Analysis_First_Chapter2

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1. Uploading Libraries

```
library(tidyr)
library(tidyverse)
library(ggplot2)
library(survival)
library(survminer)
library(ranger)
library(ggplot2)
library(ggpubr)
library(ggsci)
library(readxl)
library(showtext)
library(lubridate)
setwd("C:\\Users\\lblan\\OneDrive\\Escritorio\\CEAB\\2022\\First_chapter")
data_analysis <-
  read_excel("C:\\Users\\lblan\\OneDrive\\Escritorio\\CEAB\\2022\\First_chapter\\data_analysis_cens.xlsx
    col_types = c("numeric", "date","numeric", "date",
        "numeric", "numeric", "numeric", "numeric"))

#Now, data of weather (RH and Temperature) in both locations in the field (HOBO's data)
jardin_clima <-
  read_excel("C:\\Users\\lblan\\OneDrive\\Escritorio\\CEAB\\2022\\First_chapter\\Jardin_clima_total.xlsx
    col_types = c("date", "numeric", "numeric"))

palafolls_clima <-
  read_excel("C:\\Users\\lblan\\OneDrive\\Escritorio\\CEAB\\2022\\First_chapter\\Palafolls_clima_total.x
    col_types = c("date", "numeric", "numeric"))

#URBAN DATAFRAME OF WEATHER
temperaturemeanpal<- palafolls_clima%>%
  #v#calculating means of temperature and rhper day (HOBO makes 3 measures per day)
  group_by(DATE)%>%
  summarise(meantemperature=mean(TEMPERATURE),meanrh = mean(RH) )

temperatureminpal<- palafolls_clima%>%
  #v#calculating mins of temperature and rhper day (HOBO makes 3 measures per day)
  group_by(DATE)%>%
  summarise(mintemperature=min(TEMPERATURE),minrh = min(RH) )
```

```
temperaturemaxpal<- palafolls_clima%>%
  #v#calculating max of temperature and rhper day (HOBO makes 3 measures per day)
  group_by(DATE)%>%
  summarise(maxtemperature=max(TEMPERATURE),maxrh = max(RH) )
palafolls_clima<- merge(temperaturemaxpal, temperaturemeanpal, by = "DATE")
palafolls_clima_total<- merge(palafolls_clima, temperatureminpal, by = "DATE")
remove(palafolls_clima)
remove(temperaturemaxpal)
remove(temperatureminpal)
remove(temperaturemeanpal)

#SEMI-URBAN DATAFRAME OF WEATHER
temperaturemeanjar<- jardin_clima%>% #calculating means of temperature and rh per day
  group_by(DATE)%>%
  summarise(meantemperature=mean(TEMPERATURE),meanrh = mean(RH))

temperatureminjar<- jardin_clima%>% #calculating min of temperature and rh per day
  group_by(DATE)%>%
  summarise(mintemperature=min(TEMPERATURE),minrh = min(RH))

temperaturemaxjar<- jardin_clima%>% #calculating max of temperature and rh per day
  group_by(DATE)%>%
  summarise(maxtemperature=max(TEMPERATURE),maxrh = max(RH))
jardin_clima<- merge(temperaturemaxjar, temperaturemeanjar, by = "DATE")
jardin_clima_total<- merge(jardin_clima, temperatureminjar, by = "DATE")
remove(jardin_clima)
remove(temperaturemaxjar)
remove(temperaturemeanjar)
remove(temperatureminjar)

jardin_clima_total$location <- "1"
#creating new columns according to the locations
jardin_clima_total$location<- as.numeric(jardin_clima_total$location)
palafolls_clima_total$location<- "2"
palafolls_clima_total$location<- as.numeric(palafolls_clima_total$location)
#renaming column DATE to match with start_date column from our data_analysis dataframe
jardin_clima_total <- jardin_clima_total %>%
  rename(start_date = DATE)
palafolls_clima_total <- palafolls_clima_total %>%
  rename(start_date = DATE)

datos_semi <- inner_join(data_analysis, jardin_clima_total,
                         by = c("start_date", "location"), all= TRUE)
#Combining temperature of each location with the data
datos_urban <- inner_join(data_analysis, palafolls_clima_total,
                          by = c("start_date", "location"), all= TRUE)
datos_lab<- subset(data_analysis, location=="3")
datos_lab$meantemperature <- NA
datos_lab$meanrh <- NA
datos_lab$mintemperature <- NA
datos_lab$minrh <- NA
datos_lab$maxtemperature <- NA
datos_lab$maxrh <- NA
```

```r
datos_field_lab <- rbind(datos_semi,datos_urban, datos_lab)
#merging all to have a dataframe completed (data survival + weather)
datos_field<- rbind(datos_semi, datos_urban)
clima_field <- rbind(jardin_clima_total, palafolls_clima_total)
```

2. Creating weather variables and duplicating rows per mosquito

```r
df <- read_excel("C:\\Users\\lblan\\OneDrive\\Escritorio\\CEAB\\2022\\First_chapter\\datos_field.xlsx",
                 col_types = c("numeric",
                               "date", "date", "numeric", "numeric",
                               "numeric", "numeric", "numeric", "numeric",
                              "numeric", "numeric", "numeric", "numeric"))
clima <- read_excel("C:\\Users\\lblan\\OneDrive\\Escritorio\\CEAB\\2022\\First_chapter\\clima_field.xlsx
                    col_types = c("date",
                                  "numeric", "numeric", "numeric", "numeric",
                                   "numeric", "numeric", "numeric"))

new_df <- df[0, ]
# this also works, mantaining object structure (data.frame) and column names

id <- seq_len(nrow(df)) # since there are duplicated ID, we iterate by row

df$start_date <- as.Date(df$start_date, format = '%Y-%m-%d')

df$start_date <- as.Date(df$start_date, format = '%Y-%m-%d')
clima$start_date <- as.character(as.Date(clima$start_date, format = '%Y-%m-%d'))

new_df <- do.call('rbind', lapply(seq_len(nrow(df)), function(id){
  tmp <- do.call('rbind', replicate(df$total_lived[id],
                                    df[id, ], simplify = FALSE))
  tmp$start_date <- format(seq(tmp$start_date[1], by = 'day',
                               length.out = nrow(tmp)), '%Y-%m-%d')
  tmp
}))

vars <- c('maxtemperature', 'meantemperature',
          'mintemperature', 'maxrh', 'minrh', 'meanrh')
for(d in unique(clima$start_date)){
  new_df[new_df$start_date == d & new_df$location == 1, vars] <-
    clima[clima$start_date == d & clima$location == 1, vars]
  new_df[new_df$start_date == d & new_df$location == 2, vars] <-
    clima[clima$start_date == d & clima$location == 2, vars]
}
```

Adding photoperiod

```r
#we add photoperiod
library(meteor)
photoperiod <- photoperiod(152:334,  41.6833)
```

```
photoperiod <- as.data.frame(photoperiod)
values = seq(from = as.Date("2021-06-01"), to = as.Date("2021-11-30"),
             by = 'day')
photoperiod$dates <- values
photoperiod$dates <- as.character(as.Date(photoperiod$dates,
                                          format = '%Y-%m-%d'))
new_df$start_date <- as.character(as.Date(new_df$start_date,
                                          format = '%Y-%m-%d'))

str(photoperiod)
```

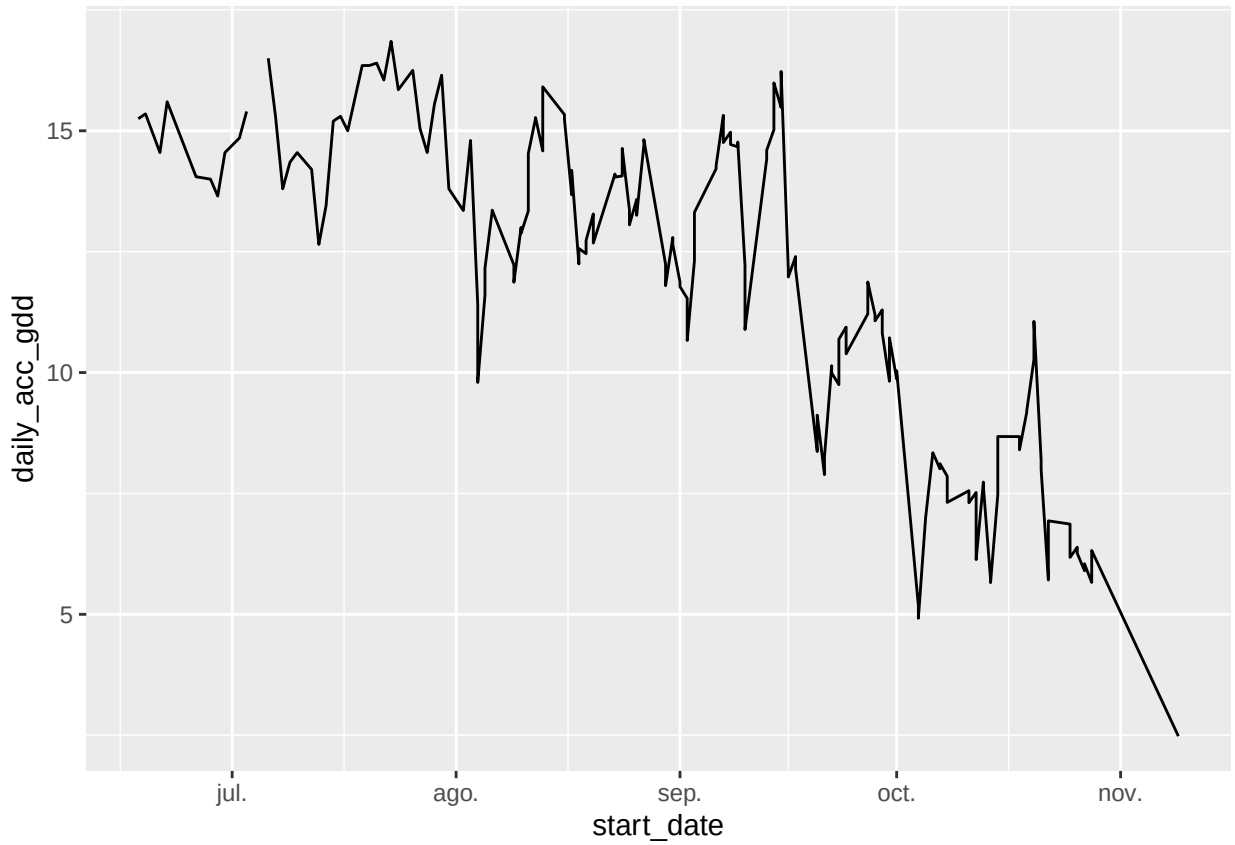
```
## 'data.frame':    183 obs. of  2 variables:
##  $ photoperiod: num  15 15 15 15 15.1 ...
##  $ dates      : chr  "2021-06-01" "2021-06-02" "2021-06-03" "2021-06-04" ...
```

```
new_df[ , 'photoperiod'] <- 0 # new column called photoperiod
vars2 <- c('photoperiod')
for(d in unique(photoperiod$dates)){
  new_df[new_df$start_date == d,vars2] <-
    photoperiod[photoperiod$dates == d, vars2]
}

new_df$`hl/bg` <- factor(new_df$`hl/bg`,
                         levels = c("1", "2"),
                         labels = c("HB", "BG"))
new_df$location <- factor(new_df$location,
                          levels = c("1", "2"),
                          labels = c("Peri_Urban", "Urban"))
```

Other weather parameters: GDD and MWI

Growing degree days

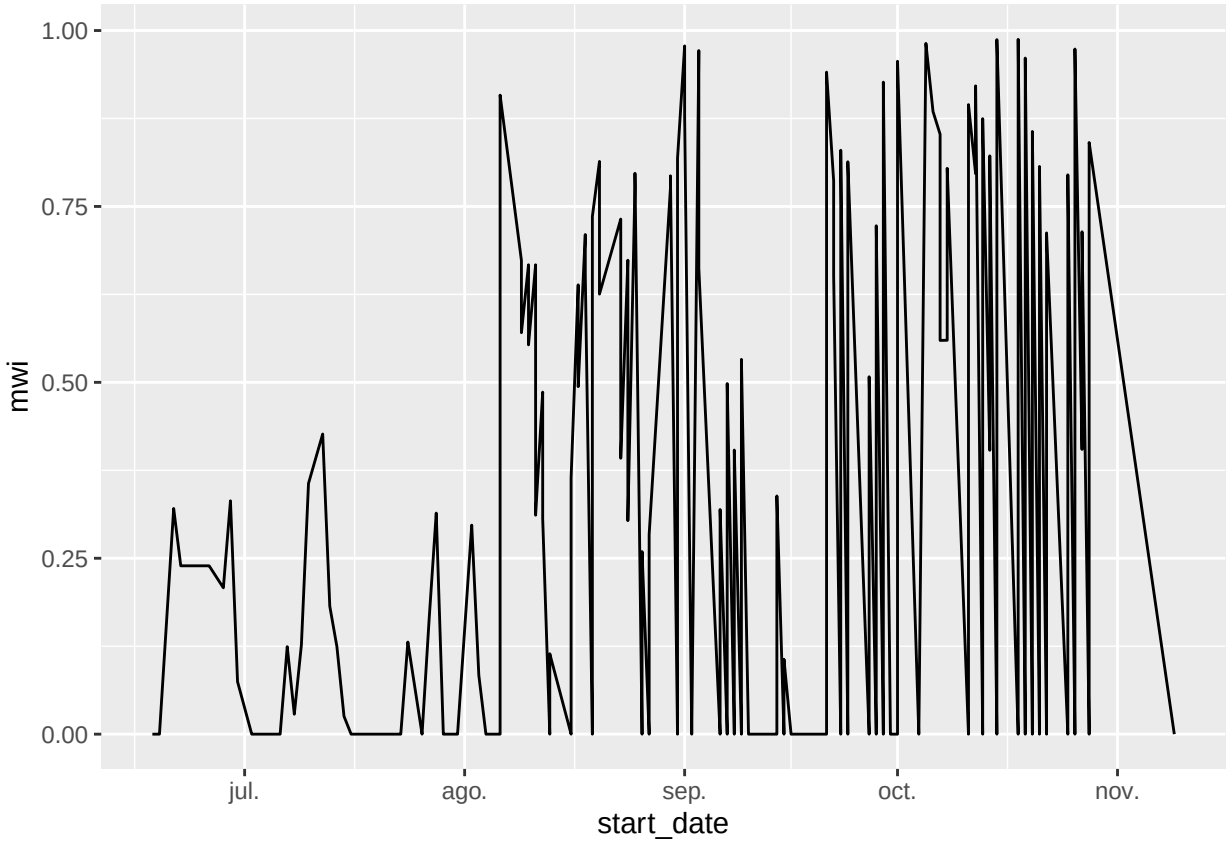
```
library(scales)
library(pollen)
new_df_gdd <- new_df %>%
  mutate(gdd = gdd(tmax = maxtemperature, tmin = mintemperature, tbase = 10,
                   tbase_max = 30)) %>%
  mutate(daily_acc_gdd = c(NA, diff(gdd)))

ddfield <- datos_field %>%
  mutate(gdd = gdd(tmax = maxtemperature, tmin = mintemperature, tbase = 10,
                   tbase_max = 30)) %>%
  mutate(daily_acc_gdd = c(NA, diff(gdd)))

gdd <-ggplot(aes(x =start_date, y= daily_acc_gdd), data = ddfield) + geom_line()
gdd
```



MWImean

```
mwi = function(Hum, Temp) {
 FH = case_when(Hum < 40~0, Hum >95~0, (Hum >=40 & Hum <= 95)~
                  ((Hum/55)-(40/55)) )
  FT = case_when(Temp<=15~0, Temp>30~0, (Temp>15 & Temp <=20)~
                   (.2*Temp)-3, (Temp>20 & Temp<=25)~1, (Temp>25 & Temp <= 30)~
                   (-.2*6)+6)
  return(FH*FT)
}



new_df_gdd = new_df_gdd %>% mutate(
  FHme = case_when(meanrh < 40~0, meanrh >95~0, (meanrh >=40 & meanrh <= 95)~
                   ((meanrh/55)-(40/55)) ),
  FTme = case_when(meantemperature<=15~0, meantemperature>30~0, (meantemperature>15 & meantemperature <=
                 (meantemperature>20 & meantemperature<=25)~1, (meantemperature>25 & meantemperature <=
  mwime = FHme*FTme)


##MIN MWI
new_df_gdd = new_df_gdd %>% mutate(
  FHmin = case_when(minrh < 40~0, minrh >95~0, (minrh >=40 & minrh <= 95)~
```

```
                    ((minrh/55)-(40/55)) ),
  FTmin = case_when(mintemperature<=15~0, mintemperature>30~0,
                     (mintemperature>15 & mintemperature <=20)~ (.2*mintemperature)-3,
                   (mintemperature>20 & mintemperature<=25)~1,
                   (mintemperature>25 & mintemperature <= 30)~ (-.2*mintemperature)+6),
  mwimin = FHmin*FTmin)

##MAX MWI
new_df_gdd = new_df_gdd %>% mutate(
  FHmax = case_when(maxrh < 40~0, maxrh >95~0, (maxrh >=40 & maxrh <= 95)~
                    ((maxrh/55)-(40/55)) ),
  FTmax = case_when(maxtemperature<=15~0, maxtemperature>30~0, (maxtemperature>15 & maxtemperature <=20)
                   (maxtemperature>20 & maxtemperature<=25)~1, (maxtemperature>25 & maxtemperature <= 30)
  mwimax = FHmax*FTmax)


ddfield <- ddfield %>%
  mutate(Hum = maxrh, Temp = maxtemperature)

ddfield = ddfield %>% mutate(
  FH = case_when(Hum < 40~0, Hum >95~0, (Hum >=40 & Hum <= 95)~
                    ((Hum/55)-(40/55)) ),
  FT = case_when(Temp<=15~0, Temp>30~0, (Temp>15 & Temp <=20)~ (.2*Temp)-3,
                   (Temp>20 & Temp<=25)~1, (Temp>25 & Temp <= 30)~ (-.2*Temp)+6),
  mwi = FH*FT)



mwiplot <-ggplot(aes(x =start_date, y= mwi), data = ddfield) + geom_line()
mwiplot
```



3.Cox-Regression models

1. No random effects
2. Random effects; level 1 (method) + level 2 (location);
    - Separated: (1|method) + (1|location)
    - Together: (1|location/method), to check the effect of the method of capture within location

