465643 1.0000000
## 30C:13-Nov-25C:31-Oct          0.1542569966 -0.08218499 0.3906990 0.5779913
## Control:05-Nov-30C:31-Oct     -0.0725929202 -0.31733363 0.1721478 0.9978572
## 25C:05-Nov-30C:31-Oct         -0.0876714630 -0.33707432 0.1617314 0.9907582
## 30C:05-Nov-30C:31-Oct         -0.0132238975 -0.25385103 0.2274032 1.0000000
## Control:09-Nov-30C:31-Oct     -0.0875090987 -0.33224981 0.1572316 0.9893784
## 25C:09-Nov-30C:31-Oct         -0.0888563509 -0.32948348 0.1517708 0.9862316
## 30C:09-Nov-30C:31-Oct          0.0027271523 -0.23789998 0.2433543 1.0000000
## Control:13-Nov-30C:31-Oct     -0.0723418901 -0.31296902 0.1682852 0.9975830
## 25C:13-Nov-30C:31-Oct         -0.0718746662 -0.32127752 0.1775282 0.9983472
## 30C:13-Nov-30C:31-Oct          0.0811854590 -0.15944167 0.3218126 0.9934313
## 25C:05-Nov-Control:05-Nov     -0.0150785428 -0.26448140 0.2343243 1.0000000
## 30C:05-Nov-Control:05-Nov      0.0593690227 -0.18125811 0.2999962 0.9996113
## Control:09-Nov-Control:05-Nov -0.0149161785 -0.25965689 0.2298245 1.0000000
## 25C:09-Nov-Control:05-Nov     -0.0162634308 -0.25689056 0.2243637 1.0000000
## 30C:09-Nov-Control:05-Nov      0.0753200725 -0.16530706 0.3159472 0.9965492
## Control:13-Nov-Control:05-Nov  0.0002510300 -0.24037610 0.2408782 1.0000000
## 25C:13-Nov-Control:05-Nov      0.0007182540 -0.24868460 0.2501211 1.0000000
## 30C:13-Nov-Control:05-Nov      0.1537783792 -0.08684875 0.3944055 0.6095693
## 30C:05-Nov-25C:05-Nov          0.0744475655 -0.17091988 0.3198150 0.9973774
## Control:09-Nov-25C:05-Nov      0.0001623643 -0.24924049 0.2495652 1.0000000
## 25C:09-Nov-25C:05-Nov         -0.0011848880 -0.24655234 0.2441826 1.0000000
## 30C:09-Nov-25C:05-Nov          0.0903986153 -0.15496883 0.3357661 0.9864818
## Control:13-Nov-25C:05-Nov      0.0153295728 -0.23003788 0.2606970 1.0000000
## 25C:13-Nov-25C:05-Nov          0.0157967968 -0.23818264 0.2697762 1.0000000
## 30C:13-Nov-25C:05-Nov          0.1688569220 -0.07651053 0.4142244 0.4932687
## Control:09-Nov-30C:05-Nov     -0.0742852012 -0.31491233 0.1663419 0.9969436
## 25C:09-Nov-30C:05-Nov         -0.0756324534 -0.31207444 0.1608095 0.9958328
## 30C:09-Nov-30C:05-Nov          0.0159510498 -0.22049094 0.2523930 1.0000000
## Control:13-Nov-30C:05-Nov     -0.0591179926 -0.29555998 0.1773240 0.9995587
## 25C:13-Nov-30C:05-Nov         -0.0586507687 -0.30401822 0.1867167 0.9997132
## 30C:13-Nov-30C:05-Nov          0.0944093565 -0.14203263 0.3308513 0.9747661
## 25C:09-Nov-Control:09-Nov     -0.0013472522 -0.24197438 0.2392799 1.0000000
## 30C:09-Nov-Control:09-Nov      0.0902362510 -0.15039088 0.3308634 0.9844430
## Control:13-Nov-Control:09-Nov  0.0151672086 -0.22545992 0.2557943 1.0000000
## 25C:13-Nov-Control:09-Nov      0.0156344325 -0.23376843 0.2650373 1.0000000
## 30C:13-Nov-Control:09-Nov      0.1686945577 -0.07193257 0.4093217 0.4632809
## 30C:09-Nov-25C:09-Nov          0.0915835033 -0.14485849 0.3280255 0.9799792
## Control:13-Nov-25C:09-Nov      0.0165144608 -0.21992753 0.2529565 1.0000000
## 25C:13-Nov-25C:09-Nov          0.0169816847 -0.22838576 0.2623491 1.0000000
## 30C:13-Nov-25C:09-Nov          0.1700418100 -0.06640018 0.4064838 0.4220662
## Control:13-Nov-30C:09-Nov     -0.0750690425 -0.31151103 0.1613729 0.9960943
```

```
## 25C:13-Nov-30C:09-Nov        -0.0746018185 -0.31996927 0.1707656 0.9973288
## 30C:13-Nov-30C:09-Nov         0.0784583067 -0.15798368 0.3149003 0.9942926
## 25C:13-Nov-Control:13-Nov     0.0004672239 -0.24490023 0.2458347 1.0000000
## 30C:13-Nov-Control:13-Nov     0.1535273492 -0.08291464 0.3899693 0.5853163
## 30C:13-Nov-25C:13-Nov         0.1530601252 -0.09230732 0.3984276 0.6453223
```

```
# Testing fit of full and reduced models using AIC
AIC(base_aov)
```

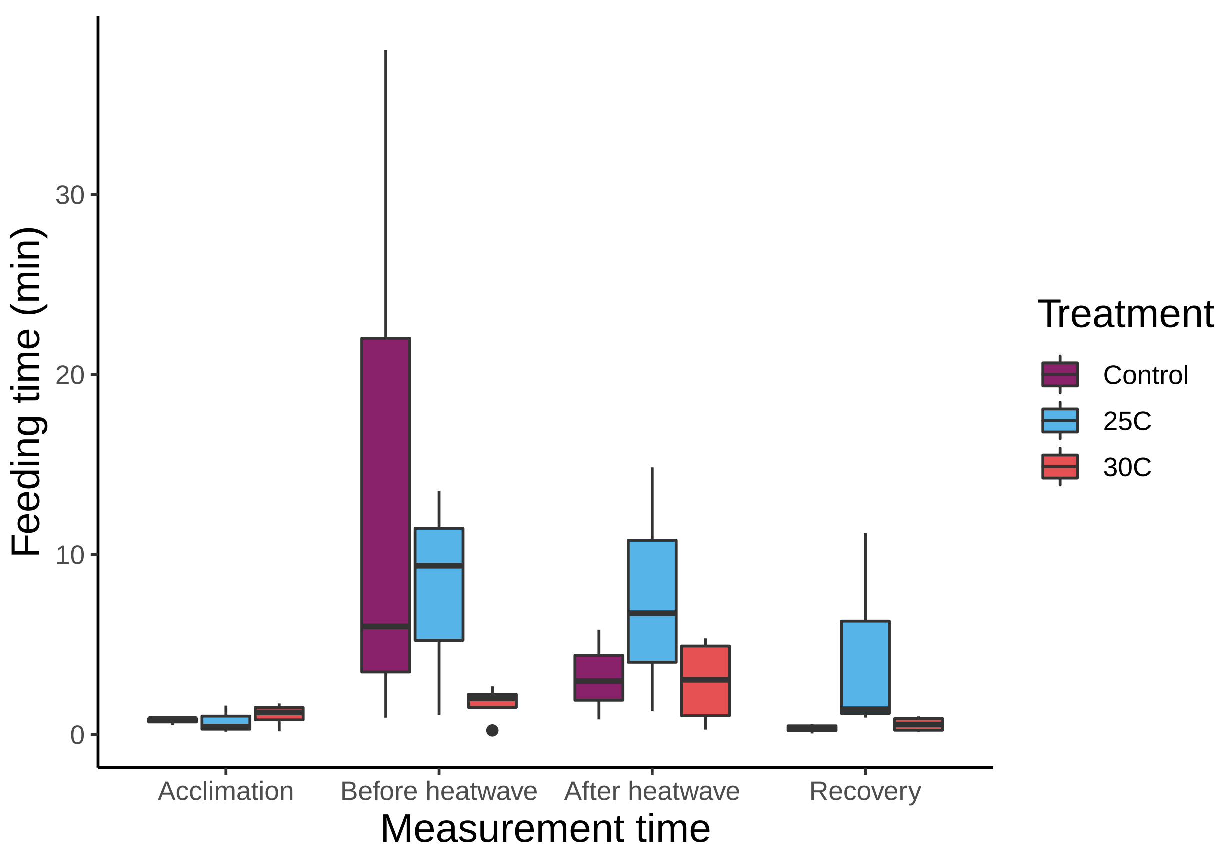
```
## [1] -60.70904
```

Feeding time

Plots

Boxplot of feeding time data for each treatment and measurement time:

```
ggplot(food_clean, aes(fill = Treatment, x = Event, y = Feeding_Time_Min)) +
    theme_classic() + geom_boxplot() + labs(x = "Measurement time",
    y = "Feeding time (min)") + scale_fill_manual(values = c("#89226AFF",
    "#56B4E9FF", "#E65154FF")) + theme(axis.text = element_text(size = 10),
    axis.title = element_text(size = 15), legend.text = element_text(size = 10),
    legend.title = element_text(size = 15))
```



```
ggsave(path = "plots", filename = "food_boxplot.png", width = 10,
    height = 7)
```

Analyzing feeding time data

```
shapiro.test(food_clean$Feeding_Time_Min)
```

```
##
##  Shapiro-Wilk normality test
##
## data:  food_clean$Feeding_Time_Min
## W = 0.52883, p-value = 3.77e-10
```

```
bartlett.test(Feeding_Time_Min ~ Treatment, data = food_clean)
```

```
##
##  Bartlett test of homogeneity of variances
##
## data:  Feeding_Time_Min by Treatment
## Bartlett's K-squared = 35.474, df = 2, p-value = 1.981e-08
```

```
# Data is non-normal and does not have equal variances

# Trying log transformation:
food_clean <- food_clean %>%
    mutate(log_Feeding_Time_Min = log(Feeding_Time_Min))

shapiro_test(food_clean$log_Feeding_Time_Min)
```

```
## # A tibble: 1 x 3
##   variable                        statistic p.value
##   <chr>                               <dbl>   <dbl>
## 1 food_clean$log_Feeding_Time_Min     0.987   0.907
```

```
bartlett.test(log_Feeding_Time_Min ~ Treatment, data = food_clean)
```

```
##
##  Bartlett test of homogeneity of variances
##
## data:  log_Feeding_Time_Min by Treatment
## Bartlett's K-squared = 1.6586, df = 2, p-value = 0.4364
```

```
food_clean %>%
    group_by(Date, Treatment) %>%
    identify_outliers(log_Feeding_Time_Min)
```

