Friday, May 5

Setup

The following packages are being used.

```
library(dplyr)      # data manipulation
library(tidyr)      # data manipulation
library(lubridate)  # working with dates
library(forcats)    # working with factors
library(whereami)   # find current directory
library(ggplot2)    # graphics
library(mgcv)       # GAMs
library(trtools)    # inference tools
library(emmeans)    # inference tools
options(digits = 4) # control number of digits displayed
```

Import and Process Tick Count Data

Here I can use `dirname(thisfile())` to find the directory containing this Rmarkdown file, so I do not have to specify the full path to the data file. Note that `thisfile()` is from the **whereami** package. I have the data stored in a sub-directory ("tickdata") of the directory containing this Rmarkdown file.

```
ticks <- read.csv(paste(dirname(thisfile()),
  "/tickdata/tick_data_Robenstein.csv", sep = ""))
names(ticks) <- c("moose","mortality","ticks","size","date","gmu","sex","note")
head(ticks)
```

```
     moose mortality ticks size       date gmu  sex note
1 21005370         H     0  100  9/16/2020   1 MALE    1
2 21005396         H    21  100 10/14/2020   1 MALE    1
3 21005452         H     0  100  10/5/2020   1 MALE    1
4 21005506         H     9  100 11/11/2020   1 MALE    1
5 21005526         H    34  100 11/22/2020   1 MALE    1
6 21005538         H     1  100  11/5/2020   1 MALE    0
```

Here I am going to process the data to get it ready for plotting and modeling.

```
ticks <- ticks %>%
  mutate(note = factor(note, levels = 0:3,
    labels = c("exclude", "include", "deterioration", "nodate"))) %>%
  mutate(date = mdy(date)) %>%
  mutate(month = month(date, label = TRUE), year = year(date), day = yday(date)) %>%
  filter(!is.na(date), month %in% c("Aug","Sep","Oct","Nov")) %>%
  mutate(year = factor(year)) %>% mutate(sex = tolower(sex)) %>%
  mutate(day = ifelse(year == "2020", day - 1, day))
head(ticks)
```

```
     moose mortality ticks size       date gmu  sex    note month year day
1 21005370         H     0  100 2020-09-16   1 male include   Sep 2020 259
2 21005396         H    21  100 2020-10-14   1 male include   Oct 2020 287
```

```
3 21005452         H      0  100 2020-10-05    1 male include   Oct 2020 278
4 21005506         H      9  100 2020-11-11    1 male include   Nov 2020 315
5 21005526         H     34  100 2020-11-22    1 male include   Nov 2020 326
6 21005538         H      1  100 2020-11-05    1 male exclude   Nov 2020 309
```

Import and Process Game Management Unit Data

Here I am going to use `rename` to rename the imported variables.

```
gmu <- read.csv(paste(dirname(thisfile()), "/tickdata/tick_study_areas.csv", sep = "")) %>%
  rename(gmu = GMU, area = study.Area, samples = hh_samples)
head(gmu, 10)
```

```
   gmu          area samples
1    1         North      27
2    2         North      36
3    3         North      19
4    4         North      24
5   4A         North       6
6    5 North Central      18
7    6 North Central      22
8    7 North Central       7
9    8 North Central       9
10  8A North Central       8
```

Merging Data Frames and Filtering

```
ticks <- left_join(ticks, gmu) %>%
  mutate(area = factor(area)) %>%
  mutate(area = fct_relevel(area, c("North", "North Central",
    "Central", "Southeast", "Island Park")))
head(ticks)
```

```
     moose mortality ticks size       date gmu  sex    note month year day  area samples
1 21005370         H     0  100 2020-09-16   1 male include   Sep 2020 259 North      27
2 21005396         H    21  100 2020-10-14   1 male include   Oct 2020 287 North      27
3 21005452         H     0  100 2020-10-05   1 male include   Oct 2020 278 North      27
4 21005506         H     9  100 2020-11-11   1 male include   Nov 2020 315 North      27
5 21005526         H    34  100 2020-11-22   1 male include   Nov 2020 326 North      27
6 21005538         H     1  100 2020-11-05   1 male exclude   Nov 2020 309 North      27
```

Some variables we do not need. Also we are going to discard some questionable observations.

```
ticks <- ticks %>% select(-mortality, -samples, -gmu) %>%
  filter(note == "include")
head(ticks)
```