Temperature

Models with minimum temperatures

```
new_df_gdd <- new_df_gdd  %>%
  rename(method = 'hl/bg')
#writexl::write_xlsx(new_df_gdd, "C:\\Users\\lblan\\OneDrive\\Escritorio\\CEAB\\2022\\First_chapter\\da
library(coxme)
```

```
# No random effect
cox_mint<- coxph(Surv(total_lived, censored) ~ mintemperature, data= new_df_gdd)

summary(cox_mint)
```

```
## Call:
## coxph(formula = Surv(total_lived, censored) ~ mintemperature,
##     data = new_df_gdd)
##
##   n= 15155, number of events= 14542
##
##                     coef exp(coef) se(coef)     z Pr(>|z|)
## mintemperature 0.030025  1.030481 0.002078 14.45   <2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
##                exp(coef) exp(-coef) lower .95 upper .95
## mintemperature      1.03     0.9704     1.026     1.035
##
## Concordance= 0.538  (se = 0.003 )
## Likelihood ratio test= 214.8  on 1 df,   p=<2e-16
## Wald test            = 208.7  on 1 df,   p=<2e-16
## Score (logrank) test = 209  on 1 df,   p=<2e-16
```

```
cox.zph(cox_mint)
```

```
##                chisq df      p
## mintemperature  9.63  1 0.0019
## GLOBAL          9.63  1 0.0019
```

```
#Random effect - separated
coxme_mint_s<- coxme(Surv(total_lived, censored) ~ mintemperature +
                   (1|location) + (1|method), data= new_df_gdd)
summary(coxme_mint_s)
```

```
## Cox mixed-effects model fit by maximum likelihood
##   Data: new_df_gdd
##   events, n = 14542, 15155
##   Iterations= 7 31
##                     NULL Integrated    Fitted
## Log-likelihood -125304.4  -125046.8 -125040.8
##
##                    Chisq   df p    AIC    BIC
## Integrated loglik 515.23 3.00 0 509.23 486.47
##  Penalized loglik 527.19 2.98 0 521.22 498.58
##
## Model:  Surv(total_lived, censored) ~ mintemperature + (1 | location) +      (1 | method)
## Fixed coefficients
##                      coef exp(coef)   se(coef)     z p
## mintemperature 0.02387999  1.024167 0.00217684 10.97 0
##
## Random effects
##  Group    Variable  Std Dev    Variance
##  location Intercept 0.11984332 0.01436242
##  method   Intercept 0.19470477 0.03790995
```

```r
#Random effect - together
coxme_mint_t<- coxme(Surv(total_lived, censored) ~ mintemperature +
                  (1|location/method), data= new_df_gdd)

summary(coxme_mint_t)
```

```
## Cox mixed-effects model fit by maximum likelihood
##   Data: new_df_gdd
##   events, n = 14542, 15155
##   Iterations= 16 67
##                     NULL Integrated    Fitted
## Log-likelihood -125304.4  -125047.3 -125038.9
##
##                    Chisq   df p    AIC    BIC
## Integrated loglik 514.21 3.00 0 508.21 485.46
##  Penalized loglik 531.13 3.97 0 523.19 493.09
##
## Model:  Surv(total_lived, censored) ~ mintemperature + (1 | location/method)
## Fixed coefficients
##                       coef exp(coef)    se(coef)     z p
## mintemperature 0.02380119  1.024087 0.002178638 10.92 0
##
## Random effects
##  Group           Variable    Std Dev      Variance
##  location/method (Intercept) 0.1849459790 0.0342050152
##  location        (Intercept) 0.0198709809 0.0003948559
```

Models with mean temperatures

```r
# No random effect
cox_meant<- coxph(Surv(total_lived, censored) ~ meantemperature,
                  data= new_df_gdd)

summary(cox_meant)
```

```
## Call:
## coxph(formula = Surv(total_lived, censored) ~ meantemperature,
##     data = new_df_gdd)
##
##   n= 15155, number of events= 14542
##
##                     coef exp(coef) se(coef)     z Pr(>|z|)
## meantemperature 0.035534  1.036173 0.002192 16.21   <2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
##                 exp(coef) exp(-coef) lower .95 upper .95
## meantemperature     1.036     0.9651     1.032     1.041
##
## Concordance= 0.547  (se = 0.003 )
## Likelihood ratio test= 271.4  on 1 df,   p=<2e-16
```

```
## Wald test            = 262.8  on 1 df,   p=<2e-16
## Score (logrank) test = 263.4  on 1 df,   p=<2e-16
```

```
#Random effect - separated
coxme_meant_s<- coxme(Surv(total_lived, censored) ~ meantemperature +
                  (1|location) + (1|method), data= new_df_gdd)
summary(coxme_meant_s)
```

```
## Cox mixed-effects model fit by maximum likelihood
##   Data: new_df_gdd
##   events, n = 14542, 15155
##   Iterations= 18 75
##                     NULL Integrated    Fitted
## Log-likelihood -125304.4  -125004.6 -124998.5
##
##                    Chisq   df p    AIC    BIC
## Integrated loglik 599.73 3.00 0 593.73 570.98
##  Penalized loglik 611.91 2.99 0 605.94 583.28
##
## Model:  Surv(total_lived, censored) ~ meantemperature + (1 | location) +      (1 | method)
## Fixed coefficients
##                        coef exp(coef)    se(coef)    z p
## meantemperature 0.03151728  1.032019 0.002218942 14.2 0
##
## Random effects
##  Group    Variable  Std Dev    Variance
##  location Intercept 0.13288329 0.01765797
##  method   Intercept 0.19425609 0.03773543
```

```
#Random effect - together
coxme_meant_t<- coxme(Surv(total_lived, censored) ~ meantemperature +
                  (1|location/method), data= new_df_gdd)

summary(coxme_meant_t)
```

```
## Cox mixed-effects model fit by maximum likelihood
##   Data: new_df_gdd
##   events, n = 14542, 15155
##   Iterations= 17 71
##                     NULL Integrated    Fitted
## Log-likelihood -125304.4  -125005.1 -124996.6
##
##                    Chisq   df p    AIC    BIC
## Integrated loglik 598.65 3.00 0 592.65 569.89
##  Penalized loglik 615.73 3.97 0 607.79 577.67
##
## Model:  Surv(total_lived, censored) ~ meantemperature + (1 | location/method)
## Fixed coefficients
##                       coef exp(coef)   se(coef)     z p
## meantemperature 0.0314699   1.03197 0.00222067 14.17 0
##
## Random effects
##  Group           Variable    Std Dev      Variance
```

```
##  location/method (Intercept) 0.1898531057 0.0360442017
##  location        (Intercept) 0.0199107424 0.0003964377
```

Models with maximum temperatures

```
# No random effect
cox_maxt<- coxph(Surv(total_lived, censored) ~ maxtemperature,
                 data= new_df_gdd)

summary(cox_maxt)
```

```
## Call:
## coxph(formula = Surv(total_lived, censored) ~ maxtemperature,
##     data = new_df_gdd)
##
##   n= 15155, number of events= 14542
##
##                     coef exp(coef) se(coef)    z Pr(>|z|)
## maxtemperature 0.033117  1.033672 0.002136 15.5   <2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
##                exp(coef) exp(-coef) lower .95 upper .95
## maxtemperature     1.034     0.9674     1.029     1.038
##
## Concordance= 0.541  (se = 0.003 )
## Likelihood ratio test= 245.8  on 1 df,   p=<2e-16
## Wald test            = 240.3  on 1 df,   p=<2e-16
## Score (logrank) test = 240.6  on 1 df,   p=<2e-16
```

```
#Random effect - separated
coxme_maxt_s<- coxme(Surv(total_lived, censored) ~ maxtemperature +
                  (1|location) + (1|method), data= new_df_gdd)
summary(coxme_maxt_s)
```

```
## Cox mixed-effects model fit by maximum likelihood
##   Data: new_df_gdd
##   events, n = 14542, 15155
##   Iterations= 7 31
##                     NULL Integrated    Fitted
## Log-likelihood -125304.4  -124979.1 -124972.8
##
##                    Chisq   df p    AIC    BIC
## Integrated loglik 650.65 3.00 0 644.65 621.89
##  Penalized loglik 663.31 2.99 0 657.33 634.64
##
## Model:  Surv(total_lived, censored) ~ maxtemperature + (1 | location) +      (1 | method)
## Fixed coefficients
##                     coef exp(coef)    se(coef)     z p
## maxtemperature 0.0340556  1.034642 0.002145233 15.88 0
##
```

```
## Random effects
##  Group    Variable  Std Dev   Variance
##  location Intercept 0.1729280 0.0299041
##  method   Intercept 0.1950528 0.0380456
```

```
#Random effect - together
coxme_maxt_t<- coxme(Surv(total_lived, censored) ~ maxtemperature +
                  (1|location/method), data= new_df_gdd)

summary(coxme_maxt_t)
```

```
## Cox mixed-effects model fit by maximum likelihood
##   Data: new_df_gdd
##   events, n = 14542, 15155
##   Iterations= 8 35
##                     NULL Integrated  Fitted
## Log-likelihood -125304.4  -124979.8 -124971
##
##                    Chisq   df p    AIC    BIC
## Integrated loglik 649.24 3.00 0 643.24 620.48
##  Penalized loglik 666.81 3.97 0 658.86 628.71
##
## Model:  Surv(total_lived, censored) ~ maxtemperature + (1 | location/method)
## Fixed coefficients
##                       coef exp(coef)    se(coef)     z p
## maxtemperature 0.03400195  1.034587 0.002146769 15.84 0
##
## Random effects
##  Group           Variable    Std Dev      Variance
##  location/method (Intercept) 0.2057477731 0.0423321461
##  location        (Intercept) 0.0200121633 0.0004004867
```

MWI (Mosquito Weather Index)

```
# No random effect
cox_mwimin<- coxph(Surv(total_lived, censored) ~ mwimin,
                  data= new_df_gdd)

summary(cox_mwimin)
```

```
## Call:
## coxph(formula = Surv(total_lived, censored) ~ mwimin, data = new_df_gdd)
##
##   n= 15155, number of events= 14542
##
##           coef exp(coef) se(coef)     z Pr(>|z|)
## mwimin 0.13159   1.14065  0.02723 4.833 1.34e-06 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
##        exp(coef) exp(-coef) lower .95 upper .95
```

```
## mwimin     1.141     0.8767     1.081     1.203
##
## Concordance= 0.511  (se = 0.003 )
## Likelihood ratio test= 23.2  on 1 df,   p=1e-06
## Wald test            = 23.36  on 1 df,   p=1e-06
## Score (logrank) test = 23.37  on 1 df,   p=1e-06
```

```
#Random effect - separated
coxme_mwimin_s<- coxme(Surv(total_lived, censored) ~ mwimin +
                  (1|location) + (1|method), data= new_df_gdd)
summary(coxme_mwimin_s)
```

```
## Cox mixed-effects model fit by maximum likelihood
##   Data: new_df_gdd
##   events, n = 14542, 15155
##   Iterations= 7 31
##                     NULL Integrated    Fitted
## Log-likelihood -125304.4  -125107.7 -125101.4
##
##                    Chisq   df p    AIC    BIC
## Integrated loglik 393.52 3.00 0 387.52 364.77
##  Penalized loglik 406.07 2.99 0 400.09 377.42
##
## Model:  Surv(total_lived, censored) ~ mwimin + (1 | location) + (1 |      method)
## Fixed coefficients
##              coef exp(coef)   se(coef)    z    p
## mwimin 0.02608084  1.026424 0.02831501 0.92 0.36
##
## Random effects
##  Group    Variable  Std Dev    Variance
##  location Intercept 0.16233492 0.02635263
##  method   Intercept 0.19660208 0.03865238
```

```
#Random effect - together
coxme_mwimin_t<- coxme(Surv(total_lived, censored) ~ mwimin +
                  (1|location/method), data= new_df_gdd)

summary(coxme_mwimin_t)
```

```
## Cox mixed-effects model fit by maximum likelihood
##   Data: new_df_gdd
##   events, n = 14542, 15155
##   Iterations= 8 35
##                     NULL Integrated  Fitted
## Log-likelihood -125304.4  -125107.8 -125099
##
##                    Chisq   df p    AIC    BIC
## Integrated loglik 393.33 3.00 0 387.33 364.58
##  Penalized loglik 410.79 3.97 0 402.84 372.70
##
## Model:  Surv(total_lived, censored) ~ mwimin + (1 | location/method)
## Fixed coefficients
##              coef exp(coef)   se(coef)   z    p
```

```
## mwimin 0.02560182  1.025932 0.02831436 0.9 0.37
##
## Random effects
##  Group           Variable    Std Dev      Variance
##  location/method (Intercept) 0.2017008176 0.0406832198
##  location        (Intercept) 0.0199834564 0.0003993385
```

MWIMEAN

```
#no random effect
cox_mwimean<- coxph(Surv(total_lived, censored) ~ mwime,
                  data= new_df_gdd)

summary(cox_mwimean)
```

```
## Call:
## coxph(formula = Surv(total_lived, censored) ~ mwime, data = new_df_gdd)
##
##   n= 15155, number of events= 14542
##
##          coef exp(coef) se(coef)     z Pr(>|z|)
## mwime 0.04790   1.04907  0.02512 1.907   0.0565 .
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
##       exp(coef) exp(-coef) lower .95 upper .95
## mwime     1.049     0.9532    0.9987     1.102
##
## Concordance= 0.497  (se = 0.003 )
## Likelihood ratio test= 3.64  on 1 df,   p=0.06
## Wald test            = 3.64  on 1 df,   p=0.06
## Score (logrank) test = 3.64  on 1 df,   p=0.06
```

```
# Random effect separated
coxme_mwimean_s<- coxme(Surv(total_lived, censored) ~ mwime +
                   (1|location) + (1|method), data= new_df_gdd)
summary(coxme_mwimean_s)
```

```
## Cox mixed-effects model fit by maximum likelihood
##   Data: new_df_gdd
##   events, n = 14542, 15155
##   Iterations= 7 31
##                     NULL Integrated    Fitted
## Log-likelihood -125304.4  -125102.9 -125096.6
##
##                    Chisq   df p    AIC    BIC
## Integrated loglik 402.97 3.00 0 396.97 374.21
##  Penalized loglik 415.60 2.99 0 409.62 386.94
##
## Model:  Surv(total_lived, censored) ~ mwime + (1 | location) + (1 | method)
## Fixed coefficients
```

```
##             coef exp(coef)   se(coef)    z      p
## mwime 0.07989576  1.083174 0.02491304 3.21 0.0013
##
## Random effects
##  Group    Variable  Std Dev    Variance
##  location Intercept 0.16859737 0.02842507
##  method   Intercept 0.19757041 0.03903407
```

```
coxme_mwimean_t<- coxme(Surv(total_lived, censored) ~ mwime +
                  (1|location/method), data= new_df_gdd)
summary(coxme_mwimean_t)
```

```
## Cox mixed-effects model fit by maximum likelihood
##   Data: new_df_gdd
##   events, n = 14542, 15155
##   Iterations= 8 35
##                     NULL Integrated    Fitted
## Log-likelihood -125304.4  -125103.2 -125094.4
##
##                    Chisq   df p    AIC    BIC
## Integrated loglik 402.53 3.00 0 396.53 373.78
##  Penalized loglik 420.09 3.97 0 412.14 381.99
##
## Model:  Surv(total_lived, censored) ~ mwime + (1 | location/method)
## Fixed coefficients
##             coef exp(coef)   se(coef)    z      p
## mwime 0.07881585  1.082005 0.02492009 3.16 0.0016
##
## Random effects
##  Group           Variable    Std Dev      Variance
##  location/method (Intercept) 0.2051734085 0.0420961276
##  location        (Intercept) 0.0199952305 0.0003998092
```

MWIMAX

```
#no random effect
cox_mwimax<- coxph(Surv(total_lived, censored) ~ mwimax,
                  data= new_df_gdd)

summary(cox_mwimax)
```

```
## Call:
## coxph(formula = Surv(total_lived, censored) ~ mwimax, data = new_df_gdd)
##
##   n= 15155, number of events= 14542
##
##             coef exp(coef) se(coef)      z Pr(>|z|)
## mwimax -0.21145   0.80941  0.02192 -9.645   <2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
```

```
##        exp(coef) exp(-coef) lower .95 upper .95
## mwimax    0.8094      1.235    0.7754    0.8449
##
## Concordance= 0.526  (se = 0.003 )
## Likelihood ratio test= 93.93  on 1 df,   p=<2e-16
## Wald test            = 93.03  on 1 df,   p=<2e-16
## Score (logrank) test = 93.2  on 1 df,   p=<2e-16
```

```
# Random effect separated
coxme_mwimax_s<- coxme(Surv(total_lived, censored) ~ mwimax +
                  (1|location) + (1|method), data= new_df_gdd)
summary(coxme_mwimax_s)
```

```
## Cox mixed-effects model fit by maximum likelihood
##   Data: new_df_gdd
##   events, n = 14542, 15155
##   Iterations= 7 31
##                     NULL Integrated    Fitted
## Log-likelihood -125304.4  -125099.9 -125093.7
##
##                    Chisq   df p    AIC    BIC
## Integrated loglik 409.10 3.00 0 403.10 380.35
##  Penalized loglik 421.39 2.99 0 415.42 392.76
##
## Model:  Surv(total_lived, censored) ~ mwimax + (1 | location) + (1 |      method)
## Fixed coefficients
##              coef exp(coef) se(coef)     z       p
## mwimax -0.0965686 0.9079476 0.023838 -4.05 5.1e-05
##
## Random effects
##  Group    Variable  Std Dev    Variance
##  location Intercept 0.14184595 0.02012027
##  method   Intercept 0.19249015 0.03705246
```

```
coxme_mwimax_t<- coxme(Surv(total_lived, censored) ~ mwimax +
                  (1|location/method), data= new_df_gdd)
summary(coxme_mwimax_t)
```

```
## Cox mixed-effects model fit by maximum likelihood
##   Data: new_df_gdd
##   events, n = 14542, 15155
##   Iterations= 14 59
##                     NULL Integrated    Fitted
## Log-likelihood -125304.4  -125099.7 -125091.1
##
##                    Chisq   df p    AIC    BIC
## Integrated loglik 409.47 3.00 0 403.47 380.71
##  Penalized loglik 426.61 3.97 0 418.68 388.57
##
## Model:  Surv(total_lived, censored) ~ mwimax + (1 | location/method)
## Fixed coefficients
##               coef exp(coef)   se(coef)     z       p
## mwimax -0.09806063 0.9065939 0.02384877 -4.11 3.9e-05
```

```
##
## Random effects
##  Group           Variable    Std Dev     Variance
##  location/method (Intercept) 0.191881637 0.036818562
##  location        (Intercept) 0.019930329 0.000397218
```