```
## # A tibble: 2 x 10
##   Date  Treatment Event Bin   Site  Anemone_ID Feeding_Time_Min log_Feeding_Tim~
##   <fct> <fct>     <fct> <fct> <fct> <fct>                 <dbl>            <dbl>
## 1 11/0~ 30C       Accl~ J     Fore~ A1F                    0.17            -1.77
## 2 11/0~ 30C       Befo~ I     Blue~ A50B                   0.22            -1.51
## # ... with 2 more variables: is.outlier <lgl>, is.extreme <lgl>
```

```
# Log transformed data fits normal distribution and has
# equal variances. There are also no extreme outliers.  We
# will use a two-way ANOVA to analyze the log-transformed
# data.
```

Performing two-way ANOVA on log transformed feeding time data:

```
# Two-way anova with treatment and date as fixed effects,
# and anemone ID as a random effect
food_aov <- aov(log_Feeding_Time_Min ~ Treatment * Date + random(Anemone_ID),
    data = food_clean)
summary(food_aov)
```

```
##                Df Sum Sq Mean Sq F value  Pr(>F)
## Treatment       2   6.05   3.025   2.033 0.14980
## Date            3  23.05   7.684   5.165 0.00574 **
## Treatment:Date  6  11.39   1.899   1.276 0.29985
## Residuals      28  41.65   1.488
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
TukeyHSD(food_aov)
```

```
##   Tukey multiple comparisons of means
##     95% family-wise confidence level
##
## Fit: aov(formula = log_Feeding_Time_Min ~ Treatment * Date + random(Anemone_ID), data = food_clean)
##
## $Treatment
##                   diff        lwr       upr     p adj
## 25C-Control  0.6334377 -0.5986261 1.8655014 0.4222660
## 30C-Control -0.2992016 -1.4516917 0.8532885 0.7981415
## 30C-25C     -0.9326393 -2.0851294 0.2198508 0.1302675
##
## $Date
##                             diff         lwr         upr     p adj
## 11/05/2021-11/01/2021  1.5167541  0.02747928  3.00602883 0.0447267
## 11/09/2021-11/01/2021  1.3728502 -0.11642456  2.86212499 0.0789776
## 11/13/2021-11/01/2021 -0.1342090 -1.62348379  1.35506576 0.9946439
## 11/09/2021-11/05/2021 -0.1439038 -1.63317861  1.34537094 0.9934219
## 11/13/2021-11/05/2021 -1.6509631 -3.14023784 -0.16168829 0.0255046
## 11/13/2021-11/09/2021 -1.5070592 -2.99633401 -0.01778446 0.0465273
##
## $`Treatment:Date`
##                                             diff        lwr       upr
## 25C:11/01/2021-Control:11/01/2021     -0.456109569 -3.9972757 3.0850565
## 30C:11/01/2021-Control:11/01/2021      0.086125976 -3.2263316 3.3985835
## Control:11/05/2021-Control:11/01/2021  2.086686277 -1.4544798 5.6278524
## 25C:11/05/2021-Control:11/01/2021      1.940713766 -1.6004523 5.4818799
## 30C:11/05/2021-Control:11/01/2021      0.515378898 -2.7970787 3.8278365
## Control:11/09/2021-Control:11/01/2021  1.189534170 -2.3516319 4.7307003
## 25C:11/09/2021-Control:11/01/2021      1.918721931 -1.6224442 5.4598880
```

```
## 30C:11/09/2021-Control:11/01/2021       0.844977266 -2.4674803 4.1574348
## Control:11/13/2021-Control:11/01/2021 -1.211757722 -4.7529238 2.3294084
## 25C:11/13/2021-Control:11/01/2021       1.194887219 -2.3462789 4.7360533
## 30C:11/13/2021-Control:11/01/2021      -0.578825866 -3.8912834 2.7336317
## 30C:11/01/2021-25C:11/01/2021           0.542235546 -2.7702220 3.8546931
## Control:11/05/2021-25C:11/01/2021       2.542795846 -0.9983703 6.0839619
## 25C:11/05/2021-25C:11/01/2021           2.396823335 -1.1443428 5.9379894
## 30C:11/05/2021-25C:11/01/2021           0.971488468 -2.3409691 4.2839460
## Control:11/09/2021-25C:11/01/2021       1.645643739 -1.8955224 5.1868098
## 25C:11/09/2021-25C:11/01/2021           2.374831500 -1.1663346 5.9159976
## 30C:11/09/2021-25C:11/01/2021           1.301086836 -2.0113707 4.6135444
## Control:11/13/2021-25C:11/01/2021      -0.755648152 -4.2968143 2.7855179
## 25C:11/13/2021-25C:11/01/2021           1.650996788 -1.8901693 5.1921629
## 30C:11/13/2021-25C:11/01/2021          -0.122716296 -3.4351739 3.1897413
## Control:11/05/2021-30C:11/01/2021       2.000560301 -1.3118973 5.3130179
## 25C:11/05/2021-30C:11/01/2021           1.854587790 -1.4578698 5.1670454
## 30C:11/05/2021-30C:11/01/2021           0.429252922 -2.6374869 3.4959927
## Control:11/09/2021-30C:11/01/2021       1.103408193 -2.2090494 4.4158658
## 25C:11/09/2021-30C:11/01/2021           1.832595955 -1.4798616 5.1450535
## 30C:11/09/2021-30C:11/01/2021           0.758851290 -2.3078885 3.8255911
## Control:11/13/2021-30C:11/01/2021      -1.297883698 -4.6103413 2.0145739
## 25C:11/13/2021-30C:11/01/2021           1.108761243 -2.2036963 4.4212188
## 30C:11/13/2021-30C:11/01/2021          -0.664951842 -3.7316916 2.4017880
## 25C:11/05/2021-Control:11/05/2021      -0.145972511 -3.6871386 3.3951936
## 30C:11/05/2021-Control:11/05/2021      -1.571307379 -4.8837650 1.7411502
## Control:11/09/2021-Control:11/05/2021 -0.897152107 -4.4383182 2.6440140
## 25C:11/09/2021-Control:11/05/2021      -0.167964346 -3.7091304 3.3732018
## 30C:11/09/2021-Control:11/05/2021      -1.241709011 -4.5541666 2.0707486
## Control:11/13/2021-Control:11/05/2021 -3.298443999 -6.8396101 0.2427221
## 25C:11/13/2021-Control:11/05/2021      -0.891799058 -4.4329652 2.6493670
## 30C:11/13/2021-Control:11/05/2021      -2.665512143 -5.9779697 0.6469454
## 30C:11/05/2021-25C:11/05/2021          -1.425334867 -4.7377924 1.8871227
## Control:11/09/2021-25C:11/05/2021      -0.751179596 -4.2923457 2.7899865
## 25C:11/09/2021-25C:11/05/2021          -0.021991835 -3.5631579 3.5191743
## 30C:11/09/2021-25C:11/05/2021          -1.095736500 -4.4081941 2.2167211
## Control:11/13/2021-25C:11/05/2021      -3.152471487 -6.6936376 0.3886946
## 25C:11/13/2021-25C:11/05/2021          -0.745826547 -4.2869926 2.7953396
## 30C:11/13/2021-25C:11/05/2021          -2.519539631 -5.8319972 0.7929179
## Control:11/09/2021-30C:11/05/2021       0.674155271 -2.6383023 3.9866128
## 25C:11/09/2021-30C:11/05/2021           1.403343033 -1.9091145 4.7158006
## 30C:11/09/2021-30C:11/05/2021           0.329598368 -2.7371414 3.3963382
## Control:11/13/2021-30C:11/05/2021      -1.727136620 -5.0395942 1.5853210
## 25C:11/13/2021-30C:11/05/2021           0.679508321 -2.6329493 3.9919659
## 30C:11/13/2021-30C:11/05/2021          -1.094204764 -4.1609446 1.9725350
## 25C:11/09/2021-Control:11/09/2021       0.729187761 -2.8119783 4.2703539
## 30C:11/09/2021-Control:11/09/2021      -0.344556903 -3.6570145 2.9679007
## Control:11/13/2021-Control:11/09/2021 -2.401291891 -5.9424580 1.1398742
## 25C:11/13/2021-Control:11/09/2021       0.005353049 -3.5358131 3.5465191
## 30C:11/13/2021-Control:11/09/2021      -1.768360035 -5.0808176 1.5440975
## 30C:11/09/2021-25C:11/09/2021          -1.073744665 -4.3862022 2.2387129
## Control:11/13/2021-25C:11/09/2021      -3.130479653 -6.6716458 0.4106864
## 25C:11/13/2021-25C:11/09/2021          -0.723834712 -4.2650008 2.8173314
## 30C:11/13/2021-25C:11/09/2021          -2.497547797 -5.8100054 0.8149098
## Control:11/13/2021-30C:11/09/2021      -2.056734988 -5.3691926 1.2557226
```

```
## 25C:11/13/2021-30C:11/09/2021          0.349909953 -2.9625476 3.6623675
## 30C:11/13/2021-30C:11/09/2021         -1.423803132 -4.4905429 1.6429367
## 25C:11/13/2021-Control:11/13/2021      2.406644941 -1.1345212 5.9478110
## 30C:11/13/2021-Control:11/13/2021      0.632931856 -2.6795257 3.9453894
## 30C:11/13/2021-25C:11/13/2021         -1.773713084 -5.0861707 1.5387445
##                                           p adj
## 25C:11/01/2021-Control:11/01/2021     0.9999981
## 30C:11/01/2021-Control:11/01/2021     1.0000000
## Control:11/05/2021-Control:11/01/2021 0.6297427
## 25C:11/05/2021-Control:11/01/2021     0.7209617
## 30C:11/05/2021-Control:11/01/2021     0.9999865
## Control:11/09/2021-Control:11/01/2021 0.9851182
## 25C:11/09/2021-Control:11/01/2021     0.7341051
## 30C:11/09/2021-Control:11/01/2021     0.9984655
## Control:11/13/2021-Control:11/01/2021 0.9828928
## 25C:11/13/2021-Control:11/01/2021     0.9846038
## 30C:11/13/2021-Control:11/01/2021     0.9999568
## 30C:11/01/2021-25C:11/01/2021         0.9999775
## Control:11/05/2021-25C:11/01/2021     0.3501880
## 25C:11/05/2021-25C:11/01/2021         0.4334987
## 30C:11/05/2021-25C:11/01/2021         0.9949293
## Control:11/09/2021-25C:11/01/2021     0.8742520
## 25C:11/09/2021-25C:11/01/2021         0.4467704
## 30C:11/09/2021-25C:11/01/2021         0.9546548
## Control:11/13/2021-25C:11/01/2021     0.9997007
## 25C:11/13/2021-25C:11/01/2021         0.8720058
## 30C:11/13/2021-25C:11/01/2021         1.0000000
## Control:11/05/2021-30C:11/01/2021     0.5962855
## 25C:11/05/2021-30C:11/01/2021         0.6953842
## 30C:11/05/2021-30C:11/01/2021         0.9999954
## Control:11/09/2021-30C:11/01/2021     0.9860381
## 25C:11/09/2021-30C:11/01/2021         0.7098066
## 30C:11/09/2021-30C:11/01/2021         0.9988298
## Control:11/13/2021-30C:11/01/2021     0.9553919
## 25C:11/13/2021-30C:11/01/2021         0.9855141
## 30C:11/13/2021-30C:11/01/2021         0.9996521
## 25C:11/05/2021-Control:11/05/2021     1.0000000
## 30C:11/05/2021-Control:11/05/2021     0.8595374
## Control:11/09/2021-Control:11/05/2021 0.9985559
## 25C:11/09/2021-Control:11/05/2021     1.0000000
## 30C:11/09/2021-Control:11/05/2021     0.9669799
## Control:11/13/2021-Control:11/05/2021 0.0854334
## 25C:11/13/2021-Control:11/05/2021     0.9986307
## 30C:11/13/2021-Control:11/05/2021     0.2088088
## 30C:11/05/2021-25C:11/05/2021         0.9191878
## Control:11/09/2021-25C:11/05/2021     0.9997170
## 25C:11/09/2021-25C:11/05/2021         1.0000000
## 30C:11/09/2021-25C:11/05/2021         0.9867633
## Control:11/13/2021-25C:11/05/2021     0.1160065
## 25C:11/13/2021-25C:11/05/2021         0.9997355
## 30C:11/13/2021-25C:11/05/2021         0.2746109
## Control:11/09/2021-30C:11/05/2021     0.9998092
## 25C:11/09/2021-30C:11/05/2021         0.9264737
## 30C:11/09/2021-30C:11/05/2021         0.9999997
```