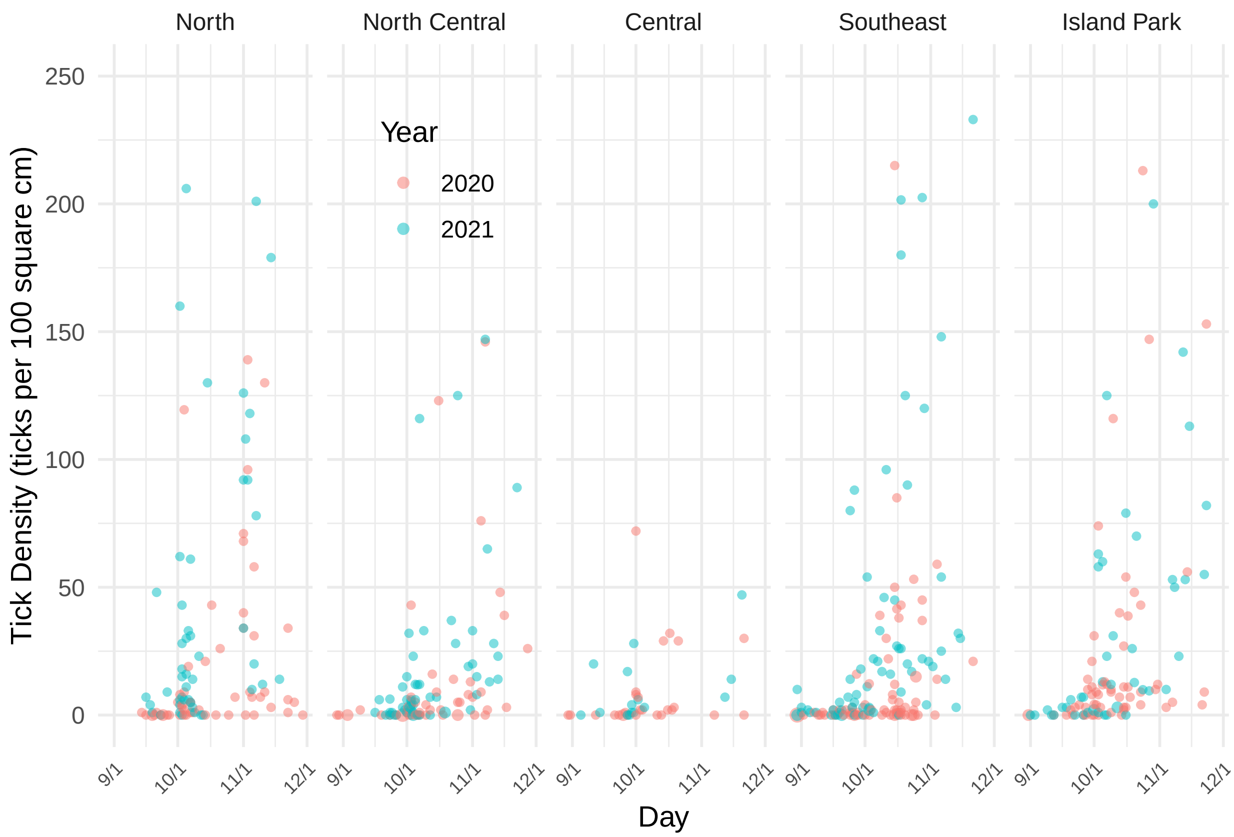
```
     moose ticks size       date  sex    note month year day  area
1 21005370     0  100 2020-09-16 male include   Sep 2020 259 North
2 21005396    21  100 2020-10-14 male include   Oct 2020 287 North
3 21005452     0  100 2020-10-05 male include   Oct 2020 278 North
4 21005506     9  100 2020-11-11 male include   Nov 2020 315 North
5 21005526    34  100 2020-11-22 male include   Nov 2020 326 North
6 21005546     1  100 2020-11-22 male include   Nov 2020 326 North
```

Raw Data Visualization

```
d09 <- yday(mdy("09/1/2021"))
d10 <- yday(mdy("10/1/2021"))
d11 <- yday(mdy("11/1/2021"))
d12 <- yday(mdy("12/1/2021"))

pv <- ggplot(ticks, aes(x = day, y = ticks/size*100, color = year)) +
  geom_count(alpha = 0.5) + scale_size_area(max_size = 2) +
  theme_minimal() + facet_grid(area ~ .) +
  labs(x = "Day", y = "Tick Density (ticks per 100 square cm)", color = "Year") +
  guides(size = "none") +
  scale_x_continuous(breaks = c(d09, d10, d11, d12),
    labels = c("9/1", "10/1", "11/1", "12/1")) + ylim(c(0,250)) +
  theme(legend.position = c(0.15, 0.925))

plot(pv)
```