GDD (Growing Degree Days)

```
# No random effect
cox_gdd<- coxph(Surv(total_lived, censored) ~ daily_acc_gdd,
                  data= new_df_gdd)

summary(cox_gdd)
```

```
## Call:
## coxph(formula = Surv(total_lived, censored) ~ daily_acc_gdd,
##     data = new_df_gdd)
##
##   n= 15154, number of events= 14541
##    (1 observation deleted due to missingness)
##
##                    coef exp(coef) se(coef)     z Pr(>|z|)
## daily_acc_gdd 0.035024  1.035645 0.002301 15.22   <2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
##               exp(coef) exp(-coef) lower .95 upper .95
## daily_acc_gdd     1.036     0.9656     1.031      1.04
##
## Concordance= 0.544  (se = 0.003 )
## Likelihood ratio test= 238  on 1 df,   p=<2e-16
## Wald test            = 231.7  on 1 df,   p=<2e-16
## Score (logrank) test = 232.3  on 1 df,   p=<2e-16
```

```
#Random effect - separated
coxme_gdd_s<- coxme(Surv(total_lived, censored) ~ daily_acc_gdd +
                    (1|location) + (1|method), data= new_df_gdd)
summary(coxme_gdd_s)
```

```
## Cox mixed-effects model fit by maximum likelihood
##   Data: new_df_gdd
##   events, n = 14541, 15154 (1 observation deleted due to missingness)
##   Iterations= 7 31
##                     NULL Integrated    Fitted
## Log-likelihood -125294.8    -125006 -124999.8
##
##                    Chisq   df p    AIC    BIC
## Integrated loglik 577.75 3.00 0 571.75 548.99
##  Penalized loglik 590.01 2.99 0 584.04 561.38
##
## Model:  Surv(total_lived, censored) ~ daily_acc_gdd + (1 | location) +      (1 | method)
```

```
## Fixed coefficients
##                      coef exp(coef)    se(coef)     z p
## daily_acc_gdd 0.03125914  1.031753 0.002322962 13.46 0
##
## Random effects
##  Group    Variable  Std Dev    Variance
##  location Intercept 0.13839373 0.01915282
##  method   Intercept 0.19408685 0.03766971
```

```
#Random effect - together
coxme_gdd_t<- coxme(Surv(total_lived, censored) ~ daily_acc_gdd +
                  (1|location/method), data= new_df_gdd)

summary(coxme_gdd_t)
```

```
## Cox mixed-effects model fit by maximum likelihood
##   Data: new_df_gdd
##   events, n = 14541, 15154 (1 observation deleted due to missingness)
##   Iterations= 16 67
##                      NULL Integrated    Fitted
## Log-likelihood -125294.8  -125006.5 -124997.9
##
##                     Chisq   df p    AIC    BIC
## Integrated loglik 576.65 3.00 0 570.65 547.90
##  Penalized loglik 593.81 3.97 0 585.87 555.75
##
## Model:  Surv(total_lived, censored) ~ daily_acc_gdd + (1 | location/method)
## Fixed coefficients
##                      coef exp(coef)   se(coef)     z p
## daily_acc_gdd 0.03120251  1.031694 0.00232466 13.42 0
##
## Random effects
##  Group           Variable    Std Dev      Variance
##  location/method (Intercept) 0.1922513923 0.0369605978
##  location        (Intercept) 0.0199271829 0.0003970926
```

Checking all temperatures together

```
# No random effect
cox_temps<- coxph(Surv(total_lived, censored) ~ mintemperature + meantemperature
                  + maxtemperature + mwime + mwimin+ mwimax + daily_acc_gdd,
                  data= new_df_gdd)

summary(cox_temps)
```

```
## Call:
## coxph(formula = Surv(total_lived, censored) ~ mintemperature +
##     meantemperature + maxtemperature + mwime + mwimin + mwimax +
##     daily_acc_gdd, data = new_df_gdd)
##
##   n= 15154, number of events= 14541
```

```
##    (1 observation deleted due to missingness)
##
##                      coef exp(coef)  se(coef)      z Pr(>|z|)
## mintemperature   0.005629  1.005645  0.021093  0.267    0.790
## meantemperature  0.177365  1.194067  0.024663  7.191 6.41e-13 ***
## maxtemperature   0.026678  1.027037  0.021320  1.251    0.211
## mwime           -0.162473  0.850039  0.034262 -4.742 2.12e-06 ***
## mwimin          -0.191866  0.825417  0.043412 -4.420 9.88e-06 ***
## mwimax          -0.191600  0.825637  0.024315 -7.880 3.28e-15 ***
## daily_acc_gdd   -0.168074  0.845291  0.033528 -5.013 5.36e-07 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
##                 exp(coef) exp(-coef) lower .95 upper .95
## mintemperature     1.0056     0.9944    0.9649    1.0481
## meantemperature    1.1941     0.8375    1.1377    1.2532
## maxtemperature     1.0270     0.9737    0.9850    1.0709
## mwime              0.8500     1.1764    0.7948    0.9091
## mwimin             0.8254     1.2115    0.7581    0.8987
## mwimax             0.8256     1.2112    0.7872    0.8659
## daily_acc_gdd      0.8453     1.1830    0.7915    0.9027
##
## Concordance= 0.557  (se = 0.003 )
## Likelihood ratio test= 503.4  on 7 df,   p=<2e-16
## Wald test            = 513.5  on 7 df,   p=<2e-16
## Score (logrank) test = 513  on 7 df,   p=<2e-16
```

```
#Random effect - separated
coxme_temps_s<- coxme(Surv(total_lived, censored) ~ mintemperature + meantemperature
                  + maxtemperature + mwime + mwimin + mwimax + daily_acc_gdd +
                   (1|location) + (1|method), data= new_df_gdd)
summary(coxme_temps_s)
```

```
## Cox mixed-effects model fit by maximum likelihood
##   Data: new_df_gdd
##   events, n = 14541, 15154 (1 observation deleted due to missingness)
##   Iterations= 7 38
##                     NULL Integrated  Fitted
## Log-likelihood -125294.8  -124894.3 -124888
##
##                    Chisq   df p    AIC    BIC
## Integrated loglik 801.03 9.00 0 783.03 714.77
##  Penalized loglik 813.59 8.99 0 795.61 727.46
##
## Model:  Surv(total_lived, censored) ~ mintemperature + meantemperature +      maxtemperature + mwime
## Fixed coefficients
##                         coef exp(coef)   se(coef)     z       p
## mintemperature   0.002025819 1.0020279 0.02066269  0.10 9.2e-01
## meantemperature  0.115133987 1.1220238 0.02549174  4.52 6.3e-06
## maxtemperature   0.058831723 1.0605968 0.02109295  2.79 5.3e-03
## mwime           -0.086976852 0.9166983 0.03449558 -2.52 1.2e-02
## mwimin          -0.218725374 0.8035424 0.04328104 -5.05 4.3e-07
## mwimax          -0.111974994 0.8940666 0.02506666 -4.47 7.9e-06
## daily_acc_gdd   -0.138257777 0.8708742 0.03253861 -4.25 2.1e-05
```

```
##
## Random effects
##  Group    Variable  Std Dev    Variance
##  location Intercept 0.16997513 0.02889154
##  method   Intercept 0.18911192 0.03576332
```

```
#Random effect - together
coxme_temps_t<- coxme(Surv(total_lived, censored) ~ mintemperature +
                        meantemperature
                    + maxtemperature + mwime + mwimin + mwimax + daily_acc_gdd +
                     (1|location/method), data= new_df_gdd)

summary(coxme_temps_t)
```

```
## Cox mixed-effects model fit by maximum likelihood
##   Data: new_df_gdd
##   events, n = 14541, 15154 (1 observation deleted due to missingness)
##   Iterations= 8 43
##                     NULL Integrated  Fitted
## Log-likelihood -125294.8  -124894.7 -124886
##
##                    Chisq   df p    AIC    BIC
## Integrated loglik 800.32 9.00 0 782.32 714.05
##  Penalized loglik 817.71 9.97 0 797.77 722.17
##
## Model:  Surv(total_lived, censored) ~ mintemperature + meantemperature +      maxtemperature + mwime
## Fixed coefficients
##                          coef exp(coef)   se(coef)     z       p
## mintemperature   0.0006155803 1.0006158 0.02068060  0.03 9.8e-01
## meantemperature  0.1171796574 1.1243214 0.02550060  4.60 4.3e-06
## maxtemperature   0.0571947850 1.0588620 0.02111213  2.71 6.7e-03
## mwime           -0.0879824255 0.9157770 0.03448132 -2.55 1.1e-02
## mwimin          -0.2187262141 0.8035417 0.04326428 -5.06 4.3e-07
## mwimax          -0.1132208763 0.8929534 0.02507098 -4.52 6.3e-06
## daily_acc_gdd   -0.1372407964 0.8717603 0.03256400 -4.21 2.5e-05
##
## Random effects
##  Group           Variable    Std Dev      Variance
##  location/method (Intercept) 0.1996628621 0.0398652585
##  location        (Intercept) 0.0200126109 0.0004005046
```

Checking collinearity in the 3 cases

```
#No random effects
rms::vif(cox_temps)
```

```
##  mintemperature meantemperature  maxtemperature           mwime          mwimin
##      102.263651      130.593575      105.648983        1.843648        2.486527
##          mwimax   daily_acc_gdd
##        1.213906      219.163823
```

```r
#daily_acc_gdd has a lot of collinearity so we should remove it and do it again
cox_temps2 <- coxph(Surv(total_lived, censored) ~ mintemperature + meantemperature
                  + maxtemperature + mwimin + mwime + mwimax,
                  data= new_df_gdd)

summary(cox_temps2)
```

```
## Call:
## coxph(formula = Surv(total_lived, censored) ~ mintemperature +
##     meantemperature + maxtemperature + mwimin + mwime + mwimax,
##     data = new_df_gdd)
##
##   n= 15155, number of events= 14542
##
##                     coef exp(coef) se(coef)      z Pr(>|z|)
## mintemperature  -0.07654   0.92631  0.01306 -5.860 4.63e-09 ***
## meantemperature  0.18651   1.20504  0.02456  7.595 3.09e-14 ***
## maxtemperature  -0.05987   0.94189  0.01271 -4.710 2.48e-06 ***
## mwimin          -0.24429   0.78326  0.04206 -5.808 6.33e-09 ***
## mwime           -0.16328   0.84935  0.03441 -4.745 2.08e-06 ***
## mwimax          -0.18482   0.83126  0.02435 -7.591 3.19e-14 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
##                 exp(coef) exp(-coef) lower .95 upper .95
## mintemperature     0.9263     1.0796    0.9029    0.9503
## meantemperature    1.2050     0.8298    1.1484    1.2645
## maxtemperature     0.9419     1.0617    0.9187    0.9656
## mwimin             0.7833     1.2767    0.7213    0.8506
## mwime              0.8493     1.1774    0.7940    0.9086
## mwimax             0.8313     1.2030    0.7925    0.8719
##
## Concordance= 0.556  (se = 0.003 )
## Likelihood ratio test= 476.9  on 6 df,   p=<2e-16
## Wald test            = 491.1  on 6 df,   p=<2e-16
## Score (logrank) test = 493.7  on 6 df,   p=<2e-16
```

```r
rms::vif(cox_temps2)
```

```
##  mintemperature meantemperature  maxtemperature          mwimin           mwime
##       40.457171      131.571547       37.445116        2.329224        1.863558
##          mwimax
##        1.210182
```

```r
#mean temperature is the next variable with higher VIF, we remove it and repeat
cox_temps3 <- coxph(Surv(total_lived, censored) ~ mintemperature
                  + maxtemperature + mwimin + mwime + mwimax,
                  data= new_df_gdd)
summary(cox_temps3)
```

```
## Call:
## coxph(formula = Surv(total_lived, censored) ~ mintemperature +
```

```
##     maxtemperature + mwimin + mwime + mwimax, data = new_df_gdd)
##
##   n= 15155, number of events= 14542
##
##                     coef exp(coef)  se(coef)      z Pr(>|z|)
## mintemperature  0.017702  1.017859  0.004226  4.189 2.80e-05 ***
## maxtemperature  0.032034  1.032552  0.003827  8.369  < 2e-16 ***
## mwimin         -0.231882  0.793040  0.042098 -5.508 3.63e-08 ***
## mwime          -0.119834  0.887067  0.033838 -3.541 0.000398 ***
## mwimax         -0.210938  0.809824  0.024137 -8.739  < 2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
##                exp(coef) exp(-coef) lower .95 upper .95
## mintemperature    1.0179     0.9825    1.0095    1.0263
## maxtemperature    1.0326     0.9685    1.0248    1.0403
## mwimin            0.7930     1.2610    0.7302    0.8612
## mwime             0.8871     1.1273    0.8301    0.9479
## mwimax            0.8098     1.2348    0.7724    0.8491
##
## Concordance= 0.552  (se = 0.003 )
## Likelihood ratio test= 419.4  on 5 df,   p=<2e-16
## Wald test            = 431.8  on 5 df,   p=<2e-16
## Score (logrank) test = 434.1  on 5 df,   p=<2e-16
```

```
rms::vif(cox_temps3)
```

```
## mintemperature maxtemperature         mwimin          mwime         mwimax
##       4.237161       3.380088       2.327549       1.794646       1.183164
```

```
stats::step(cox_temps3)
```

```
## Start:  AIC=250199.4
## Surv(total_lived, censored) ~ mintemperature + maxtemperature +
##     mwimin + mwime + mwimax
##
##                   Df    AIC
## <none>               250199
## - mwime           1 250210
## - mintemperature  1 250215
## - mwimin          1 250228
## - maxtemperature  1 250267
## - mwimax          1 250274

## Call:
## coxph(formula = Surv(total_lived, censored) ~ mintemperature +
##     maxtemperature + mwimin + mwime + mwimax, data = new_df_gdd)
##
##                     coef exp(coef)  se(coef)      z        p
## mintemperature  0.017702  1.017859  0.004226  4.189 2.80e-05
## maxtemperature  0.032034  1.032552  0.003827  8.369  < 2e-16
## mwimin         -0.231882  0.793040  0.042098 -5.508 3.63e-08
```

```
## mwime          -0.119834  0.887067  0.033838 -3.541 0.000398
## mwimax         -0.210938  0.809824  0.024137 -8.739  < 2e-16
##
## Likelihood ratio test=419.4  on 5 df, p=< 2.2e-16
## n= 15155, number of events= 14542
```

```
#Random effects - Separated
rms::vif(coxme_temps_s)
```

```
##  mintemperature meantemperature  maxtemperature           mwime          mwimin
##       88.347477      134.733872      102.076126        1.838034        2.296321
##          mwimax   daily_acc_gdd
##        1.077748      199.490299
```

```
#daily_acc_gdd has a lot of collinearity so we should remove it and do it again
coxme_temps_s2<- coxme(Surv(total_lived, censored) ~ mintemperature + meantemperature
                 + maxtemperature + mwimin + mwime + mwimax +
                  (1|location) + (1|method), data= new_df_gdd)

summary(coxme_temps_s2)
```

```
## Cox mixed-effects model fit by maximum likelihood
##   Data: new_df_gdd
##   events, n = 14542, 15155
##   Iterations= 7 31
##                     NULL Integrated    Fitted
## Log-likelihood -125304.4  -124913.5 -124907.2
##
##                    Chisq   df p    AIC    BIC
## Integrated loglik 781.93 8.00 0 765.93 705.25
##  Penalized loglik 794.55 7.99 0 778.58 718.00
##
## Model:  Surv(total_lived, censored) ~ mintemperature + meantemperature +      maxtemperature + mwimi
## Fixed coefficients
##                         coef exp(coef)   se(coef)     z       p
## mintemperature  -0.06489220 0.9371685 0.01320611 -4.91 8.9e-07
## meantemperature  0.12002183 1.1275215 0.02545589  4.71 2.4e-06
## maxtemperature  -0.01021488 0.9898371 0.01364458 -0.75 4.5e-01
## mwimin          -0.26450618 0.7675849 0.04185807 -6.32 2.6e-10
## mwime           -0.08501583 0.9184977 0.03461460 -2.46 1.4e-02
## mwimax          -0.10407127 0.9011611 0.02505272 -4.15 3.3e-05
##
## Random effects
##  Group    Variable  Std Dev    Variance
##  location Intercept 0.17637486 0.03110809
##  method   Intercept 0.18876433 0.03563197
```

```
rms::vif(coxme_temps_s2)
```

```
##  mintemperature meantemperature  maxtemperature          mwimin           mwime
##       36.964823      135.941168       42.591913        2.145265        1.854211
##          mwimax
##        1.074588
```

```
#mean temperature is the next variable with higher VIF, we remove it and repeat
coxme_temps_s3<- coxme(Surv(total_lived, censored) ~ mintemperature
                  + maxtemperature + mwimin + mwime + mwimax +
                   (1|location) + (1|method), data= new_df_gdd)
summary(coxme_temps_s3)
```

```
## Cox mixed-effects model fit by maximum likelihood
##   Data: new_df_gdd
##   events, n = 14542, 15155
##   Iterations= 8 35
##                     NULL Integrated    Fitted
## Log-likelihood -125304.4  -124924.5 -124918.1
##
##                    Chisq   df p    AIC    BIC
## Integrated loglik 759.77 7.00 0 745.77 692.67
##  Penalized loglik 772.59 6.99 0 758.62 705.61
##
## Model:  Surv(total_lived, censored) ~ mintemperature + maxtemperature +      mwimin + mwime + mwimax
## Fixed coefficients
##                         coef exp(coef)    se(coef)     z       p
## mintemperature -0.006549138 0.9934723 0.004669010 -1.40 1.6e-01
## maxtemperature  0.051068400 1.0523949 0.004136596 12.35 0.0e+00
## mwimin         -0.260951963 0.7703179 0.041853967 -6.23 4.5e-10
## mwime          -0.053350882 0.9480473 0.033848635 -1.58 1.1e-01
## mwimax         -0.111577588 0.8944220 0.025038337 -4.46 8.3e-06
##
## Random effects
##  Group    Variable  Std Dev    Variance
##  location Intercept 0.19247584 0.03704695
##  method   Intercept 0.18832066 0.03546467
```

```
rms::vif(coxme_temps_s3)
```

```
## mintemperature maxtemperature         mwimin          mwime         mwimax
##       4.623830       3.897166       2.139333       1.769940       1.068798
```

```
#Random effects - Together
rms::vif(coxme_temps_t)
```

```
##  mintemperature meantemperature  maxtemperature           mwime          mwimin
##       88.437875      134.681356      102.140549        1.836446        2.295591
##          mwimax   daily_acc_gdd
##        1.077656      199.595910
```

```
#daily_acc_gdd has a lot of collinearity so we should remove it and do it again
coxme_temps_t2<- coxme(Surv(total_lived, censored) ~ mintemperature +
                       meantemperature
                  + maxtemperature + mwimin + mwime + mwimax  +
                   (1|location/method), data= new_df_gdd)


summary(coxme_temps_t2)
```

```
## Cox mixed-effects model fit by maximum likelihood
##   Data: new_df_gdd
##   events, n = 14542, 15155
##   Iterations= 8 35
##                     NULL Integrated    Fitted
## Log-likelihood -125304.4  -124913.7 -124904.9
##
##                    Chisq   df p    AIC    BIC
## Integrated loglik 781.51 8.00 0 765.51 704.83
##  Penalized loglik 798.99 8.97 0 781.05 713.03
##
## Model:  Surv(total_lived, censored) ~ mintemperature + meantemperature +      maxtemperature + mwimi
## Fixed coefficients
##                         coef exp(coef)   se(coef)     z       p
## mintemperature  -0.06584852 0.9362727 0.01321101 -4.98 6.2e-07
## meantemperature  0.12211928 1.1298889 0.02546361  4.80 1.6e-06
## maxtemperature  -0.01140374 0.9886610 0.01364655 -0.84 4.0e-01
## mwimin          -0.26407743 0.7679141 0.04184378 -6.31 2.8e-10
## mwime           -0.08605929 0.9175398 0.03459845 -2.49 1.3e-02
## mwimax          -0.10541950 0.8999469 0.02505652 -4.21 2.6e-05
##
## Random effects
##  Group           Variable    Std Dev     Variance
##  location/method (Intercept) 0.202446146 0.040984442
##  location        (Intercept) 0.020024186 0.000400968
```

```
rms::vif(coxme_temps_t2)
```

```
##  mintemperature meantemperature  maxtemperature          mwimin           mwime
##       36.957658      135.856718       42.551951        2.144861        1.852392
##          mwimax
##        1.074502
```

```
#mean temperature is the next variable with higher VIF, we remove it and repeat
coxme_temps_t3<- coxme(Surv(total_lived, censored) ~ mintemperature
                  + maxtemperature + mwimin + mwime + mwimax  +
                   (1|location/method), data= new_df_gdd)


summary(coxme_temps_t3)
```

```
## Cox mixed-effects model fit by maximum likelihood
##   Data: new_df_gdd
##   events, n = 14542, 15155
##   Iterations= 8 35
##                     NULL Integrated    Fitted
## Log-likelihood -125304.4  -124925.1 -124916.3
##
##                    Chisq   df p    AIC    BIC
## Integrated loglik 758.58 7.00 0 744.58 691.49
##  Penalized loglik 776.36 7.97 0 760.41 699.95
##
## Model:  Surv(total_lived, censored) ~ mintemperature + maxtemperature +      mwimin + mwime + mwimax
```

```
## Fixed coefficients
##                         coef exp(coef)    se(coef)     z       p
## mintemperature -0.006466453 0.9935544 0.004667861 -1.39 1.7e-01
## maxtemperature  0.050935073 1.0522546 0.004135514 12.32 0.0e+00
## mwimin         -0.260435496 0.7707159 0.041841227 -6.22 4.8e-10
## mwime          -0.053859252 0.9475655 0.033832186 -1.59 1.1e-01
## mwimax         -0.112998540 0.8931520 0.025042877 -4.51 6.4e-06
##
## Random effects
##  Group           Variable    Std Dev      Variance
##  location/method (Intercept) 0.2125815040 0.0451908958
##  location        (Intercept) 0.0200616141 0.0004024684
```

```
rms::vif(coxme_temps_t3)
```

```
## mintemperature maxtemperature         mwimin          mwime         mwimax
##       4.617713       3.890342       2.138939       1.768050       1.068777
```