```
## Control:11/13/2021-30C:11/05/2021     0.7757314
## 25C:11/13/2021-30C:11/05/2021         0.9997942
## 30C:11/13/2021-30C:11/05/2021         0.9767329
## 25C:11/09/2021-Control:11/09/2021     0.9997866
## 30C:11/09/2021-Control:11/09/2021     0.9999998
## Control:11/13/2021-Control:11/09/2021 0.4308224
## 25C:11/13/2021-Control:11/09/2021     1.0000000
## 30C:11/13/2021-Control:11/09/2021     0.7506820
## 30C:11/09/2021-25C:11/09/2021         0.9886806
## Control:11/13/2021-25C:11/09/2021     0.1213342
## 25C:11/13/2021-25C:11/09/2021         0.9998011
## 30C:11/13/2021-25C:11/09/2021         0.2856373
## Control:11/13/2021-30C:11/09/2021     0.5575576
## 25C:11/13/2021-30C:11/09/2021         0.9999998
## 30C:11/13/2021-30C:11/09/2021         0.8749096
## 25C:11/13/2021-Control:11/13/2021     0.4276257
## 30C:11/13/2021-Control:11/13/2021     0.9998962
## 30C:11/13/2021-25C:11/13/2021         0.7473562
```

```
# Testing fit of full and reduced models using AIC
AIC(food_aov)
```

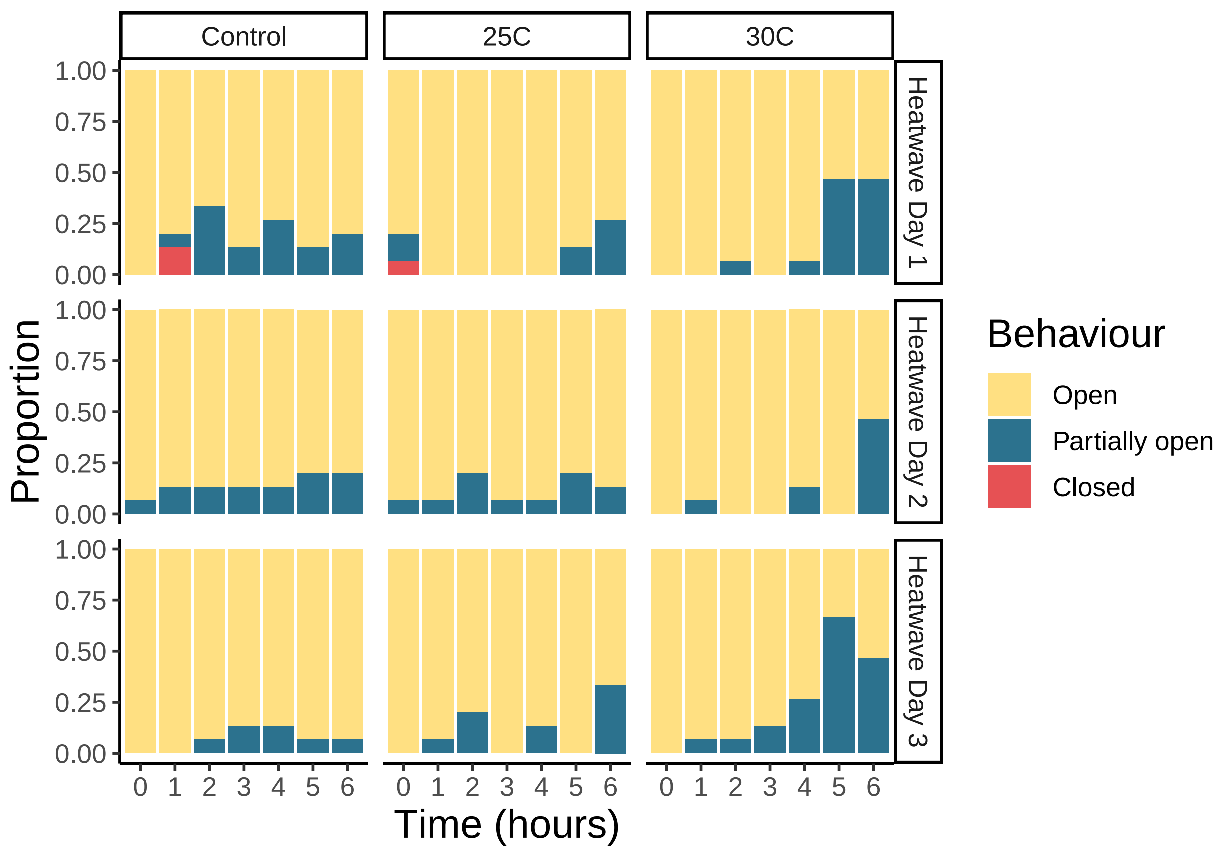
```
## [1] 141.1355
```

Heatwave response data analysis

Plots

Creating a stacked bar plot showing proportions of open, closed, and partially open anemones at each hour of the heatwave on each day

```
ggplot(data = open_closed_summary, aes(x = Time_Block, y = n,
    fill = Open_Closed)) + geom_bar(position = "fill", stat = "identity") +
    facet_grid(Event ~ Treatment) + labs(x = "Time (hours)",
    y = "Proportion", fill = "Behaviour") + theme_classic() +
    scale_fill_manual(values = c("#FFE082", "#2C728EFF", "#E65154FF")) +
    theme(strip.text.x = element_text(size = 10), strip.text.y = element_text(size = 10),
        axis.text = element_text(size = 10), axis.title = element_text(size = 15),
        legend.text = element_text(size = 10), legend.title = element_text(size = 15))
```




```
ggsave(path = "plots", filename = "open_closed_plot.png", width = 10,
    height = 7)
```

Analyzing data

Exploratory data analysis:

```
# Summarizing the data
summary(open_closed_summary)
```

```
##         Date         Event              Treatment  Time_Block        Open_Closed
##  11/6/2021:36   Length:110         Control:40   0:13       Open           :63
##  11/7/2021:38   Class :character   25C    :36   1:16       Partially open:45
##  11/8/2021:36   Mode  :character   30C    :34   2:16       Closed        : 2
##                                                 3:14
##                                                 4:17
##                                                 5:16
##                                                 6:18
##        n
##  Min.   : 1.000
##  1st Qu.: 2.000
##  Median :11.000
##  Mean   : 8.591
##  3rd Qu.:14.000
##  Max.   :15.000
##
```

```
# Making frequency table
table(open_closed_clean$Treatment, open_closed_clean$Open_Closed)
```

```
##
##           Open Partially open Closed
##   Control  274             39      2
##   25C      283             31      1
##   30C      264             51      0
```

Ordinal regression model (unsuccessful)

```
## Cumulative Link Mixed Model fitted with the Laplace approximation
##
## formula: Open_Closed ~ Treatment:Time_Block:Date + (1 | Anemone_ID)
## data:    open_closed_clean
##
##  link  threshold nobs logLik  AIC    niter        max.grad cond.H
##  logit flexible  945  -279.00 688.00 10424(41633) 7.31e-05 NaN
##
## Random effects:
##  Groups     Name        Variance Std.Dev.
##  Anemone_ID (Intercept) 1.33     1.153
## Number of groups:  Anemone_ID 45
##
## Coefficients:
##                                              Estimate Std. Error z value
## TreatmentControl:Time_Block0:Date11/6/2021 -24.29899        NaN     NaN
## Treatment25C:Time_Block0:Date11/6/2021      -1.41245        NaN     NaN
```