Year
2020
2021
North
North Central
Central
Southeast
Island Park
Tick Density (ticks per 100 square cm)
250
200
150
100
50
0
9/1
10/1
11/1
12/1
Day

```
ph <- ggplot(ticks, aes(x = day, y = ticks/size*100, color = year)) +
  geom_count(alpha = 0.5) + scale_size_area(max_size = 2) + theme_minimal() +
  facet_wrap(~ area, ncol = 5) +
  labs(x = "Day", y = "Tick Density (ticks per 100 square cm)", color = "Year") +
  guides(size = "none") +
  scale_x_continuous(breaks = c(d09, d10, d11, d12),
    labels = c("9/1", "10/1", "11/1", "12/1")) + ylim(c(0,250)) +
  theme(legend.position = c(0.3, 0.8),
    axis.text.x = element_text(angle = 45, size = 7, hjust = 1))

plot(ph)
```



Modeling

I used a generalized additive model with a log link function estimated using (penalized) quasi-likelihood to deal with considerable over-dispersion.

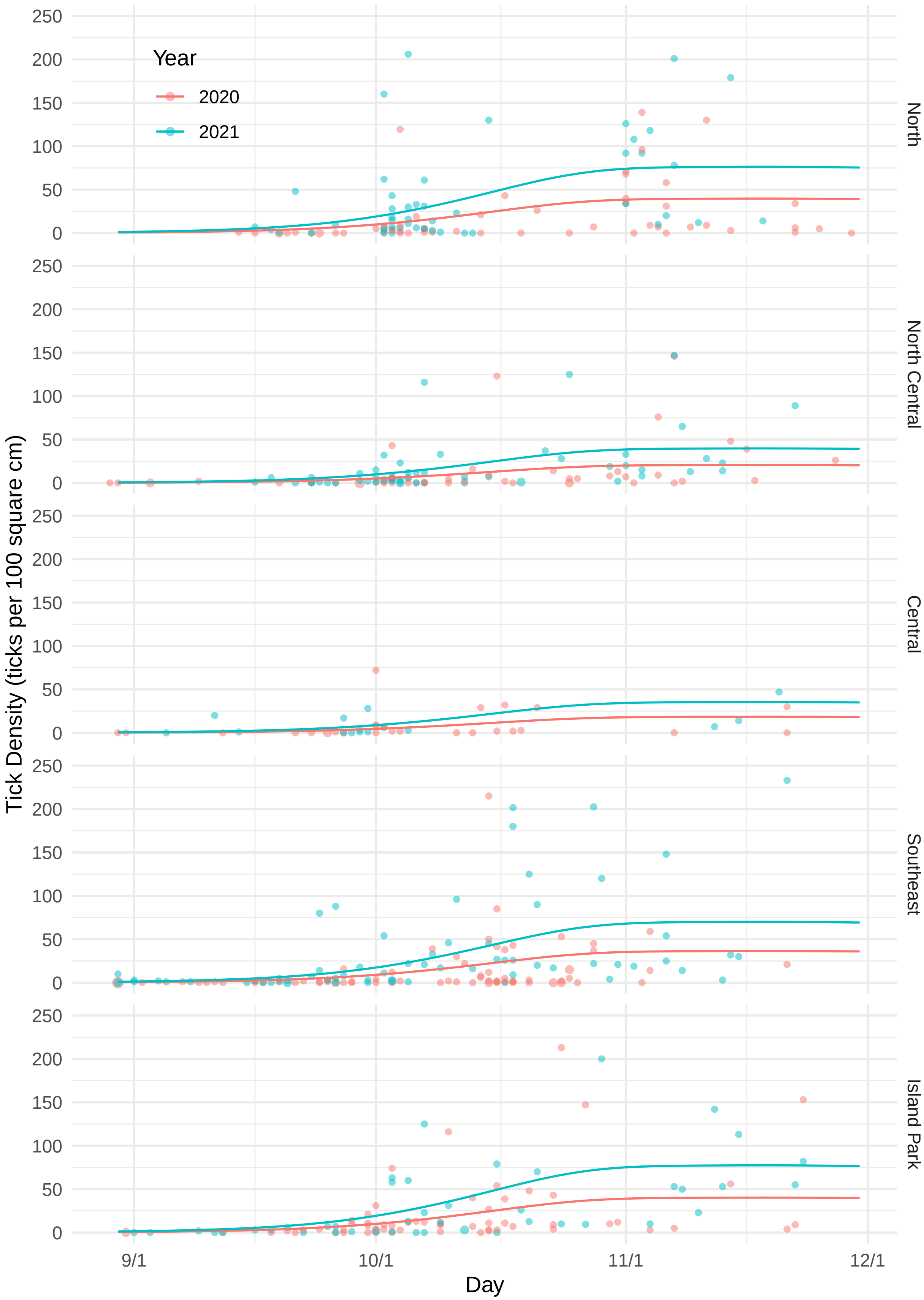
```
m <- gam(ticks ~ offset(log(size)) + s(day) + year + area,
  family = quasipoisson(link = log), data = ticks)
summary(m)
```

```
Family: quasipoisson
Link function: log

Formula:
ticks ~ offset(log(size)) + s(day) + year + area
```

```
Parametric coefficients:
                  Estimate Std. Error t value Pr(>|t|)    
(Intercept)        -2.0218     0.1855  -10.90  < 2e-16 ***
year2021            0.6547     0.1488    4.40  1.3e-05 ***
areaNorth Central  -0.6532     0.2330   -2.80   0.0053 ** 
areaCentral        -0.7678     0.4119   -1.86   0.0629 .  
areaSoutheast      -0.0852     0.1937   -0.44   0.6603    
areaIsland Park     0.0143     0.2002    0.07   0.9431    
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Approximate significance of smooth terms:
        edf Ref.df    F p-value    
s(day) 2.94   3.71 19.6  <2e-16 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

R-sq.(adj) =  0.189   Deviance explained = 32.4%
GCV = 34.323  Scale est. = 55.985    n = 497
```