Relative Humidity

Minimum relative humidity

```
# No random effect
cox_minrh<- coxph(Surv(total_lived, censored) ~ minrh,
                  data= new_df_gdd)

summary(cox_minrh)
```

```
## Call:
## coxph(formula = Surv(total_lived, censored) ~ minrh, data = new_df_gdd)
##
##   n= 15155, number of events= 14542
##
##             coef  exp(coef)   se(coef)      z Pr(>|z|)
## minrh -0.0020952  0.9979070  0.0005979 -3.504 0.000458 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
##       exp(coef) exp(-coef) lower .95 upper .95
## minrh    0.9979      1.002    0.9967    0.9991
##
## Concordance= 0.516  (se = 0.003 )
## Likelihood ratio test= 12.28  on 1 df,   p=5e-04
## Wald test            = 12.28  on 1 df,   p=5e-04
## Score (logrank) test = 12.28  on 1 df,   p=5e-04
```

```
#Random effect - separated
coxme_minrh_s<- coxme(Surv(total_lived, censored) ~ minrh +
                    (1|location) + (1|method), data= new_df_gdd)
summary(coxme_minrh_s)
```

```
## Cox mixed-effects model fit by maximum likelihood
##   Data: new_df_gdd
##   events, n = 14542, 15155
##   Iterations= 8 35
##                     NULL Integrated    Fitted
## Log-likelihood -125304.4  -125059.1 -125052.5
##
##                    Chisq   df p    AIC    BIC
## Integrated loglik 490.69 3.00 0 484.69 461.94
##  Penalized loglik 503.85 2.99 0 497.87 475.17
##
## Model:  Surv(total_lived, censored) ~ minrh + (1 | location) + (1 | method)
## Fixed coefficients
##              coef exp(coef)     se(coef)     z p
## minrh -0.00636735 0.9936529 0.0006395591 -9.96 0
##
## Random effects
##  Group    Variable  Std Dev    Variance
##  location Intercept 0.21756052 0.04733258
##  method   Intercept 0.19528677 0.03813692
```

```
#Random effect - together
coxme_minrh_t<- coxme(Surv(total_lived, censored) ~ minrh +
                  (1|location/method), data= new_df_gdd)

summary(coxme_minrh_t)
```

```
## Cox mixed-effects model fit by maximum likelihood
##   Data: new_df_gdd
##   events, n = 14542, 15155
##   Iterations= 7 31
##                     NULL Integrated    Fitted
## Log-likelihood -125304.4    -125059 -125049.9
##
##                    Chisq   df p    AIC    BIC
## Integrated loglik 490.85 3.00 0 484.85 462.10
##  Penalized loglik 509.13 3.98 0 501.17 470.99
##
## Model:  Surv(total_lived, censored) ~ minrh + (1 | location/method)
## Fixed coefficients
##               coef exp(coef)     se(coef)     z p
## minrh -0.006375774 0.9936445 0.0006395377 -9.97 0
##
## Random effects
##  Group           Variable    Std Dev      Variance
##  location/method (Intercept) 0.2312387670 0.0534713674
##  location        (Intercept) 0.0200883489 0.0004035418
```

Mean relative humidity

```
# No random effect
cox_meanrh<- coxph(Surv(total_lived, censored) ~ meanrh,
```

```
                  data= new_df_gdd)

summary(cox_meanrh)
```

```
## Call:
## coxph(formula = Surv(total_lived, censored) ~ meanrh, data = new_df_gdd)
##
##   n= 15155, number of events= 14542
##
##              coef  exp(coef)   se(coef)      z Pr(>|z|)
## meanrh -0.0034412  0.9965647  0.0007815 -4.403 1.07e-05 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
##        exp(coef) exp(-coef) lower .95 upper .95
## meanrh    0.9966      1.003     0.995    0.9981
##
## Concordance= 0.516  (se = 0.003 )
## Likelihood ratio test= 19.32  on 1 df,   p=1e-05
## Wald test            = 19.39  on 1 df,   p=1e-05
## Score (logrank) test = 19.39  on 1 df,   p=1e-05
```

```
#Random effect - separated
coxme_meanrh_s<- coxme(Surv(total_lived, censored) ~ meanrh +
                  (1|location) + (1|method), data= new_df_gdd)
summary(coxme_meanrh_s)
```

```
## Cox mixed-effects model fit by maximum likelihood
##   Data: new_df_gdd
##   events, n = 14542, 15155
##   Iterations= 8 35
##                     NULL Integrated    Fitted
## Log-likelihood -125304.4    -125061 -125054.5
##
##                    Chisq   df p    AIC    BIC
## Integrated loglik 486.88 3.00 0 480.88 458.12
##  Penalized loglik 499.94 2.99 0 493.96 471.27
##
## Model:  Surv(total_lived, censored) ~ meanrh + (1 | location) + (1 |      method)
## Fixed coefficients
##                coef exp(coef)     se(coef)    z p
## meanrh -0.007938094 0.9920933 0.0008102467 -9.8 0
##
## Random effects
##  Group    Variable  Std Dev    Variance
##  location Intercept 0.20795127 0.04324373
##  method   Intercept 0.19543977 0.03819670
```

```
#Random effect - together
coxme_meanrh_t<- coxme(Surv(total_lived, censored) ~ meanrh +
                  (1|location/method), data= new_df_gdd)

summary(coxme_meanrh_t)
```

```
## Cox mixed-effects model fit by maximum likelihood
##   Data: new_df_gdd
##   events, n = 14542, 15155
##   Iterations= 7 31
##                     NULL Integrated    Fitted
## Log-likelihood -125304.4  -125060.6 -125051.6
##
##                    Chisq   df p    AIC    BIC
## Integrated loglik 487.57 3.00 0 481.57 458.82
##  Penalized loglik 505.70 3.98 0 497.75 467.57
##
## Model:  Surv(total_lived, censored) ~ meanrh + (1 | location/method)
## Fixed coefficients
##                coef exp(coef)     se(coef)     z p
## meanrh -0.007974937 0.9920568 0.0008105245 -9.84 0
##
## Random effects
##  Group           Variable    Std Dev      Variance
##  location/method (Intercept) 0.2255651177 0.0508796223
##  location        (Intercept) 0.0200723263 0.0004028983
```

Maximum relative humidity

```
# No random effect
cox_maxrh<- coxph(Surv(total_lived, censored) ~ maxrh,
                  data= new_df_gdd)

summary(cox_maxrh)
```

```
## Call:
## coxph(formula = Surv(total_lived, censored) ~ maxrh, data = new_df_gdd)
##
##   n= 15155, number of events= 14542
##
##             coef  exp(coef)   se(coef)      z Pr(>|z|)
## maxrh -0.0030315  0.9969731  0.0009514 -3.186  0.00144 **
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
##       exp(coef) exp(-coef) lower .95 upper .95
## maxrh     0.997      1.003    0.9951    0.9988
##
## Concordance= 0.508  (se = 0.003 )
## Likelihood ratio test= 10.05  on 1 df,   p=0.002
## Wald test            = 10.15  on 1 df,   p=0.001
## Score (logrank) test = 10.15  on 1 df,   p=0.001
```

```
#Random effect - separated
coxme_maxrh_s<- coxme(Surv(total_lived, censored) ~ maxrh +
                    (1|location) + (1|method), data= new_df_gdd)
summary(coxme_maxrh_s)
```

```
## Cox mixed-effects model fit by maximum likelihood
##   Data: new_df_gdd
##   events, n = 14542, 15155
##   Iterations= 8 35
##                     NULL Integrated    Fitted
## Log-likelihood -125304.4    -125082 -125075.6
##
##                    Chisq   df p    AIC    BIC
## Integrated loglik 444.82 3.00 0 438.82 416.07
##  Penalized loglik 457.71 2.99 0 451.73 429.04
##
## Model:  Surv(total_lived, censored) ~ maxrh + (1 | location) + (1 | method)
## Fixed coefficients
##               coef exp(coef)     se(coef)     z       p
## maxrh -0.007028962 0.9929957 0.0009593589 -7.33 2.4e-13
##
## Random effects
##  Group    Variable  Std Dev    Variance
##  location Intercept 0.18996170 0.03608545
##  method   Intercept 0.19610409 0.03845681
```

```
#Random effect - together
coxme_maxrh_t<- coxme(Surv(total_lived, censored) ~ maxrh +
                  (1|location/method), data= new_df_gdd)

summary(coxme_maxrh_t)
```

```
## Cox mixed-effects model fit by maximum likelihood
##   Data: new_df_gdd
##   events, n = 14542, 15155
##   Iterations= 8 35
##                     NULL Integrated    Fitted
## Log-likelihood -125304.4  -125081.7 -125072.8
##
##                    Chisq   df p    AIC    BIC
## Integrated loglik 445.47 3.00 0 439.47 416.72
##  Penalized loglik 463.34 3.98 0 455.39 425.23
##
## Model:  Surv(total_lived, censored) ~ maxrh + (1 | location/method)
## Fixed coefficients
##               coef exp(coef)     se(coef)     z       p
## maxrh -0.007085906 0.9929391 0.0009598875 -7.38 1.6e-13
##
## Random effects
##  Group           Variable    Std Dev      Variance
##  location/method (Intercept) 0.2160507191 0.0466779132
##  location        (Intercept) 0.0200360569 0.0004014436
```