```
## Treatment30C:Time_Block0:Date11/6/2021     -24.29899        NaN      NaN
## TreatmentControl:Time_Block1:Date11/6/2021  -1.23516        NaN      NaN
## Treatment25C:Time_Block1:Date11/6/2021     -24.29899        NaN      NaN
## Treatment30C:Time_Block1:Date11/6/2021     -24.29899        NaN      NaN
## TreatmentControl:Time_Block2:Date11/6/2021  -0.72846        NaN      NaN
## Treatment25C:Time_Block2:Date11/6/2021     -24.29899        NaN      NaN
## Treatment30C:Time_Block2:Date11/6/2021      -2.87520        NaN      NaN
## TreatmentControl:Time_Block3:Date11/6/2021  -2.15105        NaN      NaN
## Treatment25C:Time_Block3:Date11/6/2021     -24.29899        NaN      NaN
## Treatment30C:Time_Block3:Date11/6/2021     -24.29899        NaN      NaN
## TreatmentControl:Time_Block4:Date11/6/2021  -1.13487        NaN      NaN
## Treatment25C:Time_Block4:Date11/6/2021     -24.29899        NaN      NaN
## Treatment30C:Time_Block4:Date11/6/2021      -2.87465        NaN      NaN
## TreatmentControl:Time_Block5:Date11/6/2021  -2.15321        NaN      NaN
## Treatment25C:Time_Block5:Date11/6/2021      -2.12696        NaN      NaN
## Treatment30C:Time_Block5:Date11/6/2021      -0.01848        NaN      NaN
## TreatmentControl:Time_Block6:Date11/6/2021  -1.58081        NaN      NaN
## Treatment25C:Time_Block6:Date11/6/2021      -1.10297        NaN      NaN
## Treatment30C:Time_Block6:Date11/6/2021      -0.01163        NaN      NaN
## TreatmentControl:Time_Block0:Date11/7/2021  -3.00253        NaN      NaN
## Treatment25C:Time_Block0:Date11/7/2021      -2.98593        NaN      NaN
## Treatment30C:Time_Block0:Date11/7/2021     -24.29899        NaN      NaN
## TreatmentControl:Time_Block1:Date11/7/2021  -2.14889        NaN      NaN
## Treatment25C:Time_Block1:Date11/7/2021      -2.98916        NaN      NaN
## Treatment30C:Time_Block1:Date11/7/2021      -2.87687        NaN      NaN
## TreatmentControl:Time_Block2:Date11/7/2021  -2.15285        NaN      NaN
## Treatment25C:Time_Block2:Date11/7/2021      -1.55758        NaN      NaN
## Treatment30C:Time_Block2:Date11/7/2021     -24.29899        NaN      NaN
## TreatmentControl:Time_Block3:Date11/7/2021  -2.15196        NaN      NaN
## Treatment25C:Time_Block3:Date11/7/2021      -2.98703        NaN      NaN
## Treatment30C:Time_Block3:Date11/7/2021     -24.29899        NaN      NaN
## TreatmentControl:Time_Block4:Date11/7/2021  -2.15196        NaN      NaN
## Treatment25C:Time_Block4:Date11/7/2021      -2.98703        NaN      NaN
## Treatment30C:Time_Block4:Date11/7/2021      -2.03933        NaN      NaN
## TreatmentControl:Time_Block5:Date11/7/2021  -1.57782        NaN      NaN
## Treatment25C:Time_Block5:Date11/7/2021      -1.55333        NaN      NaN
## Treatment30C:Time_Block5:Date11/7/2021     -24.29899        NaN      NaN
## TreatmentControl:Time_Block6:Date11/7/2021  -1.57782        NaN      NaN
## Treatment25C:Time_Block6:Date11/7/2021      -2.12738        NaN      NaN
## Treatment30C:Time_Block6:Date11/7/2021      -0.01314        NaN      NaN
## TreatmentControl:Time_Block0:Date11/8/2021 -24.29899        NaN      NaN
## Treatment25C:Time_Block0:Date11/8/2021     -24.29899        NaN      NaN
## Treatment30C:Time_Block0:Date11/8/2021     -24.29899        NaN      NaN
## TreatmentControl:Time_Block1:Date11/8/2021 -24.29899        NaN      NaN
## Treatment25C:Time_Block1:Date11/8/2021      -2.98916        NaN      NaN
## Treatment30C:Time_Block1:Date11/8/2021      -2.87520        NaN      NaN
## TreatmentControl:Time_Block2:Date11/8/2021  -3.00253        NaN      NaN
## Treatment25C:Time_Block2:Date11/8/2021      -1.55253        NaN      NaN
## Treatment30C:Time_Block2:Date11/8/2021      -2.87465        NaN      NaN
## TreatmentControl:Time_Block3:Date11/8/2021  -2.14891        NaN      NaN
## Treatment25C:Time_Block3:Date11/8/2021     -24.29899        NaN      NaN
## Treatment30C:Time_Block3:Date11/8/2021      -2.03961        NaN      NaN
## TreatmentControl:Time_Block4:Date11/8/2021  -2.15321        NaN      NaN
## Treatment25C:Time_Block4:Date11/8/2021      -2.12591        NaN      NaN
```

```
## Treatment30C:Time_Block4:Date11/8/2021      -1.04912        NaN     NaN
## TreatmentControl:Time_Block5:Date11/8/2021  -3.00551        NaN     NaN
## Treatment25C:Time_Block5:Date11/8/2021     -24.29899        NaN     NaN
## Treatment30C:Time_Block5:Date11/8/2021       0.90306        NaN     NaN
## TreatmentControl:Time_Block6:Date11/8/2021  -3.00551        NaN     NaN
## Treatment25C:Time_Block6:Date11/8/2021      -0.71106        NaN     NaN
##                                            Pr(>|z|)
## TreatmentControl:Time_Block0:Date11/6/2021      NaN
## Treatment25C:Time_Block0:Date11/6/2021          NaN
## Treatment30C:Time_Block0:Date11/6/2021          NaN
## TreatmentControl:Time_Block1:Date11/6/2021      NaN
## Treatment25C:Time_Block1:Date11/6/2021          NaN
## Treatment30C:Time_Block1:Date11/6/2021          NaN
## TreatmentControl:Time_Block2:Date11/6/2021      NaN
## Treatment25C:Time_Block2:Date11/6/2021          NaN
## Treatment30C:Time_Block2:Date11/6/2021          NaN
## TreatmentControl:Time_Block3:Date11/6/2021      NaN
## Treatment25C:Time_Block3:Date11/6/2021          NaN
## Treatment30C:Time_Block3:Date11/6/2021          NaN
## TreatmentControl:Time_Block4:Date11/6/2021      NaN
## Treatment25C:Time_Block4:Date11/6/2021          NaN
## Treatment30C:Time_Block4:Date11/6/2021          NaN
## TreatmentControl:Time_Block5:Date11/6/2021      NaN
## Treatment25C:Time_Block5:Date11/6/2021          NaN
## Treatment30C:Time_Block5:Date11/6/2021          NaN
## TreatmentControl:Time_Block6:Date11/6/2021      NaN
## Treatment25C:Time_Block6:Date11/6/2021          NaN
## Treatment30C:Time_Block6:Date11/6/2021          NaN
## TreatmentControl:Time_Block0:Date11/7/2021      NaN
## Treatment25C:Time_Block0:Date11/7/2021          NaN
## Treatment30C:Time_Block0:Date11/7/2021          NaN
## TreatmentControl:Time_Block1:Date11/7/2021      NaN
## Treatment25C:Time_Block1:Date11/7/2021          NaN
## Treatment30C:Time_Block1:Date11/7/2021          NaN
## TreatmentControl:Time_Block2:Date11/7/2021      NaN
## Treatment25C:Time_Block2:Date11/7/2021          NaN
## Treatment30C:Time_Block2:Date11/7/2021          NaN
## TreatmentControl:Time_Block3:Date11/7/2021      NaN
## Treatment25C:Time_Block3:Date11/7/2021          NaN
## Treatment30C:Time_Block3:Date11/7/2021          NaN
## TreatmentControl:Time_Block4:Date11/7/2021      NaN
## Treatment25C:Time_Block4:Date11/7/2021          NaN
## Treatment30C:Time_Block4:Date11/7/2021          NaN
## TreatmentControl:Time_Block5:Date11/7/2021      NaN
## Treatment25C:Time_Block5:Date11/7/2021          NaN
## Treatment30C:Time_Block5:Date11/7/2021          NaN
## TreatmentControl:Time_Block6:Date11/7/2021      NaN
## Treatment25C:Time_Block6:Date11/7/2021          NaN
## Treatment30C:Time_Block6:Date11/7/2021          NaN
## TreatmentControl:Time_Block0:Date11/8/2021      NaN
## Treatment25C:Time_Block0:Date11/8/2021          NaN
## Treatment30C:Time_Block0:Date11/8/2021          NaN
## TreatmentControl:Time_Block1:Date11/8/2021      NaN
## Treatment25C:Time_Block1:Date11/8/2021          NaN
```

```
## Treatment30C:Time_Block1:Date11/8/2021          NaN
## TreatmentControl:Time_Block2:Date11/8/2021      NaN
## Treatment25C:Time_Block2:Date11/8/2021          NaN
## Treatment30C:Time_Block2:Date11/8/2021          NaN
## TreatmentControl:Time_Block3:Date11/8/2021      NaN
## Treatment25C:Time_Block3:Date11/8/2021          NaN
## Treatment30C:Time_Block3:Date11/8/2021          NaN
## TreatmentControl:Time_Block4:Date11/8/2021      NaN
## Treatment25C:Time_Block4:Date11/8/2021          NaN
## Treatment30C:Time_Block4:Date11/8/2021          NaN
## TreatmentControl:Time_Block5:Date11/8/2021      NaN
## Treatment25C:Time_Block5:Date11/8/2021          NaN
## Treatment30C:Time_Block5:Date11/8/2021          NaN
## TreatmentControl:Time_Block6:Date11/8/2021      NaN
## Treatment25C:Time_Block6:Date11/8/2021          NaN
##
## Threshold coefficients:
##                      Estimate Std. Error z value
## Open|Partially open     0.2115        NaN     NaN
## Partially open|Closed   4.6973        NaN     NaN
```

Bayesian regression analysis

```
# Running a Bayesian model with weakly flat priors.  Fixed
# effects are treatment, time block, and date.  Anemone ID
# is a random effect.

# Run this code once before running model
# options(mc.cores=parallel::detectCores())

bay_mod <- brm(Open_Closed ~ Treatment + Time_Block + Date +
    (1 | Anemone_ID), data = open_closed_clean, family = cumulative("logit"))
```

```
summary(bay_mod)
```

```
##  Family: cumulative
##   Links: mu = logit; disc = identity
## Formula: Open_Closed ~ Treatment + Time_Block + Date + (1 | Anemone_ID)
##    Data: open_closed_clean (Number of observations: 945)
##   Draws: 4 chains, each with iter = 2000; warmup = 1000; thin = 1;
##          total post-warmup draws = 4000
##
## Group-Level Effects:
## ~Anemone_ID (Number of levels: 45)
##               Estimate Est.Error l-95% CI u-95% CI Rhat Bulk_ESS Tail_ESS
## sd(Intercept)     1.10      0.23     0.72     1.60 1.00     1487     2410
##
## Population-Level Effects:
##               Estimate Est.Error l-95% CI u-95% CI Rhat Bulk_ESS Tail_ESS
## Intercept[1]      3.78      0.63     2.65     5.12 1.00     1172     1481
## Intercept[2]      7.92      0.87     6.40     9.76 1.00     1926     2478
## Treatment25C     -0.28      0.52    -1.29     0.78 1.00     1793     1650
## Treatment30C      0.45      0.49    -0.52     1.44 1.00     1605     2191
```

```
## Time_Block1       0.70      0.62    -0.45     1.97 1.00     1260     1769
## Time_Block2       1.39      0.57     0.34     2.59 1.00     1170     1596
## Time_Block3       0.68      0.61    -0.47     1.92 1.00     1265     1800
## Time_Block4       1.54      0.57     0.50     2.74 1.00     1201     1522
## Time_Block5       2.15      0.55     1.18     3.29 1.00     1148     1232
## Time_Block6       2.67      0.54     1.70     3.82 1.00     1144     1406
## Date11D7D2021    -0.24      0.26    -0.74     0.26 1.00     6174     3059
## Date11D8D2021    -0.04      0.25    -0.54     0.47 1.00     5900     3079
##
## Family Specific Parameters:
##      Estimate Est.Error l-95% CI u-95% CI Rhat Bulk_ESS Tail_ESS
## disc     1.00      0.00     1.00     1.00   NA       NA       NA
##
## Draws were sampled using sampling(NUTS). For each parameter, Bulk_ESS
## and Tail_ESS are effective sample size measures, and Rhat is the potential
## scale reduction factor on split chains (at convergence, Rhat = 1).
```

```
# Calculating percent confidence for each treatment, date,
# and time block
response_post = posterior_samples(bay_mod)
sum(response_post$b_Treatment30C > 0)/4000
```