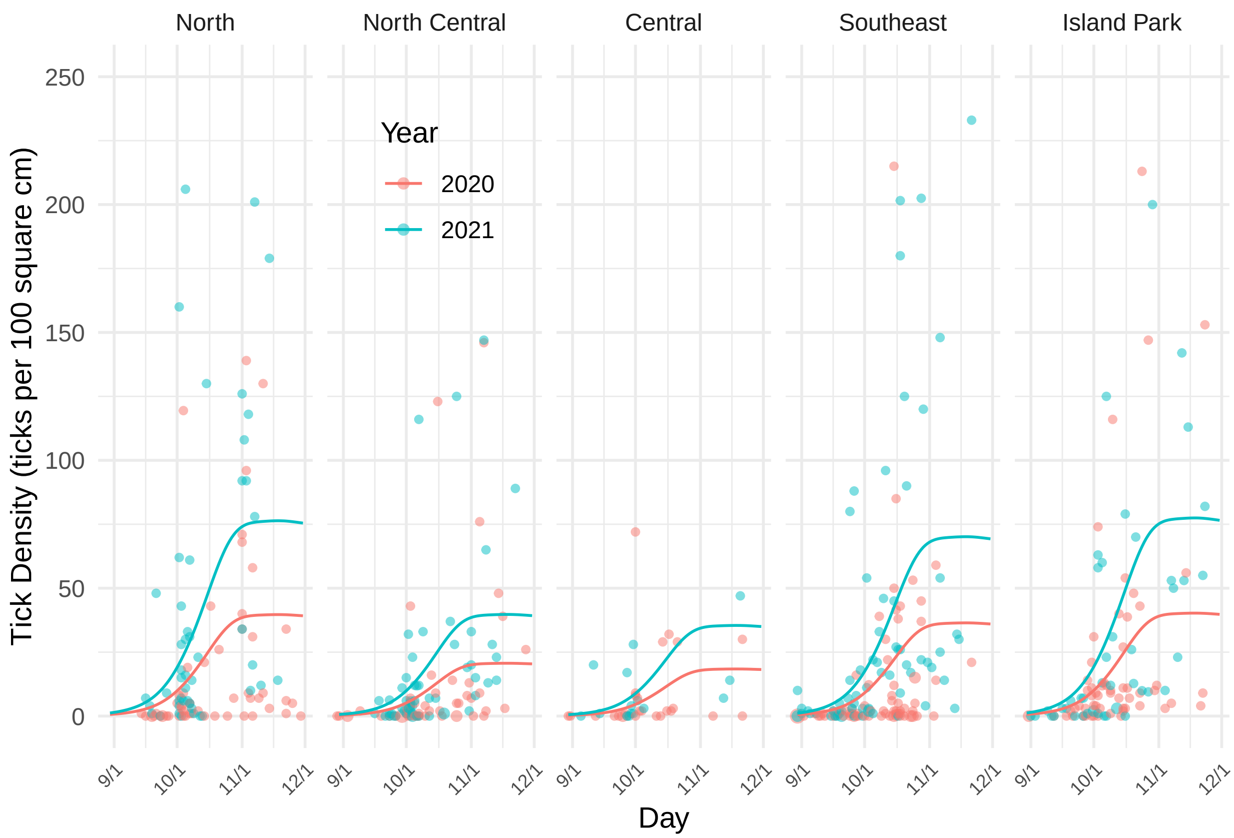
Here we can visualize this model.

```r
d <- expand.grid(year = c("2020","2021"), day = 242:334,
  area = unique(ticks$area), size = 100)
d$yhat <- predict(m, newdata = d, type = "response")

pv <- pv + geom_line(aes(y = yhat), data = d)
plot(pv)
```