All RH together + Check collinearity

```
#No random effects
cox_rhs <- coxph(Surv(total_lived, censored) ~ minrh + meanrh
```

```
                  + maxrh + mwimin + mwime + mwimax,
                  data= new_df_gdd)
rms::vif(cox_rhs)
```

```
##     minrh    meanrh     maxrh    mwimin     mwime    mwimax
## 20.542798 40.644364  8.766319  2.074767  1.836499  1.298317
```

```
#meanrh has a lot of collinearity so we should remove it and do it again
cox_rhs2 <- coxph(Surv(total_lived, censored) ~ minrh + maxrh
                  + mwimin + mwime + mwimax,
                  data= new_df_gdd)

summary(cox_rhs2)
```

```
## Call:
## coxph(formula = Surv(total_lived, censored) ~ minrh + maxrh +
##     mwimin + mwime + mwimax, data = new_df_gdd)
##
##   n= 15155, number of events= 14542
##
##              coef  exp(coef)   se(coef)       z Pr(>|z|)
## minrh  -0.0045322  0.9954780  0.0009257  -4.896 9.79e-07 ***
## maxrh  -0.0043198  0.9956895  0.0013647  -3.165  0.00155 **
## mwimin  0.1556575  1.1684260  0.0391039   3.981 6.87e-05 ***
## mwime   0.0395225  1.0403139  0.0333228   1.186  0.23560
## mwimax -0.2918190  0.7469037  0.0252557 -11.555  < 2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
##        exp(coef) exp(-coef) lower .95 upper .95
## minrh     0.9955     1.0045    0.9937    0.9973
## maxrh     0.9957     1.0043    0.9930    0.9984
## mwimin    1.1684     0.8559    1.0822    1.2615
## mwime     1.0403     0.9612    0.9745    1.1105
## mwimax    0.7469     1.3389    0.7108    0.7848
##
## Concordance= 0.54  (se = 0.003 )
## Likelihood ratio test= 201.1  on 5 df,   p=<2e-16
## Wald test            = 200.3  on 5 df,   p=<2e-16
## Score (logrank) test = 200.7  on 5 df,   p=<2e-16
```

```
rms::vif(cox_rhs2)
```

```
##    minrh    maxrh   mwimin    mwime   mwimax
## 2.463882 2.205846 2.040134 1.784256 1.295548
```

```
#Shall we eliminate a variable here?
stats::step(cox_rhs2)
```

```
## Start:  AIC=250417.8
## Surv(total_lived, censored) ~ minrh + maxrh + mwimin + mwime +
```

```
##     mwimax
##
##          Df    AIC
## - mwime   1 250417
## <none>      250418
## - maxrh   1 250426
## - mwimin  1 250431
## - minrh   1 250440
## - mwimax  1 250550
##
## Step:  AIC=250417.2
## Surv(total_lived, censored) ~ minrh + maxrh + mwimin + mwimax
##
##          Df    AIC
## <none>      250417
## - maxrh   1 250424
## - minrh   1 250445
## - mwimin  1 250452
## - mwimax  1 250554
```

```
## Call:
## coxph(formula = Surv(total_lived, censored) ~ minrh + maxrh +
##     mwimin + mwimax, data = new_df_gdd)
##
##              coef  exp(coef)   se(coef)       z        p
## minrh  -0.0048554  0.9951564  0.0008839  -5.493 3.95e-08
## maxrh  -0.0038823  0.9961252  0.0013134  -2.956  0.00312
## mwimin  0.1846594  1.2028087  0.0304151   6.071 1.27e-09
## mwimax -0.2829443  0.7535618  0.0241305 -11.726  < 2e-16
##
## Likelihood ratio test=199.7  on 4 df, p=< 2.2e-16
## n= 15155, number of events= 14542
```

```
cox_rhs3 <- coxph(Surv(total_lived, censored) ~ minrh
                  + mwimin + maxrh + mwimax,
                  data= new_df_gdd)

summary(cox_rhs3)
```

```
## Call:
## coxph(formula = Surv(total_lived, censored) ~ minrh + mwimin +
##     maxrh + mwimax, data = new_df_gdd)
##
##   n= 15155, number of events= 14542
##
##              coef  exp(coef)   se(coef)       z Pr(>|z|)
## minrh  -0.0048554  0.9951564  0.0008839  -5.493 3.95e-08 ***
## mwimin  0.1846594  1.2028087  0.0304151   6.071 1.27e-09 ***
## maxrh  -0.0038823  0.9961252  0.0013134  -2.956  0.00312 **
## mwimax -0.2829443  0.7535618  0.0241305 -11.726  < 2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
```

```
##        exp(coef) exp(-coef) lower .95 upper .95
## minrh     0.9952     1.0049    0.9934    0.9969
## mwimin    1.2028     0.8314    1.1332    1.2767
## maxrh     0.9961     1.0039    0.9936    0.9987
## mwimax    0.7536     1.3270    0.7188    0.7901
##
## Concordance= 0.54  (se = 0.003 )
## Likelihood ratio test= 199.7  on 4 df,   p=<2e-16
## Wald test            = 198.9  on 4 df,   p=<2e-16
## Score (logrank) test = 199.3  on 4 df,   p=<2e-16
```

```
#Random effects - Separated
coxme_rh_s<- coxme(Surv(total_lived, censored) ~ minrh + meanrh
                  + maxrh + mwimin + mwime + mwimax  +
                   (1|location) + (1|method), data= new_df_gdd)

summary(coxme_rh_s)
```

```
## Cox mixed-effects model fit by maximum likelihood
##   Data: new_df_gdd
##   events, n = 14542, 15155
##   Iterations= 8 35
##                     NULL Integrated    Fitted
## Log-likelihood -125304.4  -125016.8 -125010.5
##
##                    Chisq   df p    AIC    BIC
## Integrated loglik 575.18 8.00 0 559.18 498.50
##  Penalized loglik 587.95 7.99 0 571.97 511.38
##
## Model:  Surv(total_lived, censored) ~ minrh + meanrh + maxrh + mwimin +      mwime + mwimax + (1 | l
## Fixed coefficients
##                  coef exp(coef)    se(coef)     z       p
## minrh  -0.0024658278 0.9975372 0.002741716 -0.90 3.7e-01
## meanrh -0.0076783487 0.9923511 0.004973124 -1.54 1.2e-01
## maxrh  -0.0003334963 0.9996666 0.002779633 -0.12 9.0e-01
## mwimin  0.0435860336 1.0445499 0.040061071  1.09 2.8e-01
## mwime   0.1219617805 1.1297109 0.034060014  3.58 3.4e-04
## mwimax -0.2006914671 0.8181648 0.025979629 -7.72 1.1e-14
##
## Random effects
##  Group    Variable  Std Dev    Variance
##  location Intercept 0.18387708 0.03381078
##  method   Intercept 0.19187425 0.03681573
```

```
rms::vif(coxme_rh_s)
```

```
##     minrh    meanrh     maxrh    mwimin     mwime    mwimax
## 18.482950 37.965977  8.584233  1.945327  1.838866  1.177864
```

```
#meanrh has a lot of collinearity so we should remove it and do it again
coxme_rh_s2<- coxme(Surv(total_lived, censored) ~ minrh + maxrh + mwimin + mwime + mwimax  +
                   (1|location) + (1|method), data= new_df_gdd)
```

```
summary(coxme_rh_s2)
```

```
## Cox mixed-effects model fit by maximum likelihood
##   Data: new_df_gdd
##   events, n = 14542, 15155
##   Iterations= 8 35
##                     NULL Integrated    Fitted
## Log-likelihood -125304.4    -125018 -125011.6
##
##                    Chisq   df p    AIC    BIC
## Integrated loglik 572.80 7.00 0 558.80 505.71
##  Penalized loglik 585.62 6.99 0 571.64 518.63
##
## Model:  Surv(total_lived, censored) ~ minrh + maxrh + mwimin + mwime +      mwimax + (1 | location) +
## Fixed coefficients
##                coef exp(coef)     se(coef)     z       p
## minrh  -0.006446137 0.9935746 0.0009255542 -6.96 3.3e-12
## maxrh  -0.004092030 0.9959163 0.0013485616 -3.03 2.4e-03
## mwimin  0.045255454 1.0462951 0.0399619877  1.13 2.6e-01
## mwime   0.117823118 1.1250451 0.0338930200  3.48 5.1e-04
## mwimax -0.199653693 0.8190143 0.0259700313 -7.69 1.5e-14
##
## Random effects
##  Group    Variable  Std Dev    Variance
##  location Intercept 0.18824868 0.03543757
##  method   Intercept 0.19217437 0.03693099
```

```
rms::vif(coxme_rh_s2)
```

```
##    minrh    maxrh   mwimin    mwime   mwimax
## 2.104826 2.024723 1.935831 1.818998 1.175780
```

```
coxme_rh_s3<- coxme(Surv(total_lived, censored) ~ minrh + maxrh + mwimin + mwimax  +
                  (1|location) + (1|method), data= new_df_gdd)
coxme_rh_s3
```

```
## Cox mixed-effects model fit by maximum likelihood
##   Data: new_df_gdd
##   events, n = 14542, 15155
##   Iterations= 8 35
##                     NULL Integrated    Fitted
## Log-likelihood -125304.4  -125024.1 -125017.8
##
##                    Chisq   df p    AIC    BIC
## Integrated loglik 560.57 6.00 0 548.57 503.06
##  Penalized loglik 573.31 5.99 0 561.33 515.90
##
## Model:  Surv(total_lived, censored) ~ minrh + maxrh + mwimin + mwimax +      (1 | location) + (1 | m
## Fixed coefficients
##                coef exp(coef)     se(coef)     z       p
## minrh  -0.007279382 0.9927470 0.0008918036 -8.16 3.3e-16
```

```
## maxrh  -0.002865454 0.9971386 0.0013005723 -2.20 2.8e-02
## mwimin  0.132958431 1.1422025 0.0307176769  4.33 1.5e-05
## mwimax -0.176561049 0.8381476 0.0251305886 -7.03 2.1e-12
##
## Random effects
##  Group    Variable  Std Dev    Variance
##  location Intercept 0.18167954 0.03300745
##  method   Intercept 0.19113349 0.03653201
```

```
#Random effects - Together
coxme_rh_t<- coxme(Surv(total_lived, censored) ~ minrh + meanrh
                  + maxrh + mwimin + mwime + mwimax  +
                   (1|location/method), data= new_df_gdd)

summary(coxme_rh_t)
```

```
## Cox mixed-effects model fit by maximum likelihood
##   Data: new_df_gdd
##   events, n = 14542, 15155
##   Iterations= 8 35
##                     NULL Integrated    Fitted
## Log-likelihood -125304.4    -125016 -125007.2
##
##                    Chisq   df p    AIC    BIC
## Integrated loglik 576.85 8.00 0 560.85 500.17
##  Penalized loglik 594.53 8.97 0 576.59 508.53
##
## Model:  Surv(total_lived, censored) ~ minrh + meanrh + maxrh + mwimin +      mwime + mwimax + (1 | l
## Fixed coefficients
##                 coef exp(coef)    se(coef)     z       p
## minrh  -0.0022999644 0.9977027 0.002742011 -0.84 4.0e-01
## meanrh -0.0079750203 0.9920567 0.004973639 -1.60 1.1e-01
## maxrh  -0.0002894222 0.9997106 0.002779247 -0.10 9.2e-01
## mwimin  0.0439445701 1.0449244 0.040044404  1.10 2.7e-01
## mwime   0.1212331098 1.1288880 0.034042166  3.56 3.7e-04
## mwimax -0.2031542469 0.8161523 0.025994780 -7.82 5.4e-15
##
## Random effects
##  Group           Variable    Std Dev      Variance
##  location/method (Intercept) 0.2094724133 0.0438786919
##  location        (Intercept) 0.0200276249 0.0004011058
```

```
rms::vif(coxme_rh_t)
```

```
##     minrh    meanrh     maxrh    mwimin     mwime    mwimax
## 18.496728 37.970080  8.576253  1.944128  1.835882  1.178351
```

```
#meanrh has a lot of collinearity so we should remove it and do it again
coxme_rh_t2<- coxme(Surv(total_lived, censored) ~ minrh + maxrh + mwimin + mwime + mwimax  +
                   (1|location/method), data= new_df_gdd)

summary(coxme_rh_t2)
```

```
## Cox mixed-effects model fit by maximum likelihood
##   Data: new_df_gdd
##   events, n = 14542, 15155
##   Iterations= 8 35
##                     NULL Integrated    Fitted
## Log-likelihood -125304.4  -125017.3 -125008.4
##
##                    Chisq   df p    AIC    BIC
## Integrated loglik 574.28 7.00 0 560.28 507.19
##  Penalized loglik 592.04 7.97 0 576.09 515.61
##
## Model:  Surv(total_lived, censored) ~ minrh + maxrh + mwimin + mwime +      mwimax + (1 | location/m
## Fixed coefficients
##                coef exp(coef)     se(coef)     z       p
## minrh  -0.006433766 0.9935869 0.0009254865 -6.95 3.6e-12
## maxrh  -0.004191940 0.9958168 0.0013490414 -3.11 1.9e-03
## mwimin  0.045684719 1.0467443 0.0399425027  1.14 2.5e-01
## mwime   0.116946023 1.1240588 0.0338738784  3.45 5.6e-04
## mwimax -0.202054055 0.8170508 0.0259845349 -7.78 7.4e-15
##
## Random effects
##  Group           Variable    Std Dev      Variance
##  location/method (Intercept) 0.2121366569 0.0450019612
##  location        (Intercept) 0.0200365192 0.0004014621
```

```
rms::vif(coxme_rh_t2)
```

```
##    minrh    maxrh   mwimin    mwime   mwimax
## 2.105568 2.024987 1.934368 1.815834 1.176184
```

```
coxme_rh_t3<- coxme(Surv(total_lived, censored) ~ minrh + maxrh + mwimin  + mwimax  +
                  (1|location/method), data= new_df_gdd)
coxme_rh_t3
```

```
## Cox mixed-effects model fit by maximum likelihood
##   Data: new_df_gdd
##   events, n = 14542, 15155
##   Iterations= 8 35
##                     NULL Integrated    Fitted
## Log-likelihood -125304.4  -125023.3 -125014.5
##
##                    Chisq   df p    AIC    BIC
## Integrated loglik 562.22 6.00 0 550.22 504.71
##  Penalized loglik 579.86 6.97 0 565.91 513.02
##
## Model:  Surv(total_lived, censored) ~ minrh + maxrh + mwimin + mwimax +      (1 | location/method)
## Fixed coefficients
##                coef exp(coef)     se(coef)     z       p
## minrh  -0.007261308 0.9927650 0.0008917601 -8.14 3.3e-16
## maxrh  -0.002975107 0.9970293 0.0013011818 -2.29 2.2e-02
## mwimin  0.132662452 1.1418645 0.0307220811  4.32 1.6e-05
## mwimax -0.179173658 0.8359607 0.0251504298 -7.12 1.0e-12
##
```

```
## Random effects
##  Group           Variable    Std Dev      Variance
##  location/method (Intercept) 0.2079554154 0.0432454548
##  location        (Intercept) 0.0200250775 0.0004010037
```

Photoperiod

```
# No random effect
cox_pho<- coxph(Surv(total_lived, censored) ~ photoperiod,
                  data= new_df_gdd)

summary(cox_pho)
```

```
## Call:
## coxph(formula = Surv(total_lived, censored) ~ photoperiod, data = new_df_gdd)
##
##   n= 15155, number of events= 14542
##
##                coef exp(coef) se(coef)     z Pr(>|z|)
## photoperiod 0.15647   1.16938  0.00676 23.15   <2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
##             exp(coef) exp(-coef) lower .95 upper .95
## photoperiod     1.169     0.8552     1.154     1.185
##
## Concordance= 0.559  (se = 0.003 )
## Likelihood ratio test= 545.3  on 1 df,   p=<2e-16
## Wald test            = 535.8  on 1 df,   p=<2e-16
## Score (logrank) test = 533  on 1 df,   p=<2e-16
```

```
#Random effect - separated
coxme_pho_s<- coxme(Surv(total_lived, censored) ~ photoperiod +
                    (1|location) + (1|method), data= new_df_gdd)
summary(coxme_pho_s)
```

```
## Cox mixed-effects model fit by maximum likelihood
##   Data: new_df_gdd
##   events, n = 14542, 15155
##   Iterations= 7 31
##                     NULL Integrated  Fitted
## Log-likelihood -125304.4  -124884.9 -124879
##
##                    Chisq   df p    AIC    BIC
## Integrated loglik 839.04 3.00 0 833.04 810.29
##  Penalized loglik 850.96 2.99 0 844.99 822.35
##
## Model:  Surv(total_lived, censored) ~ photoperiod + (1 | location) +      (1 | method)
## Fixed coefficients
##                   coef exp(coef)    se(coef)     z p
## photoperiod 0.1432802  1.154053 0.006829712 20.98 0
```

```
##
## Random effects
##  Group    Variable  Std Dev    Variance
##  location Intercept 0.12068818 0.01456564
##  method   Intercept 0.18977992 0.03601642
```

```
#Random effect - together
coxme_pho_t<- coxme(Surv(total_lived, censored) ~ photoperiod +
                  (1|location/method), data= new_df_gdd)

summary(coxme_pho_t)
```

```
## Cox mixed-effects model fit by maximum likelihood
##   Data: new_df_gdd
##   events, n = 14542, 15155
##   Iterations= 9 39
##                     NULL Integrated    Fitted
## Log-likelihood -125304.4    -124884 -124875.6
##
##                    Chisq   df p    AIC    BIC
## Integrated loglik 840.87 3.00 0 834.87 812.11
##  Penalized loglik 857.68 3.97 0 849.75 819.65
##
## Model:  Surv(total_lived, censored) ~ photoperiod + (1 | location/method)
## Fixed coefficients
##                  coef exp(coef)    se(coef)     z p
## photoperiod 0.1438158  1.154671 0.006842644 21.02 0
##
## Random effects
##  Group           Variable    Std Dev      Variance
##  location/method (Intercept) 0.1811550683 0.0328171588
##  location        (Intercept) 0.0198150319 0.0003926355
```