```
## [1] 0.82125
```

```
sum(response_post$b_Treatment25C > 0)/4000
```

```
## [1] 0.28675
```

```
sum(response_post$b_Time_Block1 > 0)/4000
```

```
## [1] 0.87375
```

```
sum(response_post$b_Time_Block2 > 0)/4000
```

```
## [1] 0.9965
```

```
sum(response_post$b_Time_Block3 > 0)/4000
```

```
## [1] 0.86925
```

```
sum(response_post$b_Time_Block4 > 0)/4000
```

```
## [1] 0.9995
```

```
sum(response_post$b_Time_Block5 > 0)/4000
```

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

```
sum(response_post$b_Time_Block6 > 0)/4000
```

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

```
sum(response_post$b_Date11D7D2021 > 0)/4000
```

```
## [1] 0.169
```

```
sum(response_post$b_Date11D8D2021 > 0)/4000
```

```
## [1] 0.43475
```

Hemocytometer data analysis

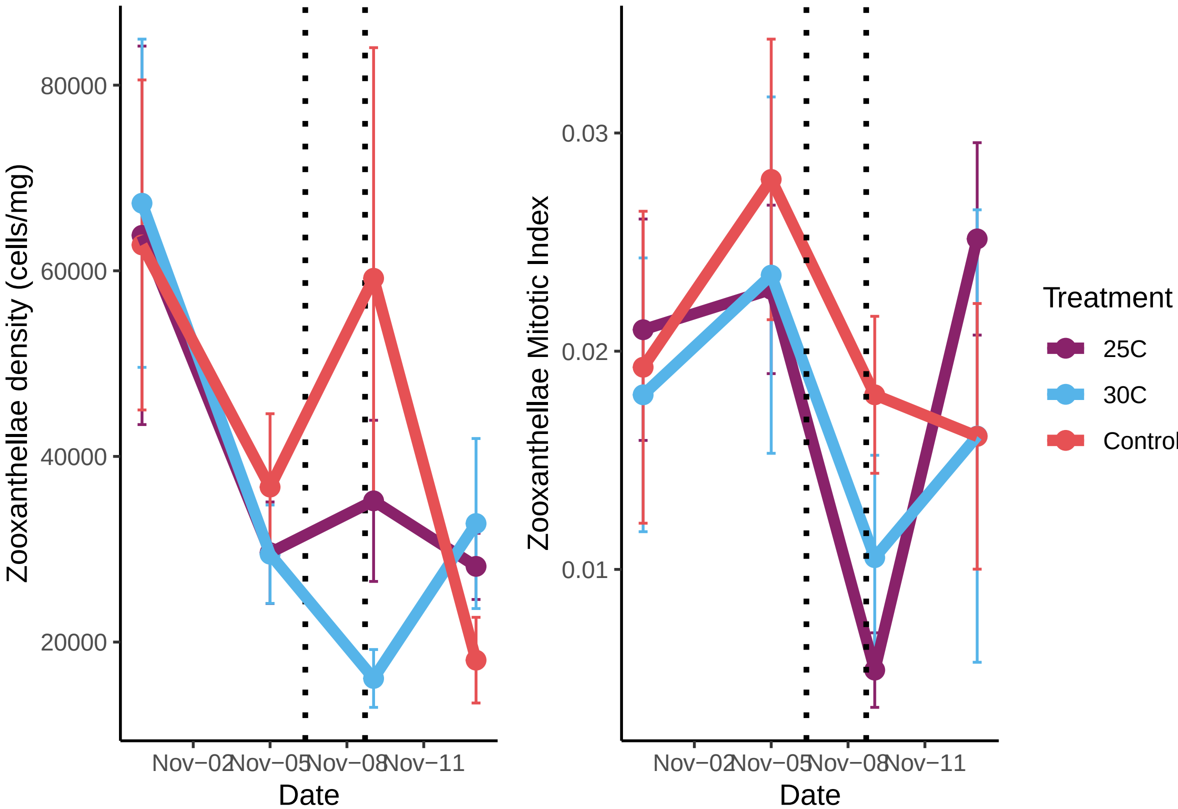
Plots

Boxplots of dinoflagellate density and mitotic index at each measurement time:

```
# Dinoflagellate density
p1 <- ggplot(data = hemo_summary, aes(x = Date, y = mean_Dino_Density,
    group = Treatment, colour = Treatment)) + theme_classic() +
    geom_errorbar(aes(ymin = mean_Dino_Density - se_Dino_Density,
        ymax = mean_Dino_Density + se_Dino_Density), width = 30000) +
    geom_vline(xintercept = as.POSIXct("2021-11-06 09:00:00"),
        linetype = "dotted", size = 1) + geom_vline(xintercept = as.POSIXct("2021-11-08 16:00:00"),
    linetype = "dotted", size = 1) + geom_point(size = 3) + geom_line(lwd = 2) +
    scale_fill_manual(values = c("#89226AFF", "#56B4E9FF", "#E65154FF")) +
    scale_colour_manual(values = c("#89226AFF", "#56B4E9FF",
        "#E65154FF")) + labs(x = "Date", y = "Zooxanthellae density (cells/mg)") +
    scale_x_datetime(breaks = date_breaks("3 days"), labels = date_format("%b-%d")) +
    theme(legend.position = "none")

# Mitotic Index of Dinoflagellates
p2 = ggplot(data = hemo_summary, aes(x = Date, y = mean_Dino_MI,
    group = Treatment, colour = Treatment)) + theme_classic() +
    geom_errorbar(aes(ymin = mean_Dino_MI - se_Dino_MI, ymax = mean_Dino_MI +
        se_Dino_MI), width = 30000) + geom_point(size = 3) +
    geom_line(lwd = 2) + geom_vline(xintercept = as.POSIXct("2021-11-06 09:00:00"),
    linetype = "dotted", size = 1) + geom_vline(xintercept = as.POSIXct("2021-11-08 16:00:00"),
    linetype = "dotted", size = 1) + scale_fill_manual(values = c("#89226AFF",
    "#56B4E9FF", "#E65154FF")) + scale_colour_manual(values = c("#89226AFF",
    "#56B4E9FF", "#E65154FF")) + labs(x = "Date", y = "Zooxanthellae Mitotic Index") +
    scale_x_datetime(breaks = date_breaks("3 days"), labels = date_format("%b-%d"))

# Combining plots
p1 + p2
```




```
ggsave(path = "plots", filename = "dinoflagellate_density_MI.png",
    width = 15, height = 4)
```

Analyzing zooxanthellae density and mitotic index

Zooxanthellae density

```
# Dinoflagellate density
shapiro_test(hemo_clean$Dino_Density)
```

```
## # A tibble: 1 x 3
##   variable                statistic      p.value
##   <chr>                       <dbl>        <dbl>
## 1 hemo_clean$Dino_Density     0.774 0.0000000317
```

```
bartlett.test(Dino_Density ~ Treatment, data = hemo_clean)
```

```
##
##  Bartlett test of homogeneity of variances
##
## data:  Dino_Density by Treatment
## Bartlett's K-squared = 2.0717, df = 2, p-value = 0.3549
```

```
# Data has equal variances but is not normal

# log transformation:
hemo_clean <- hemo_clean %>%
    mutate(log_Dino_Density = log(Dino_Density))

shapiro_test(hemo_clean$log_Dino_Density)
```

```
## # A tibble: 1 x 3
##   variable                    statistic p.value
##   <chr>                           <dbl>   <dbl>
## 1 hemo_clean$log_Dino_Density     0.977   0.306
```

```
bartlett.test(log_Dino_Density ~ Treatment, data = hemo_clean)
```

```
##
##  Bartlett test of homogeneity of variances
##
## data:  log_Dino_Density by Treatment
## Bartlett's K-squared = 2.1689, df = 2, p-value = 0.3381
```

```
hemo_clean %>%
    group_by(Treatment, Date) %>%
    identify_outliers(log_Dino_Density)
```

```
## # A tibble: 3 x 16
##   Date                Treatment Bin   Site      Anemone_ID Tentacle_Mass_mg
##   <dttm>              <fct>     <fct> <fct>     <fct>                 <dbl>
## 1 2021-10-31 00:00:00 25C       E     Foreshore A18F                      6
```

```
## 2 2021-11-05 00:00:00 25C       B     Foreshore A21F                   17
## 3 2021-11-13 00:00:00 30C       J     Scotts    A34S                    8.2
## # ... with 10 more variables: Number_Dino_Average <dbl>,
## #   Number_Green_Average <dbl>, Dividing_Dino_Average <dbl>,
## #   Dividing_Green_Average <dbl>, Dino_Density <dbl>, Green_Density <dbl>,
## #   Dino_MI <dbl>, log_Dino_Density <dbl>, is.outlier <lgl>, is.extreme <lgl>
```

```
# Log transformed data is normal and has equal variances.
# There are two extreme outliers but this will not have a
# major impact on the results.  We will use a two-way ANOVA
# to analyze this data.
```

Two-way AVOVA on zooxanthellae density data:

```
Dino_Density_aov <- aov(log_Dino_Density ~ Treatment * as.factor(Date) +
    random(Anemone_ID), data = hemo_clean)
summary(Dino_Density_aov)
```

```
##                            Df Sum Sq Mean Sq F value   Pr(>F)
## Treatment                   2  0.230  0.1148   0.328 0.722234
## as.factor(Date)             3  6.886  2.2953   6.553 0.000837 ***
## Treatment:as.factor(Date)   6  3.930  0.6550   1.870 0.105532
## Residuals                  48 16.814  0.3503
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
TukeyHSD(Dino_Density_aov)
```

```
##   Tukey multiple comparisons of means
##     95% family-wise confidence level
##
## Fit: aov(formula = log_Dino_Density ~ Treatment * as.factor(Date) + random(Anemone_ID), data = hemo_
##
## $Treatment
##                    diff        lwr       upr     p adj
## 30C-25C     -0.14024770 -0.5928985 0.3124031 0.7354862
## Control-25C -0.02049715 -0.4731479 0.4321536 0.9934105
## Control-30C  0.11975055 -0.3329002 0.5724013 0.7989600
##
## $`as.factor(Date)`
##                             diff        lwr         upr     p adj
## 2021-11-05-2021-10-31 -0.6348142 -1.2099818 -0.05964665 0.0252612
## 2021-11-09-2021-10-31 -0.7465775 -1.3217451 -0.17140996 0.0061850
## 2021-11-13-2021-10-31 -0.8843860 -1.4595536 -0.30921842 0.0009089
## 2021-11-09-2021-11-05 -0.1117633 -0.6869309  0.46340428 0.9545854
## 2021-11-13-2021-11-05 -0.2495718 -0.8247394  0.32559582 0.6578095
## 2021-11-13-2021-11-09 -0.1378085 -0.7129760  0.43735913 0.9192988
##
## $`Treatment:as.factor(Date)`
##                                              diff        lwr         upr
## 30C:2021-10-31-25C:2021-10-31          0.059673338 -1.2256598  1.345006465
## Control:2021-10-31-25C:2021-10-31     -0.036543645 -1.3218768  1.248789482
```