Year
2020
2021
North
North Central
Central
Southeast
Island Park
Tick Density (ticks per 100 square cm)
Day
9/1
10/1
11/1
12/1
0
50
100
150
200
250

```
ph <- ph + geom_line(aes(y = yhat), data = d)
plot(ph)
```



Model-Based Inferences

How much higher is the expected tick density in 2021 than in 2020?

```
emmeans(m, ~year | area, at = list(day = d10),
  type = "response", offset = log(100), data = ticks)
```

```
area = North:
 year  rate   SE  df lower.CL upper.CL
 2020  9.88 2.05 488     6.57    14.86
 2021 19.02 3.69 488    12.99    27.85

area = North Central:
 year  rate   SE  df lower.CL upper.CL
 2020  5.14 1.28 488     3.15     8.38
 2021  9.90 2.27 488     6.31    15.52

area = Central:
 year  rate   SE  df lower.CL upper.CL
 2020  4.59 1.87 488     2.06    10.21
 2021  8.82 3.59 488     3.97    19.63

area = Southeast:
 year  rate   SE  df lower.CL upper.CL
 2020  9.07 1.92 488     5.99    13.74
```

```
 2021 17.47 3.36 488    11.97    25.49

area = Island Park:
 year  rate   SE  df lower.CL upper.CL
 2020 10.02 2.13 488     6.60    15.22
 2021 19.29 3.81 488    13.09    28.43

Confidence level used: 0.95
Intervals are back-transformed from the log scale
```

```
pairs(emmeans(m, ~year | area, at = list(day = d10),
  type = "response", offset = log(100), data = ticks), reverse = TRUE, infer = TRUE)
```

```
area = North:
 contrast            ratio    SE  df lower.CL upper.CL null t.ratio p.value
 year2021 / year2020  1.92 0.286 488     1.44     2.58    1   4.401  <.0001

area = North Central:
 contrast            ratio    SE  df lower.CL upper.CL null t.ratio p.value
 year2021 / year2020  1.92 0.286 488     1.44     2.58    1   4.401  <.0001

area = Central:
 contrast            ratio    SE  df lower.CL upper.CL null t.ratio p.value
 year2021 / year2020  1.92 0.286 488     1.44     2.58    1   4.401  <.0001

area = Southeast:
 contrast            ratio    SE  df lower.CL upper.CL null t.ratio p.value
 year2021 / year2020  1.92 0.286 488     1.44     2.58    1   4.401  <.0001

area = Island Park:
 contrast            ratio    SE  df lower.CL upper.CL null t.ratio p.value
 year2021 / year2020  1.92 0.286 488     1.44     2.58    1   4.401  <.0001

Confidence level used: 0.95
Intervals are back-transformed from the log scale
Tests are performed on the log scale
```

Note: Here `emmeans` needs a bit more information that is not contained in the model object, so we pass it the data with `data = ticks`. The `contrast` function will also work here, but it needs to be told the degrees of freedom by including the argument `df = m$df.residual`.