Complete models, adding all variables

```
#No random effect

coxph_allv<- coxph(Surv(total_lived, censored) ~ photoperiod + minrh + meanrh +
                  maxrh + mintemperature + meantemperature + maxtemperature +
                  mwimin + mwimax + daily_acc_gdd +location + method, data= new_df_gdd)

summary(coxph_allv)
```

```
## Call:
## coxph(formula = Surv(total_lived, censored) ~ photoperiod + minrh +
##     meanrh + maxrh + mintemperature + meantemperature + maxtemperature +
##     mwimin + mwimax + daily_acc_gdd + location + method, data = new_df_gdd)
##
##   n= 15154, number of events= 14541
##    (1 observation deleted due to missingness)
##
```

```
##                       coef  exp(coef)   se(coef)      z Pr(>|z|)
## photoperiod      0.1906794  1.2100714  0.0153200 12.446  < 2e-16 ***
## minrh            0.0052923  1.0053063  0.0029442  1.797 0.072257 .
## meanrh          -0.0096410  0.9904054  0.0052477 -1.837 0.066181 .
## maxrh            0.0004344  1.0004345  0.0029496  0.147 0.882916
## mintemperature   0.0511587  1.0524899  0.0208027  2.459 0.013924 *
## meantemperature  0.0361044  1.0367641  0.0266779  1.353 0.175946
## maxtemperature   0.0725365  1.0752321  0.0215929  3.359 0.000781 ***
## mwimin          -0.2238359  0.7994464  0.0424768 -5.270 1.37e-07 ***
## mwimax          -0.1727860  0.8413177  0.0256793 -6.729 1.71e-11 ***
## daily_acc_gdd   -0.1794742  0.8357095  0.0332042 -5.405 6.48e-08 ***
## locationUrban   -0.1805325  0.8348255  0.0224977 -8.024 1.02e-15 ***
## methodBG         0.2573507  1.2934987  0.0188582 13.647  < 2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
##                 exp(coef) exp(-coef) lower .95 upper .95
## photoperiod        1.2101     0.8264    1.1743    1.2470
## minrh              1.0053     0.9947    0.9995    1.0111
## meanrh             0.9904     1.0097    0.9803    1.0006
## maxrh              1.0004     0.9996    0.9947    1.0062
## mintemperature     1.0525     0.9501    1.0104    1.0963
## meantemperature    1.0368     0.9645    0.9839    1.0924
## maxtemperature     1.0752     0.9300    1.0307    1.1217
## mwimin             0.7994     1.2509    0.7356    0.8689
## mwimax             0.8413     1.1886    0.8000    0.8847
## daily_acc_gdd      0.8357     1.1966    0.7831    0.8919
## locationUrban      0.8348     1.1979    0.7988    0.8725
## methodBG           1.2935     0.7731    1.2466    1.3422
##
## Concordance= 0.594  (se = 0.003 )
## Likelihood ratio test= 1057  on 12 df,   p=<2e-16
## Wald test            = 1087  on 12 df,   p=<2e-16
## Score (logrank) test = 1085  on 12 df,   p=<2e-16
```

```
rms::vif(coxph_allv) #gdd and meant with high vif
```

```
##     photoperiod           minrh          meanrh           maxrh  mintemperature
##        5.501676       25.347756       47.008089        9.996244       98.821174
## meantemperature  maxtemperature          mwimin          mwimax   daily_acc_gdd
##      153.526652      109.607534        2.304056        1.333834      214.036271
##   locationUrban        methodBG
##        1.768127        1.005939
```

```
cox_allv2<- coxph(Surv(total_lived, censored) ~ photoperiod + minrh + meanrh +
                  maxrh + mintemperature  + maxtemperature +
                  mwimin + mwimax + meantemperature+ location + method, data= new_df_gdd)

summary(cox_allv2)
```

```
## Call:
## coxph(formula = Surv(total_lived, censored) ~ photoperiod + minrh +
##     meanrh + maxrh + mintemperature + maxtemperature + mwimin +
```

```
##     mwimax + meantemperature + location + method, data = new_df_gdd)
##
##   n= 15155, number of events= 14542
##
##                      coef exp(coef)  se(coef)      z Pr(>|z|)
## photoperiod      0.191019  1.210482  0.015345 12.448  < 2e-16 ***
## minrh            0.005897  1.005914  0.002924  2.016   0.0438 *
## meanrh          -0.011137  0.988925  0.005206 -2.139   0.0324 *
## maxrh            0.002604  1.002607  0.002909  0.895   0.3707
## mintemperature  -0.034009  0.966563  0.013392 -2.539   0.0111 *
## maxtemperature  -0.015903  0.984223  0.014301 -1.112   0.2661
## mwimin          -0.294252  0.745089  0.040049 -7.347 2.02e-13 ***
## mwimax          -0.155100  0.856330  0.025557 -6.069 1.29e-09 ***
## meantemperature  0.040306  1.041129  0.026696  1.510   0.1311
## locationUrban   -0.188302  0.828364  0.022543 -8.353  < 2e-16 ***
## methodBG         0.256845  1.292845  0.018857 13.621  < 2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
##                 exp(coef) exp(-coef) lower .95 upper .95
## photoperiod        1.2105     0.8261    1.1746    1.2474
## minrh              1.0059     0.9941    1.0002    1.0117
## meanrh             0.9889     1.0112    0.9789    0.9991
## maxrh              1.0026     0.9974    0.9969    1.0083
## mintemperature     0.9666     1.0346    0.9415    0.9923
## maxtemperature     0.9842     1.0160    0.9570    1.0122
## mwimin             0.7451     1.3421    0.6888    0.8059
## mwimax             0.8563     1.1678    0.8145    0.9003
## meantemperature    1.0411     0.9605    0.9881    1.0971
## locationUrban      0.8284     1.2072    0.7926    0.8658
## methodBG           1.2928     0.7735    1.2459    1.3415
##
## Concordance= 0.592  (se = 0.003 )
## Likelihood ratio test= 1025  on 11 df,   p=<2e-16
## Wald test            = 1050  on 11 df,   p=<2e-16
## Score (logrank) test = 1049  on 11 df,   p=<2e-16
```

```
rms::vif(cox_allv2) #meant with high vif
```

```
##     photoperiod           minrh          meanrh           maxrh  mintemperature
##        5.523461       25.260099       46.631211        9.743359       42.323823
##  maxtemperature          mwimin          mwimax meantemperature   locationUrban
##       47.780199        2.045632        1.316528      156.116715        1.775538
##        methodBG
##        1.005864
```

```
cox_allv3<- coxph(Surv(total_lived, censored) ~ photoperiod + minrh  + meanrh +
                  maxrh + mintemperature  + maxtemperature +
                  mwimin + mwimax +location + method, data= new_df_gdd)
summary(cox_allv3)
```

```
## Call:
## coxph(formula = Surv(total_lived, censored) ~ photoperiod + minrh +
```

```
##     meanrh + maxrh + mintemperature + maxtemperature + mwimin +
##     mwimax + location + method, data = new_df_gdd)
##
##   n= 15155, number of events= 14542
##
##                     coef exp(coef)  se(coef)      z Pr(>|z|)
## photoperiod     0.197847  1.218775  0.014676 13.481  < 2e-16 ***
## minrh           0.006381  1.006401  0.002905  2.196  0.02806 *
## meanrh         -0.011557  0.988509  0.005196 -2.224  0.02612 *
## maxrh           0.002960  1.002964  0.002898  1.021  0.30715
## mintemperature -0.015366  0.984752  0.005209 -2.950  0.00318 **
## maxtemperature  0.004129  1.004138  0.005331  0.775  0.43859
## mwimin         -0.291293  0.747296  0.039992 -7.284 3.24e-13 ***
## mwimax         -0.153180  0.857976  0.025545 -5.996 2.02e-09 ***
## locationUrban  -0.192770  0.824672  0.022347 -8.626  < 2e-16 ***
## methodBG        0.256598  1.292525  0.018856 13.608  < 2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
##                exp(coef) exp(-coef) lower .95 upper .95
## photoperiod       1.2188     0.8205    1.1842    1.2543
## minrh             1.0064     0.9936    1.0007    1.0121
## meanrh            0.9885     1.0116    0.9785    0.9986
## maxrh             1.0030     0.9970    0.9973    1.0087
## mintemperature    0.9848     1.0155    0.9747    0.9949
## maxtemperature    1.0041     0.9959    0.9937    1.0147
## mwimin            0.7473     1.3382    0.6910    0.8082
## mwimax            0.8580     1.1655    0.8161    0.9020
## locationUrban     0.8247     1.2126    0.7893    0.8616
## methodBG          1.2925     0.7737    1.2456    1.3412
##
## Concordance= 0.592  (se = 0.003 )
## Likelihood ratio test= 1023  on 10 df,   p=<2e-16
## Wald test            = 1047  on 10 df,   p=<2e-16
## Score (logrank) test = 1045  on 10 df,   p=<2e-16
```

```
rms::vif(cox_allv3) #meanrh with high vif
```

```
##    photoperiod          minrh         meanrh          maxrh mintemperature
##       5.045235      24.961279      46.481892       9.678595       6.402543
## maxtemperature         mwimin         mwimax  locationUrban       methodBG
##       6.629356       2.041007       1.314909       1.744838       1.005766
```

```
cox_allv4<- coxph(Surv(total_lived, censored) ~ photoperiod + minrh  +
                  maxrh   + mintemperature +
                  mwimin + mwimax +  maxtemperature + location + method, data= new_df_gdd)
summary(cox_allv4)
```

```
## Call:
## coxph(formula = Surv(total_lived, censored) ~ photoperiod + minrh +
##     maxrh + mintemperature + mwimin + mwimax + maxtemperature +
##     location + method, data = new_df_gdd)
##
```

```
##   n= 15155, number of events= 14542
##
##                      coef  exp(coef)   se(coef)      z Pr(>|z|)
## photoperiod     0.2004713  1.2219785  0.0146208 13.711  < 2e-16 ***
## minrh           0.0003504  1.0003505  0.0010319  0.340  0.73418
## maxrh          -0.0027321  0.9972717  0.0013686 -1.996  0.04590 *
## mintemperature -0.0142210  0.9858797  0.0051887 -2.741  0.00613 **
## mwimin         -0.2925570  0.7463527  0.0400157 -7.311 2.65e-13 ***
## mwimax         -0.1536004  0.8576147  0.0255384 -6.014 1.80e-09 ***
## maxtemperature  0.0019605  1.0019625  0.0052352  0.374  0.70804
## locationUrban  -0.1988404  0.8196807  0.0222054 -8.955  < 2e-16 ***
## methodBG        0.2572753  1.2934011  0.0188530 13.646  < 2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
##                exp(coef) exp(-coef) lower .95 upper .95
## photoperiod       1.2220     0.8183    1.1875    1.2575
## minrh             1.0004     0.9996    0.9983    1.0024
## maxrh             0.9973     1.0027    0.9946    1.0000
## mintemperature    0.9859     1.0143    0.9759    0.9960
## mwimin            0.7464     1.3398    0.6901    0.8072
## mwimax            0.8576     1.1660    0.8157    0.9016
## maxtemperature    1.0020     0.9980    0.9917    1.0123
## locationUrban     0.8197     1.2200    0.7848    0.8561
## methodBG          1.2934     0.7732    1.2465    1.3421
##
## Concordance= 0.592  (se = 0.003 )
## Likelihood ratio test= 1018  on 9 df,   p=<2e-16
## Wald test            = 1041  on 9 df,   p=<2e-16
## Score (logrank) test = 1038  on 9 df,   p=<2e-16
```

```
rms::vif(cox_allv4)
```

```
##    photoperiod          minrh          maxrh mintemperature         mwimin
##       4.995515       3.143992       2.165525       6.339214       2.041679
##         mwimax maxtemperature  locationUrban       methodBG
##       1.314570       6.389881       1.722815       1.005464
```

```
stats::step(cox_allv4) #with function step, maxtemperature is removed
```

```
## Start:  AIC=249608.6
## Surv(total_lived, censored) ~ photoperiod + minrh + maxrh + mintemperature +
##     mwimin + mwimax + maxtemperature + location + method
##
##                   Df    AIC
## - minrh            1 249607
## - maxtemperature   1 249607
## <none>               249609
## - maxrh            1 249611
## - mintemperature   1 249614
## - mwimax           1 249643
## - mwimin           1 249659
## - location         1 249687
```

```
## - photoperiod     1 249794
## - method          1 249800
##
## Step:  AIC=249606.7
## Surv(total_lived, censored) ~ photoperiod + maxrh + mintemperature +
##     mwimin + mwimax + maxtemperature + location + method
##
##                  Df    AIC
## - maxtemperature  1 249605
## <none>              249607
## - maxrh           1 249610
## - mintemperature  1 249613
## - mwimax          1 249642
## - mwimin          1 249659
## - location        1 249686
## - method          1 249798
## - photoperiod     1 249806
##
## Step:  AIC=249604.8
## Surv(total_lived, censored) ~ photoperiod + maxrh + mintemperature +
##     mwimin + mwimax + location + method
##
##                  Df    AIC
## <none>              249605
## - maxrh           1 249608
## - mintemperature  1 249613
## - mwimax          1 249640
## - mwimin          1 249658
## - location        1 249706
## - method          1 249796
## - photoperiod     1 249935

## Call:
## coxph(formula = Surv(total_lived, censored) ~ photoperiod + maxrh +
##     mintemperature + mwimin + mwimax + location + method, data = new_df_gdd)
##
##                      coef exp(coef)  se(coef)       z        p
## photoperiod     0.201714  1.223498  0.011010  18.321  < 2e-16
## maxrh          -0.002423  0.997580  0.001099  -2.205   0.0275
## mintemperature -0.012703  0.987377  0.003950  -3.216   0.0013
## mwimin         -0.291592  0.747073  0.038981  -7.480 7.42e-14
## mwimax         -0.154265  0.857045  0.025428  -6.067 1.31e-09
## locationUrban  -0.196218  0.821833  0.019257 -10.189  < 2e-16
## methodBG        0.257290  1.293420  0.018853  13.647  < 2e-16
##
## Likelihood ratio test=1018  on 7 df, p=< 2.2e-16
## n= 15155, number of events= 14542
```

```
cox_allv5<- coxph(Surv(total_lived, censored) ~ photoperiod +  mintemperature +
                    maxrh + mwimin+ mwimax + location + method, data= new_df_gdd)
summary(cox_allv5) #now we know that the parameters with collinearity have been
```

```
## Call:
```

```
## coxph(formula = Surv(total_lived, censored) ~ photoperiod + mintemperature +
##     maxrh + mwimin + mwimax + location + method, data = new_df_gdd)
##
##   n= 15155, number of events= 14542
##
##                     coef exp(coef)  se(coef)       z Pr(>|z|)
## photoperiod     0.201714  1.223498  0.011010  18.321  < 2e-16 ***
## mintemperature -0.012703  0.987377  0.003950  -3.216   0.0013 **
## maxrh          -0.002423  0.997580  0.001099  -2.205   0.0275 *
## mwimin         -0.291592  0.747073  0.038981  -7.480 7.42e-14 ***
## mwimax         -0.154265  0.857045  0.025428  -6.067 1.31e-09 ***
## locationUrban  -0.196218  0.821833  0.019257 -10.189  < 2e-16 ***
## methodBG        0.257290  1.293420  0.018853  13.647  < 2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
##                exp(coef) exp(-coef) lower .95 upper .95
## photoperiod       1.2235     0.8173    1.1974    1.2502
## mintemperature    0.9874     1.0128    0.9798    0.9951
## maxrh             0.9976     1.0024    0.9954    0.9997
## mwimin            0.7471     1.3386    0.6921    0.8064
## mwimax            0.8570     1.1668    0.8154    0.9008
## locationUrban     0.8218     1.2168    0.7914    0.8534
## methodBG          1.2934     0.7731    1.2465    1.3421
##
## Concordance= 0.592  (se = 0.003 )
## Likelihood ratio test= 1018  on 7 df,   p=<2e-16
## Wald test            = 1040  on 7 df,   p=<2e-16
## Score (logrank) test = 1034  on 7 df,   p=<2e-16
```

```
#removed. Let's find the best model!
coxph_2<- coxph(Surv(total_lived, censored) ~ photoperiod + mwimin  +
                    mwimax  + location + method,
                    data= new_df_gdd)
summary(coxph_2)
```

```
## Call:
## coxph(formula = Surv(total_lived, censored) ~ photoperiod + mwimin +
##     mwimax + location + method, data = new_df_gdd)
##
##   n= 15155, number of events= 14542
##
##                    coef exp(coef) se(coef)       z Pr(>|z|)
## photoperiod    0.18344   1.20135  0.00753  24.363  < 2e-16 ***
## mwimin        -0.37504   0.68727  0.03300 -11.365  < 2e-16 ***
## mwimax        -0.13644   0.87246  0.02421  -5.635 1.75e-08 ***
## locationUrban -0.17883   0.83625  0.01880  -9.511  < 2e-16 ***
## methodBG       0.25850   1.29499  0.01885  13.714  < 2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
##               exp(coef) exp(-coef) lower .95 upper .95
## photoperiod      1.2013     0.8324    1.1837    1.2192
## mwimin           0.6873     1.4550    0.6442    0.7332
```

```
## mwimax           0.8725     1.1462    0.8320    0.9149
## locationUrban    0.8363     1.1958    0.8060    0.8676
## methodBG         1.2950     0.7722    1.2480    1.3437
##
## Concordance= 0.593  (se = 0.003 )
## Likelihood ratio test= 1001  on 5 df,   p=<2e-16
## Wald test            = 1018  on 5 df,   p=<2e-16
## Score (logrank) test = 1015  on 5 df,   p=<2e-16
```

```
coxph_3<- coxph(Surv(total_lived, censored) ~ photoperiod +  mwimin +
                    + location + method,
                     data= new_df_gdd)
summary(coxph_3)
```

```
## Call:
## coxph(formula = Surv(total_lived, censored) ~ photoperiod + mwimin +
##     +location + method, data = new_df_gdd)
##
##   n= 15155, number of events= 14542
##
##                    coef exp(coef)  se(coef)      z Pr(>|z|)
## photoperiod    0.181945  1.199548  0.007593  23.96   <2e-16 ***
## mwimin        -0.356819  0.699899  0.033031 -10.80   <2e-16 ***
## locationUrban -0.216570  0.805276  0.017617 -12.29   <2e-16 ***
## methodBG       0.264166  1.302344  0.018819  14.04   <2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
##               exp(coef) exp(-coef) lower .95 upper .95
## photoperiod      1.1995     0.8336    1.1818    1.2175
## mwimin           0.6999     1.4288    0.6560    0.7467
## locationUrban    0.8053     1.2418    0.7779    0.8336
## methodBG         1.3023     0.7678    1.2552    1.3513
##
## Concordance= 0.593  (se = 0.003 )
## Likelihood ratio test= 969.1  on 4 df,   p=<2e-16
## Wald test            = 979.1  on 4 df,   p=<2e-16
## Score (logrank) test = 976.1  on 4 df,   p=<2e-16
```

```
coxph_4<- coxph(Surv(total_lived, censored) ~ photoperiod + mwimax +
                    + location + method,
                     data= new_df_gdd)
summary(coxph_4)
```

```
## Call:
## coxph(formula = Surv(total_lived, censored) ~ photoperiod + mwimax +
##     +location + method, data = new_df_gdd)
##
##   n= 15155, number of events= 14542
##
##                    coef exp(coef)  se(coef)      z Pr(>|z|)
## photoperiod    0.142976  1.153702  0.006795 21.042  < 2e-16 ***
## mwimax        -0.106032  0.899396  0.024014 -4.415 1.01e-05 ***
```

```
## locationUrban -0.138441  0.870715  0.018516 -7.477 7.61e-14 ***
## methodBG       0.265714  1.304361  0.018829 14.112  < 2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
##               exp(coef) exp(-coef) lower .95 upper .95
## photoperiod      1.1537     0.8668    1.1384    1.1692
## mwimax           0.8994     1.1119    0.8580    0.9427
## locationUrban    0.8707     1.1485    0.8397    0.9029
## methodBG         1.3044     0.7667    1.2571    1.3534
##
## Concordance= 0.589  (se = 0.003 )
## Likelihood ratio test= 870.6  on 4 df,   p=<2e-16
## Wald test            = 856  on 4 df,   p=<2e-16
## Score (logrank) test = 858.1  on 4 df,   p=<2e-16
```

```
coxph_5<- coxph(Surv(total_lived, censored) ~ photoperiod + mintemperature
                  + minrh +  location + method,
                     data= new_df_gdd)
summary(coxph_5)
```

```
## Call:
## coxph(formula = Surv(total_lived, censored) ~ photoperiod + mintemperature +
##     minrh + location + method, data = new_df_gdd)
##
##   n= 15155, number of events= 14542
##
##                      coef  exp(coef)   se(coef)       z Pr(>|z|)
## photoperiod     0.1984012  1.2194516  0.0124192  15.975  < 2e-16 ***
## mintemperature -0.0247420  0.9755615  0.0039844  -6.210 5.31e-10 ***
## minrh          -0.0016500  0.9983513  0.0007686  -2.147   0.0318 *
## locationUrban  -0.2282029  0.7959627  0.0191163 -11.938  < 2e-16 ***
## methodBG        0.2656275  1.3042492  0.0188157  14.117  < 2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
##                exp(coef) exp(-coef) lower .95 upper .95
## photoperiod       1.2195     0.8200    1.1901    1.2495
## mintemperature    0.9756     1.0251    0.9680    0.9832
## minrh             0.9984     1.0017    0.9968    0.9999
## locationUrban     0.7960     1.2563    0.7667    0.8264
## methodBG          1.3042     0.7667    1.2570    1.3532
##
## Concordance= 0.59  (se = 0.003 )
## Likelihood ratio test= 926.5  on 5 df,   p=<2e-16
## Wald test            = 930.1  on 5 df,   p=<2e-16
## Score (logrank) test = 923.4  on 5 df,   p=<2e-16
```

```
coxph_6<- coxph(Surv(total_lived, censored) ~ photoperiod + mintemperature
                  + maxrh +  location + method,
                     data= new_df_gdd)
summary(coxph_6)
```

```
## Call:
## coxph(formula = Surv(total_lived, censored) ~ photoperiod + mintemperature +
##     maxrh + location + method, data = new_df_gdd)
##
##   n= 15155, number of events= 14542
##
##                     coef exp(coef)  se(coef)       z Pr(>|z|)
## photoperiod     0.204765  1.227236  0.011125  18.406  < 2e-16 ***
## mintemperature -0.026964  0.973396  0.003565  -7.563 3.94e-14 ***
## maxrh          -0.002319  0.997684  0.001026  -2.260   0.0238 *
## locationUrban  -0.223065  0.800063  0.018394 -12.127  < 2e-16 ***
## methodBG        0.265906  1.304612  0.018817  14.132  < 2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
##                exp(coef) exp(-coef) lower .95 upper .95
## photoperiod       1.2272     0.8148    1.2008    1.2543
## mintemperature    0.9734     1.0273    0.9666    0.9802
## maxrh             0.9977     1.0023    0.9957    0.9997
## locationUrban     0.8001     1.2499    0.7717    0.8294
## methodBG          1.3046     0.7665    1.2574    1.3536
##
## Concordance= 0.59  (se = 0.003 )
## Likelihood ratio test= 926.9  on 5 df,   p=<2e-16
## Wald test            = 930.9  on 5 df,   p=<2e-16
## Score (logrank) test = 923.5  on 5 df,   p=<2e-16
```