```
## 25C:2021-11-05-25C:2021-10-31          -0.704674448 -1.9900076  0.580658680
## 30C:2021-11-05-25C:2021-10-31          -0.686050129 -1.9713833  0.599282998
## Control:2021-11-05-25C:2021-10-31      -0.490588444 -1.7759216  0.794744684
## 25C:2021-11-09-25C:2021-10-31          -0.616066237 -1.9013994  0.669266890
## 30C:2021-11-09-25C:2021-10-31          -1.311573994 -2.5969071 -0.026240866
## Control:2021-11-09-25C:2021-10-31      -0.288962707 -1.5742958  0.996370420
## 25C:2021-11-13-25C:2021-10-31          -0.699871033 -1.9852042  0.585462095
## 30C:2021-11-13-25C:2021-10-31          -0.643651740 -1.9289849  0.641681388
## Control:2021-11-13-25C:2021-10-31      -1.286505539 -2.5718387 -0.001172412
## Control:2021-10-31-30C:2021-10-31      -0.096216983 -1.3815501  1.189116145
## 25C:2021-11-05-30C:2021-10-31          -0.764347785 -2.0496809  0.520985342
## 30C:2021-11-05-30C:2021-10-31          -0.745723467 -2.0310566  0.539609661
## Control:2021-11-05-30C:2021-10-31      -0.550261781 -1.8355949  0.735071346
## 25C:2021-11-09-30C:2021-10-31          -0.675739575 -1.9610727  0.609593553
## 30C:2021-11-09-30C:2021-10-31          -1.371247332 -2.6565805 -0.085914204
## Control:2021-11-09-30C:2021-10-31      -0.348636045 -1.6339692  0.936697083
## 25C:2021-11-13-30C:2021-10-31          -0.759544371 -2.0448775  0.525788757
## 30C:2021-11-13-30C:2021-10-31          -0.703325077 -1.9886582  0.582008050
## Control:2021-11-13-30C:2021-10-31      -1.346178877 -2.6315120 -0.060845749
## 25C:2021-11-05-Control:2021-10-31      -0.668130803 -1.9534639  0.617202325
## 30C:2021-11-05-Control:2021-10-31      -0.649506484 -1.9348396  0.635826643
## Control:2021-11-05-Control:2021-10-31 -0.454044799 -1.7393779  0.831288329
## 25C:2021-11-09-Control:2021-10-31      -0.579522592 -1.8648557  0.705810535
## 30C:2021-11-09-Control:2021-10-31      -1.275030349 -2.5603635  0.010302779
## Control:2021-11-09-Control:2021-10-31 -0.252419062 -1.5377522  1.032914065
## 25C:2021-11-13-Control:2021-10-31      -0.663327388 -1.9486605  0.622005740
## 30C:2021-11-13-Control:2021-10-31      -0.607108095 -1.8924412  0.678225033
## Control:2021-11-13-Control:2021-10-31 -1.249961894 -2.5352950  0.035371233
## 30C:2021-11-05-25C:2021-11-05           0.018624319 -1.2667088  1.303957446
## Control:2021-11-05-25C:2021-11-05       0.214086004 -1.0712471  1.499419131
## 25C:2021-11-09-25C:2021-11-05           0.088608210 -1.1967249  1.373941338
## 30C:2021-11-09-25C:2021-11-05          -0.606899546 -1.8922327  0.678433581
## Control:2021-11-09-25C:2021-11-05       0.415711740 -0.8696214  1.701044868
## 25C:2021-11-13-25C:2021-11-05           0.004803415 -1.2805297  1.290136542
## 30C:2021-11-13-25C:2021-11-05           0.061022708 -1.2243104  1.346355835
## Control:2021-11-13-25C:2021-11-05      -0.581831092 -1.8671642  0.703502036
## Control:2021-11-05-30C:2021-11-05       0.195461685 -1.0898714  1.480794813
## 25C:2021-11-09-30C:2021-11-05           0.069983892 -1.2153492  1.355317019
## 30C:2021-11-09-30C:2021-11-05          -0.625523865 -1.9108570  0.659809263
## Control:2021-11-09-30C:2021-11-05       0.397087422 -0.8882457  1.682420549
## 25C:2021-11-13-30C:2021-11-05          -0.013820904 -1.2991540  1.271512224
## 30C:2021-11-13-30C:2021-11-05           0.042398389 -1.2429347  1.327731517
## Control:2021-11-13-30C:2021-11-05      -0.600455410 -1.8857885  0.684877717
## 25C:2021-11-09-Control:2021-11-05      -0.125477794 -1.4108109  1.159855334
## 30C:2021-11-09-Control:2021-11-05      -0.820985550 -2.1063187  0.464347577
## Control:2021-11-09-Control:2021-11-05  0.201625736 -1.0837074  1.486958864
## 25C:2021-11-13-Control:2021-11-05      -0.209282589 -1.4946157  1.076050538
## 30C:2021-11-13-Control:2021-11-05      -0.153063296 -1.4383964  1.132269831
## Control:2021-11-13-Control:2021-11-05 -0.795917096 -2.0812502  0.489416032
## 30C:2021-11-09-25C:2021-11-09          -0.695507757 -1.9808409  0.589825371
## Control:2021-11-09-25C:2021-11-09       0.327103530 -0.9582296  1.612436657
## 25C:2021-11-13-25C:2021-11-09          -0.083804796 -1.3691379  1.201528332
## 30C:2021-11-13-25C:2021-11-09          -0.027585502 -1.3129186  1.257747625
## Control:2021-11-13-25C:2021-11-09      -0.670439302 -1.9557724  0.614893825
```

```
## Control:2021-11-09-30C:2021-11-09      1.022611287 -0.2627218  2.307944414
## 25C:2021-11-13-30C:2021-11-09          0.611702961 -0.6736302  1.897036088
## 30C:2021-11-13-30C:2021-11-09          0.667922254 -0.6174109  1.953255382
## Control:2021-11-13-30C:2021-11-09      0.025068455 -1.2602647  1.310401582
## 25C:2021-11-13-Control:2021-11-09     -0.410908326 -1.6962415  0.874424802
## 30C:2021-11-13-Control:2021-11-09     -0.354689032 -1.6400222  0.930644095
## Control:2021-11-13-Control:2021-11-09 -0.997542832 -2.2828760  0.287790296
## 30C:2021-11-13-25C:2021-11-13          0.056219293 -1.2291138  1.341552421
## Control:2021-11-13-25C:2021-11-13     -0.586634506 -1.8719676  0.698698621
## Control:2021-11-13-30C:2021-11-13     -0.642853799 -1.9281869  0.642479328
##                                           p adj
## 30C:2021-10-31-25C:2021-10-31         1.0000000
## Control:2021-10-31-25C:2021-10-31     1.0000000
## 25C:2021-11-05-25C:2021-10-31         0.7636550
## 30C:2021-11-05-25C:2021-10-31         0.7920952
## Control:2021-11-05-25C:2021-10-31     0.9736599
## 25C:2021-11-09-25C:2021-10-31         0.8827904
## 30C:2021-11-09-25C:2021-10-31         0.0417097
## Control:2021-11-09-25C:2021-10-31     0.9997178
## 25C:2021-11-13-25C:2021-10-31         0.7711393
## 30C:2021-11-13-25C:2021-10-31         0.8503494
## Control:2021-11-13-25C:2021-10-31     0.0496006
## Control:2021-10-31-30C:2021-10-31     1.0000000
## 25C:2021-11-05-30C:2021-10-31         0.6637528
## 30C:2021-11-05-30C:2021-10-31         0.6960933
## Control:2021-11-05-30C:2021-10-31     0.9415677
## 25C:2021-11-09-30C:2021-10-31         0.8071333
## 30C:2021-11-09-30C:2021-10-31         0.0272581
## Control:2021-11-09-30C:2021-10-31     0.9983947
## 25C:2021-11-13-30C:2021-10-31         0.6721711
## 30C:2021-11-13-30C:2021-10-31         0.7657675
## Control:2021-11-13-30C:2021-10-31     0.0326615
## 25C:2021-11-05-Control:2021-10-31     0.8178847
## 30C:2021-11-05-Control:2021-10-31     0.8428896
## Control:2021-11-05-Control:2021-10-31 0.9852927
## 25C:2021-11-09-Control:2021-10-31     0.9186639
## 30C:2021-11-09-Control:2021-10-31     0.0536341
## Control:2021-11-09-Control:2021-10-31 0.9999241
## 25C:2021-11-13-Control:2021-10-31     0.8245150
## 30C:2021-11-13-Control:2021-10-31     0.8923399
## Control:2021-11-13-Control:2021-10-31 0.0634610
## 30C:2021-11-05-25C:2021-11-05         1.0000000
## Control:2021-11-05-25C:2021-11-05     0.9999855
## 25C:2021-11-09-25C:2021-11-05         1.0000000
## 30C:2021-11-09-25C:2021-11-05         0.8925564
## Control:2021-11-09-25C:2021-11-05     0.9927230
## 25C:2021-11-13-25C:2021-11-05         1.0000000
## 30C:2021-11-13-25C:2021-11-05         1.0000000
## Control:2021-11-13-25C:2021-11-05     0.9166391
## Control:2021-11-05-30C:2021-11-05     0.9999943
## 25C:2021-11-09-30C:2021-11-05         1.0000000
## 30C:2021-11-09-30C:2021-11-05         0.8721796
## Control:2021-11-09-30C:2021-11-05     0.9950274
## 25C:2021-11-13-30C:2021-11-05         1.0000000
```

```
## 30C:2021-11-13-30C:2021-11-05         1.0000000
## Control:2021-11-13-30C:2021-11-05     0.8991145
## 25C:2021-11-09-Control:2021-11-05     0.9999999
## 30C:2021-11-09-Control:2021-11-05     0.5621842
## Control:2021-11-09-Control:2021-11-05 0.9999921
## 25C:2021-11-13-Control:2021-11-05     0.9999885
## 30C:2021-11-13-Control:2021-11-05     0.9999996
## Control:2021-11-13-Control:2021-11-05 0.6074723
## 30C:2021-11-09-25C:2021-11-09         0.7778498
## Control:2021-11-09-25C:2021-11-09     0.9990990
## 25C:2021-11-13-25C:2021-11-09         1.0000000
## 30C:2021-11-13-25C:2021-11-09         1.0000000
## Control:2021-11-13-25C:2021-11-09     0.8146546
## Control:2021-11-09-30C:2021-11-09     0.2425124
## 25C:2021-11-13-30C:2021-11-09         0.8875029
## 30C:2021-11-13-30C:2021-11-09         0.8181751
## Control:2021-11-13-30C:2021-11-09     1.0000000
## 25C:2021-11-13-Control:2021-11-09     0.9933866
## 30C:2021-11-13-Control:2021-11-09     0.9981284
## Control:2021-11-13-Control:2021-11-09 0.2746160
## 30C:2021-11-13-25C:2021-11-13         1.0000000
## Control:2021-11-13-25C:2021-11-13     0.9123221
## Control:2021-11-13-30C:2021-11-13     0.8513508
```