How about the *difference* in the expected density for each area and the first of October? This is a *discrete marginal effect*, and both area and day matter.

```
trtools::margeff(m,
  a = list(year = "2021", area = unique(ticks$area), day = d10, size = 100),
  b = list(year = "2020", area = unique(ticks$area), day = d10, size = 100),
  cnames = unique(ticks$area), df = m$df.residual)
```

```
              estimate    se  lower  upper tvalue    df    pvalue
North            9.137 2.610 4.0093 14.265  3.501 488.1 0.0005058
North Central    4.755 1.442 1.9210  7.589  3.297 488.1 0.0010493
Central          4.240 1.964 0.3801  8.100  2.158 488.1 0.0313905
Southeast        8.391 2.352 3.7705 13.012  3.568 488.1 0.0003950
Island Park      9.269 2.655 4.0512 14.486  3.490 488.1 0.0005259
```

Interestingly this can also be done using the **emmeans** package through use of the `regrid` function.

```r
tmp <- emmeans(m, ~year | area, at = list(day = d10),
  type = "response", offset = log(100), data = ticks)
pairs(regrid(tmp, type = "response"), reverse = TRUE, infer = TRUE)
```

```
area = North:
 contrast            estimate   SE  df lower.CL upper.CL t.ratio p.value
 year2021 - year2020     9.14 2.61 488     4.01    14.27   3.501  0.0005

area = North Central:
 contrast            estimate   SE  df lower.CL upper.CL t.ratio p.value
 year2021 - year2020     4.75 1.44 488     1.92     7.59   3.297  0.0010

area = Central:
 contrast            estimate   SE  df lower.CL upper.CL t.ratio p.value
 year2021 - year2020     4.24 1.96 488     0.38     8.10   2.158  0.0314

area = Southeast:
 contrast            estimate   SE  df lower.CL upper.CL t.ratio p.value
 year2021 - year2020     8.39 2.35 488     3.77    13.01   3.568  0.0004

area = Island Park:
 contrast            estimate   SE  df lower.CL upper.CL t.ratio p.value
 year2021 - year2020     9.27 2.66 488     4.05    14.49   3.490  0.0005

Confidence level used: 0.95
```

How about inferences for the *average* difference across areas?

```r
emmeans(regrid(pairs(regrid(tmp, type = "response"), reverse = TRUE)), ~1)
```

```
 1       estimate   SE  df lower.CL upper.CL
 overall     7.16 1.86 488     3.51     10.8

Results are averaged over the levels of: area
Confidence level used: 0.95
```

Tricky!