```
coxph_7<- coxph(Surv(total_lived, censored) ~ photoperiod + mintemperature
                + maxrh + minrh +  location + method,
                   data= new_df_gdd)
summary(coxph_7)
```

```
## Call:
## coxph(formula = Surv(total_lived, censored) ~ photoperiod + mintemperature +
##     maxrh + minrh + location + method, data = new_df_gdd)
##
##   n= 15155, number of events= 14542
##
##                      coef  exp(coef)   se(coef)       z Pr(>|z|)
## photoperiod     0.1994671  1.2207520  0.0124537  16.017  < 2e-16 ***
## mintemperature -0.0252326  0.9750831  0.0040069  -6.297 3.03e-10 ***
## maxrh          -0.0015369  0.9984643  0.0013164  -1.167    0.243
## minrh          -0.0009336  0.9990669  0.0009850  -0.948    0.343
## locationUrban  -0.2280341  0.7960971  0.0191182 -11.928  < 2e-16 ***
## methodBG        0.2658586  1.3045506  0.0188167  14.129  < 2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
##                exp(coef) exp(-coef) lower .95 upper .95
## photoperiod       1.2208     0.8192    1.1913    1.2509
## mintemperature    0.9751     1.0256    0.9675    0.9828
## maxrh             0.9985     1.0015    0.9959    1.0010
## minrh             0.9991     1.0009    0.9971    1.0010
## locationUrban     0.7961     1.2561    0.7668    0.8265
```

```
## methodBG          1.3046     0.7665    1.2573    1.3536
##
## Concordance= 0.59  (se = 0.003 )
## Likelihood ratio test= 927.8  on 6 df,   p=<2e-16
## Wald test            = 932  on 6 df,   p=<2e-16
## Score (logrank) test = 925.4  on 6 df,   p=<2e-16
```

```
coxph_8<- coxph(Surv(total_lived, censored) ~ photoperiod + daily_acc_gdd +
                minrh + location + method,
                    data= new_df_gdd)
summary(coxph_8)
```

```
## Call:
## coxph(formula = Surv(total_lived, censored) ~ photoperiod + daily_acc_gdd +
##     minrh + location + method, data = new_df_gdd)
##
##   n= 15154, number of events= 14541
##    (1 observation deleted due to missingness)
##
##                      coef  exp(coef)   se(coef)       z Pr(>|z|)
## photoperiod    0.2117265  1.2358099  0.0142287  14.880  < 2e-16 ***
## daily_acc_gdd -0.0298312  0.9706094  0.0047996  -6.215 5.12e-10 ***
## minrh         -0.0022731  0.9977294  0.0007215  -3.151  0.00163 **
## locationUrban -0.1985510  0.8199179  0.0193388 -10.267  < 2e-16 ***
## methodBG       0.2665397  1.3054394  0.0188128  14.168  < 2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
##               exp(coef) exp(-coef) lower .95 upper .95
## photoperiod      1.2358     0.8092    1.2018    1.2708
## daily_acc_gdd    0.9706     1.0303    0.9615    0.9798
## minrh            0.9977     1.0023    0.9963    0.9991
## locationUrban    0.8199     1.2196    0.7894    0.8516
## methodBG         1.3054     0.7660    1.2582    1.3545
##
## Concordance= 0.591  (se = 0.003 )
## Likelihood ratio test= 926.8  on 5 df,   p=<2e-16
## Wald test            = 927.1  on 5 df,   p=<2e-16
## Score (logrank) test = 919.8  on 5 df,   p=<2e-16
```

```
coxph_9<- coxph(Surv(total_lived, censored) ~ photoperiod + daily_acc_gdd +
                maxrh + location + method,
                    data= new_df_gdd)
summary(coxph_9)
```

```
## Call:
## coxph(formula = Surv(total_lived, censored) ~ photoperiod + daily_acc_gdd +
##     maxrh + location + method, data = new_df_gdd)
##
##   n= 15154, number of events= 14541
##    (1 observation deleted due to missingness)
##
##                     coef exp(coef)  se(coef)       z Pr(>|z|)
```

```
## photoperiod    0.221744  1.248251  0.013367  16.588  < 2e-16 ***
## daily_acc_gdd -0.033013  0.967526  0.004551  -7.255 4.02e-13 ***
## maxrh         -0.002494  0.997509  0.001020  -2.446   0.0145 *
## locationUrban -0.183340  0.832485  0.017959 -10.209  < 2e-16 ***
## methodBG       0.267027  1.306076  0.018814  14.193  < 2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
##               exp(coef) exp(-coef) lower .95 upper .95
## photoperiod      1.2483     0.8011    1.2160    1.2814
## daily_acc_gdd    0.9675     1.0336    0.9589    0.9762
## maxrh            0.9975     1.0025    0.9955    0.9995
## locationUrban    0.8325     1.2012    0.8037    0.8623
## methodBG         1.3061     0.7657    1.2588    1.3551
##
## Concordance= 0.59  (se = 0.003 )
## Likelihood ratio test= 922.8  on 5 df,   p=<2e-16
## Wald test            = 922.2  on 5 df,   p=<2e-16
## Score (logrank) test = 913.7  on 5 df,   p=<2e-16
```

```
coxph_10<- coxph(Surv(total_lived, censored) ~ photoperiod + daily_acc_gdd +
                 maxrh + minrh+ location + method,
                     data= new_df_gdd)
summary(coxph_10)
```

```
## Call:
## coxph(formula = Surv(total_lived, censored) ~ photoperiod + daily_acc_gdd +
##     maxrh + minrh + location + method, data = new_df_gdd)
##
##   n= 15154, number of events= 14541
##    (1 observation deleted due to missingness)
##
##                      coef  exp(coef)   se(coef)       z Pr(>|z|)
## photoperiod    0.2117368  1.2358225  0.0142303  14.879  < 2e-16 ***
## daily_acc_gdd -0.0298809  0.9705611  0.0048014  -6.223 4.87e-10 ***
## maxrh         -0.0007886  0.9992117  0.0013067  -0.604   0.5462
## minrh         -0.0019266  0.9980753  0.0009229  -2.088   0.0368 *
## locationUrban -0.1983560  0.8200779  0.0193424 -10.255  < 2e-16 ***
## methodBG       0.2666880  1.3056330  0.0188144  14.175  < 2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
##               exp(coef) exp(-coef) lower .95 upper .95
## photoperiod      1.2358     0.8092    1.2018    1.2708
## daily_acc_gdd    0.9706     1.0303    0.9615    0.9797
## maxrh            0.9992     1.0008    0.9967    1.0018
## minrh            0.9981     1.0019    0.9963    0.9999
## locationUrban    0.8201     1.2194    0.7896    0.8518
## methodBG         1.3056     0.7659    1.2584    1.3547
##
## Concordance= 0.591  (se = 0.003 )
## Likelihood ratio test= 927.1  on 6 df,   p=<2e-16
## Wald test            = 927.7  on 6 df,   p=<2e-16
## Score (logrank) test = 920.6  on 6 df,   p=<2e-16
```

```
#Random effect - separated
coxme_allv<- coxme(Surv(total_lived, censored) ~ photoperiod + minrh + meanrh +
                     maxrh + mintemperature + meantemperature + maxtemperature +
                     mwimin + mwimax + daily_acc_gdd + (1|location) + (1|method),
                     data= new_df_gdd)
summary(coxme_allv)
```

```
## Cox mixed-effects model fit by maximum likelihood
##   Data: new_df_gdd
##   events, n = 14541, 15154 (1 observation deleted due to missingness)
##   Iterations= 7 38
##                     NULL Integrated    Fitted
## Log-likelihood -125294.8  -124772.6 -124766.6
##
##                     Chisq    df p     AIC    BIC
## Integrated loglik 1044.57 12.00 0 1020.57 929.55
##  Penalized loglik 1056.51 11.98 0 1032.55 941.69
##
## Model:  Surv(total_lived, censored) ~ photoperiod + minrh + meanrh +      maxrh + mintemperature + m
## Fixed coefficients
##                         coef exp(coef)    se(coef)     z       p
## photoperiod      0.191085710 1.2105632 0.015312392 12.48 0.0e+00
## minrh            0.005343319 1.0053576 0.002944014  1.81 7.0e-02
## meanrh          -0.009722990 0.9903241 0.005247197 -1.85 6.4e-02
## maxrh            0.000480935 1.0004811 0.002949257  0.16 8.7e-01
## mintemperature   0.051308980 1.0526481 0.020807059  2.47 1.4e-02
## meantemperature  0.036504359 1.0371788 0.026673296  1.37 1.7e-01
## maxtemperature   0.072220268 1.0748921 0.021595982  3.34 8.3e-04
## mwimin          -0.224062949 0.7992648 0.042480989 -5.27 1.3e-07
## mwimax          -0.173647518 0.8405931 0.025667028 -6.77 1.3e-11
## daily_acc_gdd   -0.179782370 0.8354520 0.033215771 -5.41 6.2e-08
##
## Random effects
##  Group    Variable  Std Dev    Variance
##  location Intercept 0.12734932 0.01621785
##  method   Intercept 0.18093581 0.03273777
```

```
rms::vif(coxme_allv) #gdd with high vif
```

```
##     photoperiod           minrh          meanrh           maxrh  mintemperature
##        5.364759       21.400220       41.665226        9.290150       89.986723
## meantemperature  maxtemperature          mwimin          mwimax   daily_acc_gdd
##      149.577812      109.440476        2.124712        1.141033      210.359839
```

```
coxme_allv2<- coxme(Surv(total_lived, censored) ~ photoperiod + minrh + meanrh +
                     maxrh + mintemperature  + maxtemperature +
                     mwimin + mwimax + meantemperature+ (1|location) + (1|method),
                     data= new_df_gdd)
summary(coxme_allv2)
```

```
## Cox mixed-effects model fit by maximum likelihood
##   Data: new_df_gdd
```

```
##   events, n = 14542, 15155
##   Iterations= 17 71
##                     NULL Integrated    Fitted
## Log-likelihood -125304.4  -124797.7 -124791.7
##
##                     Chisq    df p     AIC    BIC
## Integrated loglik 1013.43 11.00 0  991.43 908.00
##  Penalized loglik 1025.45 10.98 0 1003.49 920.21
##
## Model:  Surv(total_lived, censored) ~ photoperiod + minrh + meanrh +      maxrh + mintemperature + ma
## Fixed coefficients
##                          coef exp(coef)    se(coef)     z       p
## photoperiod      0.191422792 1.2109713 0.015337475 12.48 0.0e+00
## minrh            0.005945639 1.0059633 0.002924109  2.03 4.2e-02
## meanrh          -0.011214962 0.9888477 0.005205444 -2.15 3.1e-02
## maxrh            0.002649577 1.0026531 0.002908365  0.91 3.6e-01
## mintemperature  -0.034010182 0.9665617 0.013391192 -2.54 1.1e-02
## maxtemperature  -0.016367058 0.9837662 0.014292513 -1.15 2.5e-01
## mwimin          -0.294566831 0.7448542 0.040052378 -7.35 1.9e-13
## mwimax          -0.155927574 0.8556212 0.025545790 -6.10 1.0e-09
## meantemperature  0.040708420 1.0415484 0.026691186  1.53 1.3e-01
##
## Random effects
##  Group    Variable  Std Dev    Variance
##  location Intercept 0.13189652 0.01739669
##  method   Intercept 0.18115728 0.03281796
```

```
rms::vif(coxme_allv2) #meantemperature with high vif
```

```
##     photoperiod           minrh          meanrh           maxrh  mintemperature
##        5.378187       21.209896       41.174527        9.034150       38.354073
##  maxtemperature          mwimin          mwimax meantemperature
##       47.665330        1.887320        1.128233      151.721135
```

```
coxme_allv3<- coxme(Surv(total_lived, censored) ~ photoperiod + minrh  + meanrh +
                      maxrh + mintemperature  + maxtemperature +
                      mwimin + mwimax + (1|location) + (1|method), data= new_df_gdd)
summary(coxme_allv3)
```

```
## Cox mixed-effects model fit by maximum likelihood
##   Data: new_df_gdd
##   events, n = 14542, 15155
##   Iterations= 17 71
##                     NULL Integrated    Fitted
## Log-likelihood -125304.4  -124798.9 -124792.8
##
##                     Chisq    df p     AIC    BIC
## Integrated loglik 1011.11 10.00 0  991.11 915.26
##  Penalized loglik 1023.18  9.98 0 1003.21 927.51
##
## Model:  Surv(total_lived, censored) ~ photoperiod + minrh + meanrh +      maxrh + mintemperature + ma
## Fixed coefficients
##                        coef exp(coef)    se(coef)     z       p
```

```
## photoperiod     0.198309690 1.2193400 0.014666753 13.52 0.0e+00
## minrh           0.006433544 1.0064543 0.002904900  2.21 2.7e-02
## meanrh         -0.011637887 0.9884296 0.005195279 -2.24 2.5e-02
## maxrh           0.003008289 1.0030128 0.002898026  1.04 3.0e-01
## mintemperature -0.015185208 0.9849295 0.005206641 -2.92 3.5e-03
## maxtemperature  0.003871228 1.0038787 0.005324338  0.73 4.7e-01
## mwimin         -0.291565821 0.7470928 0.039994792 -7.29 3.1e-13
## mwimax         -0.153974637 0.8572938 0.025535299 -6.03 1.6e-09
##
## Random effects
##  Group    Variable  Std Dev    Variance
##  location Intercept 0.13488119 0.01819293
##  method   Intercept 0.18100896 0.03276424
```

```
rms::vif(coxme_allv3) #meanrh with high vif
```

```
##    photoperiod          minrh         meanrh          maxrh mintemperature
##       4.910955      20.922308      40.980724       8.964856       5.797130
## maxtemperature         mwimin         mwimax
##       6.604858       1.881333       1.125991
```

```
coxme_allv4<- coxme(Surv(total_lived, censored) ~ photoperiod + minrh  +
                      maxrh +  mwimin + mwimax + mintemperature + maxtemperature +
                      (1|location) + (1|method),
                    data= new_df_gdd,
                    refine.n = 500)
rms::vif(coxme_allv4) #removing maxtemperature
```

```
##    photoperiod          minrh          maxrh         mwimin         mwimax
##       4.864309       2.635473       2.006080       1.883040       1.124280
## mintemperature maxtemperature
##       5.746569       6.363009
```

```
coxme_allv5<- coxme(Surv(total_lived, censored) ~ photoperiod + minrh  +
                      maxrh + mintemperature +mwimin +mwimax+  (1|location) + (1|method),
                    data= new_df_gdd,
                    refine.n = 500)
rms::vif(coxme_allv5) #we know now the variables that doesn't have collinearity
```

```
##    photoperiod          minrh          maxrh mintemperature         mwimin
##       3.594018       2.483403       1.907389       3.828726       1.870953
##         mwimax
##       1.124612
```

```
coxme_allv5_gdd <- coxme(Surv(total_lived, censored) ~ photoperiod + minrh  +
                      maxrh + daily_acc_gdd +mwimin +mwimax+  (1|location) + (1|method),
                    data= new_df_gdd,
                    refine.n = 500)
rms::vif(coxme_allv5_gdd) #if we change temperature and put gdd, we still not
```

```
##   photoperiod         minrh         maxrh daily_acc_gdd        mwimin
```

```
##      4.631990      2.257495      1.882668      4.780805      1.844852
##        mwimax
##      1.123011
```

```
#have collinearity
```

```
##Random effect - together
coxme_allv_t<- coxme(Surv(total_lived, censored) ~ photoperiod + minrh + meanrh +
                     maxrh + mintemperature + meantemperature + maxtemperature +
                     mwimin + mwimax + (1|location/method), data= new_df_gdd)

summary(coxme_allv_t)
```

```
## Cox mixed-effects model fit by maximum likelihood
##   Data: new_df_gdd
##   events, n = 14542, 15155
##   Iterations= 9 39
##                     NULL Integrated    Fitted
## Log-likelihood -125304.4  -124795.1 -124786.7
##
##                     Chisq    df p     AIC    BIC
## Integrated loglik 1018.70 11.00 0  996.70 913.26
##  Penalized loglik 1035.44 11.96 0 1011.52 920.81
##
## Model:  Surv(total_lived, censored) ~ photoperiod + minrh + meanrh +      maxrh + mintemperature + m
## Fixed coefficients
##                          coef exp(coef)    se(coef)     z       p
## photoperiod      0.194315724 1.2144797 0.015374354 12.64 0.0e+00
## minrh            0.006118273 1.0061370 0.002924249  2.09 3.6e-02
## meanrh          -0.011466536 0.9885990 0.005205284 -2.20 2.8e-02
## maxrh            0.002669859 1.0026734 0.002908164  0.92 3.6e-01
## mintemperature  -0.035114791 0.9654946 0.013394674 -2.62 8.8e-03
## meantemperature  0.042477181 1.0433922 0.026694947  1.59 1.1e-01
## maxtemperature  -0.017929724 0.9822301 0.014298472 -1.25 2.1e-01
## mwimin          -0.294390010 0.7449859 0.040052231 -7.35 2.0e-13
## mwimax          -0.158453729 0.8534625 0.025562401 -6.20 5.7e-10
##
## Random effects
##  Group           Variable    Std Dev      Variance
##  location/method (Intercept) 0.1791964102 0.0321113534
##  location        (Intercept) 0.0198553460 0.0003942348
```

```
rms::vif(coxme_allv_t) #meantemperature with high vif
```

```
##     photoperiod           minrh          meanrh           maxrh  mintemperature
##        5.387307       21.221851       41.172871        9.030419       38.314688
## meantemperature  maxtemperature          mwimin          mwimax
##      151.511584       47.638213        1.887397        1.128727
```

```
coxme_allv_t2<- coxme(Surv(total_lived, censored) ~ photoperiod + minrh + meanrh +
                      maxrh + mintemperature + maxtemperature +
                     mwimin + mwimax + (1|location/method), data= new_df_gdd)
```

```
summary(coxme_allv_t2)
```

```
## Cox mixed-effects model fit by maximum likelihood
##   Data: new_df_gdd
##   events, n = 14542, 15155
##   Iterations= 10 43
##                     NULL Integrated  Fitted
## Log-likelihood -125304.4  -124796.3 -124788
##
##                     Chisq    df p     AIC    BIC
## Integrated loglik 1016.17 10.00 0  996.17 920.32
##  Penalized loglik 1032.96 10.96 0 1011.04 927.90
##
## Model:  Surv(total_lived, censored) ~ photoperiod + minrh + meanrh +      maxrh + mintemperature + ma
## Fixed coefficients
##                         coef exp(coef)    se(coef)     z       p
## photoperiod     0.201488980 1.2232228 0.014710199 13.70 0.0e+00
## minrh           0.006625414 1.0066474 0.002905207  2.28 2.3e-02
## meanrh         -0.011903840 0.9881667 0.005195208 -2.29 2.2e-02
## maxrh           0.003043832 1.0030485 0.002897885  1.05 2.9e-01
## mintemperature -0.015463141 0.9846558 0.005209189 -2.97 3.0e-03
## maxtemperature  0.003184164 1.0031892 0.005327295  0.60 5.5e-01
## mwimin         -0.291247975 0.7473303 0.039993941 -7.28 3.3e-13
## mwimax         -0.156401730 0.8552156 0.025551213 -6.12 9.3e-10
##
## Random effects
##  Group           Variable    Std Dev      Variance
##  location/method (Intercept) 0.1805299880 0.0325910766
##  location        (Intercept) 0.0198756161 0.0003950401
```

```
rms::vif(coxme_allv_t2) #meanrh with highest vif
```

```
##    photoperiod          minrh         meanrh          maxrh mintemperature
##       4.924631      20.937025      40.980529       8.961508       5.794014
## maxtemperature         mwimin         mwimax
##       6.602567       1.881342       1.126422
```

```
coxme_allv_t3<- coxme(Surv(total_lived, censored) ~ photoperiod + minrh  +
                    maxrh + mintemperature + maxtemperature +
                    mwimin + mwimax + (1|location/method), data= new_df_gdd)

summary(coxme_allv_t3)
```

```
## Cox mixed-effects model fit by maximum likelihood
##   Data: new_df_gdd
##   events, n = 14542, 15155
##   Iterations= 10 43
##                     NULL Integrated    Fitted
## Log-likelihood -125304.4    -124799 -124790.5
##
##                     Chisq   df p     AIC    BIC
```

```
## Integrated loglik 1010.92 9.00 0  992.92 924.66
##  Penalized loglik 1027.78 9.96 0 1007.86 932.30
##
## Model:  Surv(total_lived, censored) ~ photoperiod + minrh + maxrh + mintemperature +      maxtempera
## Fixed coefficients
##                          coef exp(coef)    se(coef)     z       p
## photoperiod     0.2041548398 1.2264880 0.014655438 13.93 0.0e+00
## minrh           0.0004138402 1.0004139 0.001032333  0.40 6.9e-01
## maxrh          -0.0028179702 0.9971860 0.001369011 -2.06 4.0e-02
## mintemperature -0.0142815709 0.9858199 0.005188518 -2.75 5.9e-03
## maxtemperature  0.0009568861 1.0009573 0.005231416  0.18 8.5e-01
## mwimin         -0.2925182974 0.7463816 0.040019188 -7.31 2.7e-13
## mwimax         -0.1568075820 0.8548685 0.025544342 -6.14 8.3e-10
##
## Random effects
##  Group           Variable    Std Dev     Variance
##  location/method (Intercept) 0.182699325 0.033379043
##  location        (Intercept) 0.019894572 0.000395794
```

```
rms::vif(coxme_allv_t3) #maxtemperature with highest vif
```

```
##    photoperiod          minrh          maxrh mintemperature maxtemperature
##       4.878457       2.638661       2.006729       5.743697       6.362156
##         mwimin         mwimax
##       1.883169       1.124701
```

```
coxme_allv_t4<- coxme(Surv(total_lived, censored) ~ photoperiod + minrh  +
                    maxrh + mintemperature  +
                    mwimin + mwimax + (1|location/method), data= new_df_gdd)
rms::vif(coxme_allv_t4) #maxtemperature with highest vif
```

```
##    photoperiod          minrh          maxrh mintemperature         mwimin
##       3.599549       2.487661       1.909199       3.836999       1.870662
##         mwimax
##       1.124857
```

```
library(finalfit)
explanatory = c("photoperiod", "mintemperature","minrh", "maxrh", "mwimin", "mwimax", "daily_acc_gdd",
dependent = "Surv(total_lived, censored)"
new_df_gdd %>%
  finalfit(dependent, explanatory) -> t1
knitr::kable(t1, align=c("l", "l", "r", "r", "r"))
```