```
# Testing fit of full and reduced models using AIC
AIC(Dino_Density_aov)
```

```
## [1] 119.9459
```

Zooxanthellae mitotic index

```
# Dinoflagellate mitotic index
shapiro_test(hemo_clean$Dino_MI)
```

```
## # A tibble: 1 x 3
##   variable           statistic p.value
##   <chr>                  <dbl>   <dbl>
## 1 hemo_clean$Dino_MI     0.949  0.0141
```

```
bartlett.test(Dino_MI ~ Treatment, data = hemo_clean)
```

```
##
##  Bartlett test of homogeneity of variances
##
## data:  Dino_MI by Treatment
## Bartlett's K-squared = 2.5973, df = 2, p-value = 0.2729
```

```
# Data has equal variances but is not normal

# Trying transformations:
```

```r
hemo_clean <- hemo_clean %>%
    mutate(log_Dino_MI = log(Dino_MI + 0.1), arcsine_Dino_MI = asin(sqrt(Dino_MI)),
        sqrt_Dino_MI = sqrt(Dino_MI))

# Testing normality of transformed data
shapiro_test(hemo_clean$log_Dino_MI)
```

```
## # A tibble: 1 x 3
##   variable              statistic p.value
##   <chr>                     <dbl>   <dbl>
## 1 hemo_clean$log_Dino_MI     0.963  0.0664
```

```r
shapiro_test(hemo_clean$arcsine_Dino_MI)
```

```
## # A tibble: 1 x 3
##   variable                  statistic p.value
##   <chr>                         <dbl>   <dbl>
## 1 hemo_clean$arcsine_Dino_MI     0.932 0.00248
```

```r
shapiro_test(hemo_clean$sqrt_Dino_MI)
```

```
## # A tibble: 1 x 3
##   variable               statistic p.value
##   <chr>                      <dbl>   <dbl>
## 1 hemo_clean$sqrt_Dino_MI     0.931 0.00213
```

```r
# Arcsin and square root tranformations are not normal, but
# the log transformed data is.

bartlett.test(log_Dino_MI ~ Treatment, data = hemo_clean)  #0.03211
```

```
##
##  Bartlett test of homogeneity of variances
##
## data:  log_Dino_MI by Treatment
## Bartlett's K-squared = 2.4483, df = 2, p-value = 0.294
```

```r
# log transformed data has equal variances

hemo_clean %>%
    group_by(Treatment, Date) %>%
    identify_outliers(log_Dino_MI)
```

```
## # A tibble: 8 x 19
##   Date                Treatment Bin   Site      Anemone_ID Tentacle_Mass_mg
##   <dttm>              <fct>     <fct> <fct>     <fct>                 <dbl>
## 1 2021-10-31 00:00:00 25C       C     Foreshore A23F                    4.4
## 2 2021-11-05 00:00:00 25C       B     Foreshore A21F                   17
## 3 2021-10-31 00:00:00 30C       F     Scotts    A35S                    1
## 4 2021-10-31 00:00:00 30C       F     Scotts    A42S                    6.6
```

```
## 5 2021-11-13 00:00:00 30C       J     Scotts    A34S                    8.2
## 6 2021-10-31 00:00:00 Control   K     Bluestone A45B                    3.1
## 7 2021-10-31 00:00:00 Control   M     Bluestone A60B                    6.3
## 8 2021-11-05 00:00:00 Control   K     Bluestone A45B                   24
## # ... with 13 more variables: Number_Dino_Average <dbl>,
## #   Number_Green_Average <dbl>, Dividing_Dino_Average <dbl>,
## #   Dividing_Green_Average <dbl>, Dino_Density <dbl>, Green_Density <dbl>,
## #   Dino_MI <dbl>, log_Dino_Density <dbl>, log_Dino_MI <dbl>,
## #   arcsine_Dino_MI <dbl>, sqrt_Dino_MI <dbl>, is.outlier <lgl>,
## #   is.extreme <lgl>
```

```
# The data has three extreme outliers, but this will not
# have a major effect on the results.  We will use an
# two-way ANOVA on the log transformed data.
```

Two-way ANOVA on mitotic index data:

```
# Dinoflagellate mitotic index
Dino_MI_aov <- aov(log_Dino_MI ~ Treatment * as.factor(Date) +
    random(Anemone_ID), data = hemo_clean)
summary(Dino_MI_aov)
```

```
##                            Df Sum Sq  Mean Sq F value Pr(>F)
## Treatment                   2 0.0097 0.004852   0.397 0.6747
## as.factor(Date)             3 0.0948 0.031600   2.584 0.0641 .
## Treatment:as.factor(Date)   6 0.0515 0.008588   0.702 0.6492
## Residuals                  48 0.5871 0.012231
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
TukeyHSD(Dino_MI_aov)
```

```
##   Tukey multiple comparisons of means
##     95% family-wise confidence level
##
## Fit: aov(formula = log_Dino_MI ~ Treatment * as.factor(Date) + random(Anemone_ID), data = hemo_clean
##
## $Treatment
##                    diff         lwr        upr     p adj
## 30C-25C     -0.01774403 -0.10232621 0.06683814 0.8681217
## Control-25C  0.01330095 -0.07128123 0.09788312 0.9234967
## Control-30C  0.03104498 -0.05353720 0.11562715 0.6506202
##
## $`as.factor(Date)`
##                               diff         lwr          upr     p adj
## 2021-11-05-2021-10-31  0.043403792 -0.06407183  0.150879419 0.7063883
## 2021-11-09-2021-10-31 -0.068052179 -0.17552781  0.039423449 0.3425844
## 2021-11-13-2021-10-31 -0.005033865 -0.11250949  0.102441763 0.9992979
## 2021-11-09-2021-11-05 -0.111455971 -0.21893160 -0.003980344 0.0394185
## 2021-11-13-2021-11-05 -0.048437657 -0.15591328  0.059037970 0.6301841
## 2021-11-13-2021-11-09  0.063018314 -0.04445731  0.170493941 0.4104712
##
```

```
## $`Treatment:as.factor(Date)`
##                                                diff         lwr        upr
## 30C:2021-10-31-25C:2021-10-31           -0.027298769 -0.26747570 0.21287816
## Control:2021-10-31-25C:2021-10-31       -0.018027487 -0.25820441 0.22214944
## 25C:2021-11-05-25C:2021-10-31            0.016367544 -0.22380938 0.25654447
## 30C:2021-11-05-25C:2021-10-31            0.014566340 -0.22561059 0.25474327
## Control:2021-11-05-25C:2021-10-31        0.053951238 -0.18622569 0.29412817
## 25C:2021-11-09-25C:2021-10-31           -0.135278971 -0.37545590 0.10489796
## 30C:2021-11-09-25C:2021-10-31           -0.090619878 -0.33079681 0.14955705
## Control:2021-11-09-25C:2021-10-31       -0.023583942 -0.26376087 0.21659299
## 25C:2021-11-13-25C:2021-10-31            0.034718281 -0.20545865 0.27489521
## 30C:2021-11-13-25C:2021-10-31           -0.051816965 -0.29199389 0.18835996
## Control:2021-11-13-25C:2021-10-31       -0.043329165 -0.28350609 0.19684776
## Control:2021-10-31-30C:2021-10-31        0.009271282 -0.23090565 0.24944821
## 25C:2021-11-05-30C:2021-10-31            0.043666312 -0.19651062 0.28384324
## 30C:2021-11-05-30C:2021-10-31            0.041865108 -0.19831182 0.28204204
## Control:2021-11-05-30C:2021-10-31        0.081250006 -0.15892692 0.32142693
## 25C:2021-11-09-30C:2021-10-31           -0.107980203 -0.34815713 0.13219673
## 30C:2021-11-09-30C:2021-10-31           -0.063321109 -0.30349804 0.17685582
## Control:2021-11-09-30C:2021-10-31        0.003714827 -0.23646210 0.24389176
## 25C:2021-11-13-30C:2021-10-31            0.062017050 -0.17815988 0.30219398
## 30C:2021-11-13-30C:2021-10-31           -0.024518197 -0.26469512 0.21565873
## Control:2021-11-13-30C:2021-10-31       -0.016030396 -0.25620732 0.22414653
## 25C:2021-11-05-Control:2021-10-31        0.034395031 -0.20578190 0.27457196
## 30C:2021-11-05-Control:2021-10-31        0.032593826 -0.20758310 0.27277075
## Control:2021-11-05-Control:2021-10-31    0.071978725 -0.16819820 0.31215565
## 25C:2021-11-09-Control:2021-10-31       -0.117251485 -0.35742841 0.12292544
## 30C:2021-11-09-Control:2021-10-31       -0.072592391 -0.31276932 0.16758454
## Control:2021-11-09-Control:2021-10-31   -0.005556455 -0.24573338 0.23462047
## 25C:2021-11-13-Control:2021-10-31        0.052745768 -0.18743116 0.29292270
## 30C:2021-11-13-Control:2021-10-31       -0.033789479 -0.27396641 0.20638745
## Control:2021-11-13-Control:2021-10-31   -0.025301678 -0.26547861 0.21487525
## 30C:2021-11-05-25C:2021-11-05           -0.001801204 -0.24197813 0.23837572
## Control:2021-11-05-25C:2021-11-05        0.037583694 -0.20259323 0.27776062
## 25C:2021-11-09-25C:2021-11-05           -0.151646515 -0.39182344 0.08853041
## 30C:2021-11-09-25C:2021-11-05           -0.106987422 -0.34716435 0.13318951
## Control:2021-11-09-25C:2021-11-05       -0.039951486 -0.28012841 0.20022544
## 25C:2021-11-13-25C:2021-11-05            0.018350737 -0.22182619 0.25852767
## 30C:2021-11-13-25C:2021-11-05           -0.068184509 -0.30836144 0.17199242
## Control:2021-11-13-25C:2021-11-05       -0.059696709 -0.29987364 0.18048022
## Control:2021-11-05-30C:2021-11-05        0.039384898 -0.20079203 0.27956183
## 25C:2021-11-09-30C:2021-11-05           -0.149845311 -0.39002224 0.09033162
## 30C:2021-11-09-30C:2021-11-05           -0.105186218 -0.34536315 0.13499071
## Control:2021-11-09-30C:2021-11-05       -0.038150281 -0.27832721 0.20202665
## 25C:2021-11-13-30C:2021-11-05            0.020151941 -0.22002499 0.26032887
## 30C:2021-11-13-30C:2021-11-05           -0.066383305 -0.30656023 0.17379362
## Control:2021-11-13-30C:2021-11-05       -0.057895504 -0.29807243 0.18228142
## 25C:2021-11-09-Control:2021-11-05       -0.189230209 -0.42940714 0.05094672
## 30C:2021-11-09-Control:2021-11-05       -0.144571116 -0.38474804 0.09560581
## Control:2021-11-09-Control:2021-11-05   -0.077535180 -0.31771211 0.16264175
## 25C:2021-11-13-Control:2021-11-05       -0.019232957 -0.25940989 0.22094397
## 30C:2021-11-13-Control:2021-11-05       -0.105768203 -0.34594513 0.13440872
## Control:2021-11-13-Control:2021-11-05   -0.097280403 -0.33745733 0.14289653
## 30C:2021-11-09-25C:2021-11-09            0.044659094 -0.19551783 0.28483602
```