How much does the expected tick density increase between, say, the first day of October and November?

```r
emmeans(m, ~ day | year * area, at = list(day = c(d11,d10)),
  data = ticks, type = "response")
```

```
year = 2020, area = North:
 day  rate    SE  df lower.CL upper.CL
 305 36.34  6.56 488    25.49    51.82
 274  9.33  1.94 488     6.20    14.04

year = 2021, area = North:
 day  rate    SE  df lower.CL upper.CL
 305 69.95 11.98 488    49.95    97.95
 274 17.96  3.49 488    12.26    26.30

year = 2020, area = North Central:
 day  rate    SE  df lower.CL upper.CL
 305 18.91  4.30 488    12.10    29.56
 274  4.86  1.21 488     2.98     7.92
```

```
year = 2021, area = North Central:
 day  rate    SE  df lower.CL upper.CL
 305 36.40  7.67 488    24.06    55.07
 274  9.34  2.14 488     5.96    14.65

year = 2020, area = Central:
 day  rate    SE  df lower.CL upper.CL
 305 16.86  6.94 488     7.51    37.87
 274  4.33  1.76 488     1.94     9.65

year = 2021, area = Central:
 day  rate    SE  df lower.CL upper.CL
 305 32.46 13.43 488    14.40    73.16
 274  8.33  3.39 488     3.75    18.53

year = 2020, area = Southeast:
 day  rate    SE  df lower.CL upper.CL
 305 33.38  6.06 488    23.36    47.70
 274  8.57  1.81 488     5.66    12.98

year = 2021, area = Southeast:
 day  rate    SE  df lower.CL upper.CL
 305 64.24 10.67 488    46.35    89.03
 274 16.49  3.17 488    11.30    24.07

year = 2020, area = Island Park:
 day  rate    SE  df lower.CL upper.CL
 305 36.87  7.21 488    25.11    54.13
 274  9.47  2.01 488     6.23    14.37

year = 2021, area = Island Park:
 day  rate    SE  df lower.CL upper.CL
 305 70.95 13.13 488    49.33   102.06
 274 18.22  3.60 488    12.36    26.85

Confidence level used: 0.95
Intervals are back-transformed from the log scale
```

```
pairs(emmeans(m, ~ day | year * area, at = list(day = c(d11,d10)),
  data = ticks, type = "response"), infer = TRUE)
```

```
year = 2020, area = North:
 contrast        ratio    SE  df lower.CL upper.CL null t.ratio p.value
 day305 / day274   3.9 0.735 488     2.69     5.64    1   7.211  <.0001

year = 2021, area = North:
 contrast        ratio    SE  df lower.CL upper.CL null t.ratio p.value
 day305 / day274   3.9 0.735 488     2.69     5.64    1   7.211  <.0001

year = 2020, area = North Central:
 contrast        ratio    SE  df lower.CL upper.CL null t.ratio p.value
 day305 / day274   3.9 0.735 488     2.69     5.64    1   7.211  <.0001

year = 2021, area = North Central:
```

```
 contrast        ratio    SE  df lower.CL upper.CL null t.ratio p.value
 day305 / day274   3.9 0.735 488     2.69     5.64    1   7.211  <.0001

year = 2020, area = Central:
 contrast        ratio    SE  df lower.CL upper.CL null t.ratio p.value
 day305 / day274   3.9 0.735 488     2.69     5.64    1   7.211  <.0001

year = 2021, area = Central:
 contrast        ratio    SE  df lower.CL upper.CL null t.ratio p.value
 day305 / day274   3.9 0.735 488     2.69     5.64    1   7.211  <.0001

year = 2020, area = Southeast:
 contrast        ratio    SE  df lower.CL upper.CL null t.ratio p.value
 day305 / day274   3.9 0.735 488     2.69     5.64    1   7.211  <.0001

year = 2021, area = Southeast:
 contrast        ratio    SE  df lower.CL upper.CL null t.ratio p.value
 day305 / day274   3.9 0.735 488     2.69     5.64    1   7.211  <.0001

year = 2020, area = Island Park:
 contrast        ratio    SE  df lower.CL upper.CL null t.ratio p.value
 day305 / day274   3.9 0.735 488     2.69     5.64    1   7.211  <.0001

year = 2021, area = Island Park:
 contrast        ratio    SE  df lower.CL upper.CL null t.ratio p.value
 day305 / day274   3.9 0.735 488     2.69     5.64    1   7.211  <.0001

Confidence level used: 0.95
Intervals are back-transformed from the log scale
Tests are performed on the log scale
```

What about the *difference* in the expected densities (i.e., marginal effects)?

```
tmp <- emmeans(m, ~ day | year * area, at = list(day = c(d11,d10)),
  data = ticks, type = "response")
pairs(regrid(tmp, type = "response"), infer = TRUE)
```

```
year = 2020, area = North:
 contrast        estimate    SE  df lower.CL upper.CL t.ratio p.value
 day305 - day274     27.0  5.76 488    15.69     38.3   4.689  <.0001

year = 2021, area = North:
 contrast        estimate    SE  df lower.CL upper.CL t.ratio p.value
 day305 - day274     52.0 10.78 488    30.80     73.2   4.822  <.0001

year = 2020, area = North Central:
 contrast        estimate    SE  df lower.CL upper.CL t.ratio p.value
 day305 - day274     14.1  3.57 488     7.04     21.1   3.934  0.0001

year = 2021, area = North Central:
 contrast        estimate    SE  df lower.CL upper.CL t.ratio p.value
 day305 - day274     27.1  6.53 488    14.23     39.9   4.146  <.0001

year = 2020, area = Central:
 contrast        estimate    SE  df lower.CL upper.CL t.ratio p.value
```

```
 day305 - day274     12.5  5.42 488     1.88     23.2   2.311  0.0212

year = 2021, area = Central:
 contrast        estimate    SE  df lower.CL upper.CL t.ratio p.value
 day305 - day274     24.1 10.50 488     3.49     44.8   2.297  0.0221

year = 2020, area = Southeast:
 contrast        estimate    SE  df lower.CL upper.CL t.ratio p.value
 day305 - day274     24.8  5.29 488    14.41     35.2   4.687  <.0001

year = 2021, area = Southeast:
 contrast        estimate    SE  df lower.CL upper.CL t.ratio p.value
 day305 - day274     47.7  9.65 488    28.78     66.7   4.946  <.0001

year = 2020, area = Island Park:
 contrast        estimate    SE  df lower.CL upper.CL t.ratio p.value
 day305 - day274     27.4  6.27 488    15.09     39.7   4.372  <.0001

year = 2021, area = Island Park:
 contrast        estimate    SE  df lower.CL upper.CL t.ratio p.value
 day305 - day274     52.7 11.69 488    29.77     75.7   4.511  <.0001

Confidence level used: 0.95
```