	Dependent: Surv(total_lived, censored)		all	HR (univariable)	HR (multivariable)
11	photoperiod	Mean (SD)	12.4 (1.4)	1.17 (1.15-1.18, p<0.001)	1.24 (1.20-1.27, p<0.001)
8	mintemperature	Mean (SD)	18.1 (4.0)	1.03 (1.03-1.03, p<0.001)	1.00 (0.98-1.02, p=0.816)
7	minrh	Mean (SD)	71.2 (14.4)	1.00 (1.00-1.00, p<0.001)	1.00 (1.00-1.00, p=0.939)

	Dependent: Surv(total_lived, censored)		all	HR (univariable)	HR (multivariable)
4	maxrh	Mean (SD)	90.8 (8.8)	1.00 (1.00-1.00, p=0.001)	1.00 (1.00-1.00, p=0.085)
10	mwimin	Mean (SD)	0.3 (0.3)	1.14 (1.08-1.20, p<0.001)	0.75 (0.69-0.81, p<0.001)
9	mwimax	Mean (SD)	0.4 (0.4)	0.81 (0.78-0.84, p<0.001)	0.86 (0.81-0.90, p<0.001)
1	daily_acc_gdd	Mean (SD)	10.9 (3.7)	1.04 (1.03-1.04, p<0.001)	0.99 (0.97-1.00, p=0.139)
2	location	Peri_Urban	6840 (45.1)	-	-
3		Urban	8315 (54.9)	0.80 (0.77-0.82, p<0.001)	0.83 (0.80-0.87, p<0.001)
6	method	HB	3943 (26.0)	-	-
5		BG	11212 (74.0)	1.31 (1.27-1.36, p<0.001)	1.29 (1.25-1.34, p<0.001)

#Finally... which one?

We should check the AIC and BIC of each model, maybe taking only the option of (1|location) + (1|method) (1|location/method) (1|location) + (1|method) + (1|location/method) for:

1. model with MWImin + MWImax, photoperiod
2. model with MWImin, photoperiod
3. model with MWImax, photoperiod
4. model with MinT, minRH, photoperiod
5. model with MinT, maxRH, photoperiod
6. model with MinT, minRH, maxRH, photoperiod
7. model with GDD, minRH, photoperiod
8. model with GDD, maxRH, photoperiod
9. model with GDD, minRH, maxRH, photoperiod

Create tables with the HR, CI95%, var and sd + tables with the AIC + BIC + loglikelihood (integrated)

```
#model 1.
model1<- coxme(Surv(total_lived, censored) ~ photoperiod + mwimin  +
                       mwimax + (1|location)+ (1|method) +(1|location/method),
                       data= new_df_gdd,
                     refine.n = 500)
exp(confint(model1))
```

```
##                 2.5 %    97.5 %
## photoperiod 1.1845745 1.2201030
## mwimin      0.6437911 0.7326543
## mwimax      0.8297227 0.9123047
```

```
model2<- coxme(Surv(total_lived, censored) ~ photoperiod + mwimin  +
                       (1|location)+ (1|method) +(1|location/method),
                       data= new_df_gdd,
                     refine.n = 500)
exp(confint(model2))
```

```
##                 2.5 %    97.5 %
## photoperiod 1.1825784 1.2183540
## mwimin      0.6558115 0.7464272
```

```
model3<- coxme(Surv(total_lived, censored) ~ photoperiod + mwimax  +
                      (1|location)+ (1|method) +(1|location/method),
                      data= new_df_gdd,
                    refine.n = 500)
exp(confint(model3))
```

```
##                 2.5 %    97.5 %
## photoperiod 1.1391838 1.1699713
## mwimax      0.8556262 0.9399508
```

```
model4<- coxme(Surv(total_lived, censored) ~ photoperiod + mintemperature+ minrh  +
                      (1|location)+ (1|method) +(1|location/method),
                      data= new_df_gdd,
                    refine.n = 500)
exp(confint(model4))
```

```
##                    2.5 %    97.5 %
## photoperiod    1.1924641 1.2520933
## mintemperature 0.9674649 0.9827193
## minrh          0.9969140 0.9999224
```

```
model5<- coxme(Surv(total_lived, censored) ~ photoperiod + mintemperature+ maxrh  +
                      (1|location)+ (1|method) +(1|location/method),
                      data= new_df_gdd,
                    refine.n = 500)
exp(confint(model5))
```

```
##                    2.5 %    97.5 %
## photoperiod    1.2025193 1.2562194
## mintemperature 0.9662746 0.9798863
## maxrh          0.9956735 0.9996873
```

```
model6<- coxme(Surv(total_lived, censored) ~ photoperiod + mintemperature+ maxrh  +
                 minrh +  (1|location)+ (1|method) +(1|location/method),
                      data= new_df_gdd,
                    refine.n = 500)
exp(confint(model6))
```

```
##                    2.5 %    97.5 %
## photoperiod    1.1937695 1.2536415
## mintemperature 0.9669061 0.9822412
## maxrh          0.9957892 1.0009451
## minrh          0.9972518 1.0011118
```

```
model7<- coxme(Surv(total_lived, censored) ~ photoperiod + daily_acc_gdd  +
                 minrh +  (1|location)+ (1|method) +(1|location/method),
                      data= new_df_gdd,
                    refine.n = 500)
exp(confint(model7))
```

```
##                   2.5 %    97.5 %
## photoperiod   1.2055464 1.2748514
## daily_acc_gdd 0.9606125 0.9788891
## minrh         0.9963944 0.9992132
```

```
model8<- coxme(Surv(total_lived, censored) ~ photoperiod + daily_acc_gdd  +
                 maxrh +  (1|location)+ (1|method) +(1|location/method),
                       data= new_df_gdd,
                    refine.n = 500)
exp(confint(model8))
```

```
##                   2.5 %    97.5 %
## photoperiod   1.2191593 1.2848994
## daily_acc_gdd 0.9581704 0.9754464
## maxrh         0.9955322 0.9995187
```

```
model9<- coxme(Surv(total_lived, censored) ~ photoperiod + daily_acc_gdd+ minrh+
                 maxrh +  (1|location)+ (1|method) +(1|location/method),
                       data= new_df_gdd,
                    refine.n = 500)
exp(confint(model9))
```

```
##                   2.5 %    97.5 %
## photoperiod   1.2055787 1.2748948
## daily_acc_gdd 0.9605491 0.9788325
## minrh         0.9963840 0.9999935
## maxrh         0.9965675 1.0016881
```

```
#model 1.
model1<- coxme(Surv(total_lived, censored) ~ photoperiod + mwimin  +
                      mwimax + (1|location/method),
                      data= new_df_gdd,
                    refine.n = 500)
exp(confint(model1))
```

```
##                  2.5 %    97.5 %
## photoperiod 1.1846775 1.2202159
## mwimin      0.6435122 0.7323372
## mwimax      0.8297022 0.9123092
```

```
model2<- coxme(Surv(total_lived, censored) ~ photoperiod + mwimin  + (1|location/method),
                      data= new_df_gdd,
                    refine.n = 500)
exp(confint(model2))
```

```
##                  2.5 %    97.5 %
## photoperiod 1.1826942 1.2184806
## mwimin      0.6556853 0.7462802
```

```
model3<- coxme(Surv(total_lived, censored) ~ photoperiod + mwimax  +(1|location/method),
                      data= new_df_gdd,
                    refine.n = 500)
exp(confint(model3))
```

```
##                 2.5 %    97.5 %
## photoperiod 1.1391478 1.1699488
## mwimax      0.8561063 0.9405797
```

```
model4<- coxme(Surv(total_lived, censored) ~ photoperiod + mintemperature+ minrh  +
                      (1|location/method),
                      data= new_df_gdd,
                    refine.n = 500)
exp(confint(model4))
```

```
##                     2.5 %    97.5 %
## photoperiod    1.1927485 1.2524086
## mintemperature 0.9673990 0.9826554
## minrh          0.9969193 0.9999278
```

```
model5<- coxme(Surv(total_lived, censored) ~ photoperiod + mintemperature+ maxrh  +
                      (1|location/method),
                      data= new_df_gdd,
                    refine.n = 500)
exp(confint(model5))
```

```
##                     2.5 %    97.5 %
## photoperiod    1.2027475 1.2564702
## mintemperature 0.9662399 0.9798522
## maxrh          0.9956776 0.9996914
```

```
model6<- coxme(Surv(total_lived, censored) ~ photoperiod + mintemperature+ maxrh  +
                 minrh + (1|location/method),
                       data= new_df_gdd,
                    refine.n = 500)
exp(confint(model6))
```

```
##                     2.5 %    97.5 %
## photoperiod    1.1940586 1.2539623
## mintemperature 0.9668374 0.9821747
## maxrh          0.9957788 1.0009349
## minrh          0.9972617 1.0011219
```

```
model7<- coxme(Surv(total_lived, censored) ~ photoperiod + daily_acc_gdd  +
                 minrh  +(1|location/method),
                       data= new_df_gdd,
                    refine.n = 500)
exp(confint(model7))
```

```
##                   2.5 %    97.5 %
## photoperiod   1.2058032 1.2751531
## daily_acc_gdd 0.9605394 0.9788201
## minrh         0.9963909 0.9992104
```

```
model8<- coxme(Surv(total_lived, censored) ~ photoperiod + daily_acc_gdd  +
                maxrh +(1|location/method),
                      data= new_df_gdd,
                   refine.n = 500)
exp(confint(model8))
```

```
##                   2.5 %    97.5 %
## photoperiod   1.2193721 1.2851477
## daily_acc_gdd 0.9581047 0.9753838
## maxrh         0.9955209 0.9995077
```

```
model9<- coxme(Surv(total_lived, censored) ~ photoperiod + daily_acc_gdd+ minrh+
                maxrh +(1|location/method),
                      data= new_df_gdd,
                   refine.n = 500)
exp(confint(model9))
```

```
##                   2.5 %    97.5 %
## photoperiod   1.2058309 1.2751919
## daily_acc_gdd 0.9604764 0.9787641
## minrh         0.9963833 0.9999934
## maxrh         0.9965607 1.0016813
```

```
#model 1.
model1<- coxme(Surv(total_lived, censored) ~ photoperiod + mwimin  +
                       mwimax + (1|location)+ (1|method),
                       data= new_df_gdd,
                    refine.n = 500)
exp(confint(model1))
```

```
##                  2.5 %    97.5 %
## photoperiod 1.1838107 1.2192717
## mwimin      0.6445590 0.7335642
## mwimax      0.8312299 0.9139315
```

```
model2<- coxme(Surv(total_lived, censored) ~ photoperiod + mwimin  +
                       (1|location)+ (1|method),
                       data= new_df_gdd,
                    refine.n = 500)
exp(confint(model2))
```

```
##                  2.5 %    97.5 %
## photoperiod 1.1818738 1.2175816
## mwimin      0.6563785 0.7471077
```

```
model3<- coxme(Surv(total_lived, censored) ~ photoperiod + mwimax  +
                      (1|location)+ (1|method),
                      data= new_df_gdd,
                    refine.n = 500)
exp(confint(model3))
```

```
##                 2.5 %    97.5 %
## photoperiod 1.1386060 1.1693316
## mwimax      0.8569781 0.9414562
```

```
model4<- coxme(Surv(total_lived, censored) ~ photoperiod + mintemperature+ minrh  +
                      (1|location)+ (1|method),
                      data= new_df_gdd,
                    refine.n = 500)
exp(confint(model4))
```

```
##                    2.5 %    97.5 %
## photoperiod    1.1902581 1.2496358
## mintemperature 0.9679856 0.9832226
## minrh          0.9968704 0.9998776
```

```
model5<- coxme(Surv(total_lived, censored) ~ photoperiod + mintemperature+ maxrh  +
                      (1|location)+ (1|method),
                      data= new_df_gdd,
                    refine.n = 500)
exp(confint(model5))
```

```
##                    2.5 %    97.5 %
## photoperiod    1.2007490 1.2542707
## mintemperature 0.9666726 0.9802752
## maxrh          0.9956981 0.9997108
```

```
model6<- coxme(Surv(total_lived, censored) ~ photoperiod + mintemperature+ maxrh  +
                 minrh +  (1|location)+ (1|method),
                      data= new_df_gdd,
                    refine.n = 500)
exp(confint(model6))
```

```
##                    2.5 %    97.5 %
## photoperiod    1.1914468 1.2510529
## mintemperature 0.9674684 0.9827837
## maxrh          0.9958909 1.0010441
## minrh          0.9971618 1.0010188
```

```
model7<- coxme(Surv(total_lived, censored) ~ photoperiod + daily_acc_gdd  +
                 minrh +  (1|location)+ (1|method),
                      data= new_df_gdd,
                    refine.n = 500)
exp(confint(model7))
```

```
##                    2.5 %    97.5 %
## photoperiod   1.2023226 1.2712546
## daily_acc_gdd 0.9614371 0.9796916
## minrh         0.9963534 0.9991727
```

```
model8<- coxme(Surv(total_lived, censored) ~ photoperiod + daily_acc_gdd  +
                 maxrh +  (1|location)+ (1|method),
                       data= new_df_gdd,
                    refine.n = 500)
exp(confint(model8))
```

```
##                    2.5 %    97.5 %
## photoperiod   1.2162727 1.2816910
## daily_acc_gdd 0.9588999 0.9761563
## maxrh         0.9955486 0.9995348
```

```
model9<- coxme(Surv(total_lived, censored) ~ photoperiod + daily_acc_gdd+ minrh+
                 maxrh +  (1|location)+ (1|method),
                       data= new_df_gdd,
                    refine.n = 500)
exp(confint(model9))
```

```
##                    2.5 %    97.5 %
## photoperiod   1.2023317 1.2712721
## daily_acc_gdd 0.9613858 0.9796462
## minrh         0.9963056 0.9999143
## maxrh         0.9966545 1.0017734
```

##MODEL SELECTION AND INTERPRETATION