```
## Control:2021-11-09-25C:2021-11-09      0.111695030 -0.12848190 0.35187196
## 25C:2021-11-13-25C:2021-11-09          0.169997252 -0.07017968 0.41017418
## 30C:2021-11-13-25C:2021-11-09          0.083462006 -0.15671492 0.32363893
## Control:2021-11-13-25C:2021-11-09      0.091949807 -0.14822712 0.33212673
## Control:2021-11-09-30C:2021-11-09      0.067035936 -0.17314099 0.30721286
## 25C:2021-11-13-30C:2021-11-09          0.125338159 -0.11483877 0.36551509
## 30C:2021-11-13-30C:2021-11-09          0.038802913 -0.20137402 0.27897984
## Control:2021-11-13-30C:2021-11-09      0.047290713 -0.19288622 0.28746764
## 25C:2021-11-13-Control:2021-11-09      0.058302223 -0.18187471 0.29847915
## 30C:2021-11-13-Control:2021-11-09     -0.028233024 -0.26840995 0.21194390
## Control:2021-11-13-Control:2021-11-09 -0.019745223 -0.25992215 0.22043171
## 30C:2021-11-13-25C:2021-11-13         -0.086535246 -0.32671217 0.15364168
## Control:2021-11-13-25C:2021-11-13     -0.078047446 -0.31822437 0.16212948
## Control:2021-11-13-30C:2021-11-13      0.008487801 -0.23168913 0.24866473
##                                           p adj
## 30C:2021-10-31-25C:2021-10-31         0.9999997
## Control:2021-10-31-25C:2021-10-31     1.0000000
## 25C:2021-11-05-25C:2021-10-31         1.0000000
## 30C:2021-11-05-25C:2021-10-31         1.0000000
## Control:2021-11-05-25C:2021-10-31     0.9997200
## 25C:2021-11-09-25C:2021-10-31         0.7326566
## 30C:2021-11-09-25C:2021-10-31         0.9757974
## Control:2021-11-09-25C:2021-10-31     0.9999999
## 25C:2021-11-13-25C:2021-10-31         0.9999966
## 30C:2021-11-13-25C:2021-10-31         0.9998099
## Control:2021-11-13-25C:2021-10-31     0.9999674
## Control:2021-10-31-30C:2021-10-31     1.0000000
## 25C:2021-11-05-30C:2021-10-31         0.9999648
## 30C:2021-11-05-30C:2021-10-31         0.9999769
## Control:2021-11-05-30C:2021-10-31     0.9895335
## 25C:2021-11-09-30C:2021-10-31         0.9200954
## 30C:2021-11-09-30C:2021-10-31         0.9987568
## Control:2021-11-09-30C:2021-10-31     1.0000000
## 25C:2021-11-13-30C:2021-10-31         0.9989709
## 30C:2021-11-13-30C:2021-10-31         0.9999999
## Control:2021-11-13-30C:2021-10-31     1.0000000
## 25C:2021-11-05-Control:2021-10-31     0.9999969
## 30C:2021-11-05-Control:2021-10-31     0.9999982
## Control:2021-11-05-Control:2021-10-31 0.9961571
## 25C:2021-11-09-Control:2021-10-31     0.8699129
## 30C:2021-11-09-Control:2021-10-31     0.9958685
## Control:2021-11-09-Control:2021-10-31 1.0000000
## 25C:2021-11-13-Control:2021-10-31     0.9997745
## 30C:2021-11-13-Control:2021-10-31     0.9999974
## Control:2021-11-13-Control:2021-10-31 0.9999999
## 30C:2021-11-05-25C:2021-11-05         1.0000000
## Control:2021-11-05-25C:2021-11-05     0.9999923
## 25C:2021-11-09-25C:2021-11-05         0.5792412
## 30C:2021-11-09-25C:2021-11-05         0.9245799
## Control:2021-11-09-25C:2021-11-05     0.9999856
## 25C:2021-11-13-25C:2021-11-05         1.0000000
## 30C:2021-11-13-25C:2021-11-05         0.9975958
## Control:2021-11-13-25C:2021-11-05     0.9992750
## Control:2021-11-05-30C:2021-11-05     0.9999876
```

```
## 25C:2021-11-09-30C:2021-11-05         0.5966589
## 30C:2021-11-09-30C:2021-11-05         0.9322843
## Control:2021-11-09-30C:2021-11-05     0.9999910
## 25C:2021-11-13-30C:2021-11-05         1.0000000
## 30C:2021-11-13-30C:2021-11-05         0.9981016
## Control:2021-11-13-30C:2021-11-05     0.9994547
## 25C:2021-11-09-Control:2021-11-05     0.2549065
## 30C:2021-11-09-Control:2021-11-05     0.6472538
## Control:2021-11-09-Control:2021-11-05 0.9928334
## 25C:2021-11-13-Control:2021-11-05     1.0000000
## 30C:2021-11-13-Control:2021-11-05     0.9298554
## Control:2021-11-13-Control:2021-11-05 0.9597977
## 30C:2021-11-09-25C:2021-11-09         0.9999559
## Control:2021-11-09-25C:2021-11-09     0.9017937
## 25C:2021-11-13-25C:2021-11-09         0.4066072
## 30C:2021-11-13-25C:2021-11-09         0.9870574
## Control:2021-11-13-25C:2021-11-09     0.9730704
## Control:2021-11-09-30C:2021-11-09     0.9979298
## 25C:2021-11-13-30C:2021-11-09         0.8142024
## 30C:2021-11-13-30C:2021-11-09         0.9999893
## Control:2021-11-13-30C:2021-11-09     0.9999221
## 25C:2021-11-13-Control:2021-11-09     0.9994179
## 30C:2021-11-13-Control:2021-11-09     0.9999996
## Control:2021-11-13-Control:2021-11-09 1.0000000
## 30C:2021-11-13-25C:2021-11-13         0.9828793
## Control:2021-11-13-25C:2021-11-13     0.9924362
## Control:2021-11-13-30C:2021-11-13     1.0000000
```

```
# Testing fit of full and reduced models using AIC
AIC(Dino_MI_aov)
```

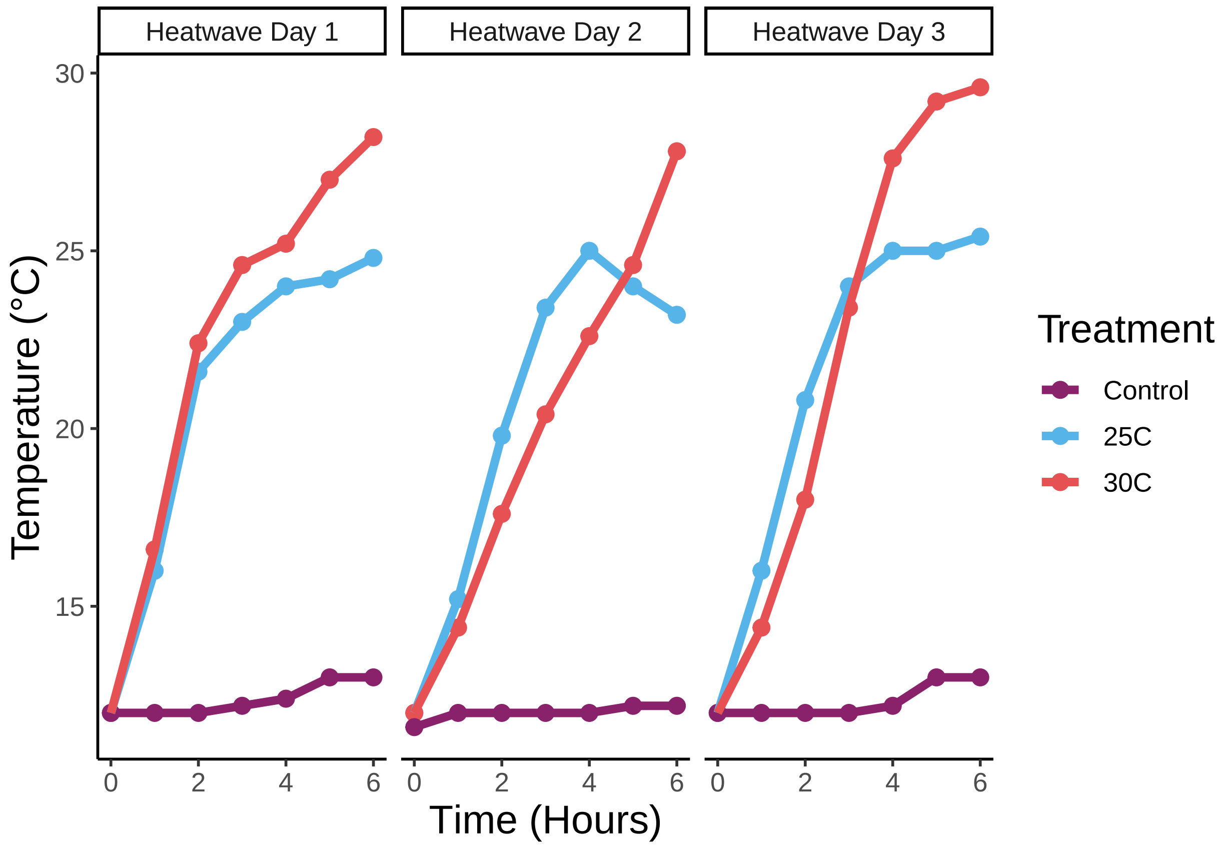
```
## [1] -81.34178
```

Heatwave temperature

##Plots

Creating a plot to show the average temperature in the final 3 hours of the heatwave (after the temperature ramp) on each day

```
ggplot(data = temp_summary, aes(x = Time_Block, y = mean_temp,
    group = Treatment, colour = Treatment)) + theme_classic() +
    geom_point(size = 2.5) + geom_line(lwd = 1.5) + facet_grid(. ~
    Event) + scale_fill_manual(values = c("#89226AFF", "#56B4E9FF",
    "#E65154FF")) + scale_colour_manual(values = c("#89226AFF",
    "#56B4E9FF", "#E65154FF")) + labs(x = "Time (Hours)", y = "Temperature (°C)") +
    theme(strip.text.x = element_text(size = 10), axis.text = element_text(size = 10),
        axis.title = element_text(size = 15), legend.text = element_text(size = 10),
        legend.title = element_text(size = 15))
```




```
ggsave(path = "plots", filename = "temp_plot.png", width = 10,
    height = 7)
```