Here is the average marginal effect for each year (i.e., averaging across areas).

```
emmeans(regrid(pairs(regrid(tmp, type = "response"))), ~year)
```

```
 year estimate   SE  df lower.CL upper.CL
 2020     21.2 4.00 488     13.3     29.0
 2021     40.7 7.36 488     26.3     55.2

Results are averaged over the levels of: area
Confidence level used: 0.95
```

How fast was the expected tick density increasing on the first day of October? This is an *instantaneous* marginal effect.

```
trtools::margeff(m, delta = 0.001, df = m$df.residual,
  a = list(day = d10 + 0.001, area = unique(ticks$area), year = "2020", size = 100),
  b = list(day = d10, area = unique(ticks$area), year = "2020", size = 100),
  cnames = unique(ticks$area))
```

```
              estimate     se   lower  upper tvalue    df    pvalue
North           0.7546 0.1900 0.38121 1.1280  3.971 488.1 8.238e-05
North Central   0.3927 0.1123 0.17203 0.6133  3.497 488.1 5.140e-04
Central         0.3501 0.1549 0.04583 0.6545  2.261 488.1 2.422e-02
Southeast       0.6930 0.1735 0.35209 1.0339  3.994 488.1 7.490e-05
Island Park     0.7655 0.1942 0.38391 1.1470  3.942 488.1 9.267e-05
```

We can approximate this fairly well with the change in the expected tick density between the first and second days of October.

```
tmp <- emmeans(m, ~ day | year * area, at = list(day = c(d10 + 1, d10), year = "2020"),
  data = ticks, type = "response")
pairs(regrid(tmp, type = "response"), infer = TRUE)
```

```
year = 2020, area = North:
```

```
 contrast        estimate    SE  df lower.CL upper.CL t.ratio p.value
 day275 - day274    0.732 0.185 488   0.3682    1.096   3.953  0.0001

year = 2020, area = North Central:
 contrast        estimate    SE  df lower.CL upper.CL t.ratio p.value
 day275 - day274    0.381 0.109 488   0.1663    0.596   3.487  0.0005

year = 2020, area = Central:
 contrast        estimate    SE  df lower.CL upper.CL t.ratio p.value
 day275 - day274    0.340 0.151 488   0.0437    0.636   2.255  0.0246

year = 2020, area = Southeast:
 contrast        estimate    SE  df lower.CL upper.CL t.ratio p.value
 day275 - day274    0.672 0.168 488   0.3416    1.003   3.995  0.0001

year = 2020, area = Island Park:
 contrast        estimate    SE  df lower.CL upper.CL t.ratio p.value
 day275 - day274    0.743 0.189 488   0.3714    1.114   3.931  0.0001

Confidence level used: 0.95
```

Finally consider a comparison of areas.

```
pairs(emmeans(m, ~area | year, at = list(day = d10), type = "response",
  data = ticks), adjust = "none")
```

```
year = 2020:
 contrast                    ratio    SE  df null t.ratio p.value
 North / North Central       1.922 0.448 488    1   2.804  0.0053
 North / Central             2.155 0.888 488    1   1.864  0.0629
 North / Southeast           1.089 0.211 488    1   0.440  0.6603
 North / Island Park         0.986 0.197 488    1  -0.071  0.9431
 North Central / Central     1.121 0.485 488    1   0.265  0.7913
 North Central / Southeast   0.567 0.131 488    1  -2.461  0.0142
 North Central / Island Park 0.513 0.122 488    1  -2.801  0.0053
 Central / Southeast         0.505 0.209 488    1  -1.653  0.0990
 Central / Island Park       0.457 0.189 488    1  -1.890  0.0594
 Southeast / Island Park     0.905 0.179 488    1  -0.503  0.6151

year = 2021:
 contrast                    ratio    SE  df null t.ratio p.value
 North / North Central       1.922 0.448 488    1   2.804  0.0053
 North / Central             2.155 0.888 488    1   1.864  0.0629
 North / Southeast           1.089 0.211 488    1   0.440  0.6603
 North / Island Park         0.986 0.197 488    1  -0.071  0.9431
 North Central / Central     1.121 0.485 488    1   0.265  0.7913
 North Central / Southeast   0.567 0.131 488    1  -2.461  0.0142
 North Central / Island Park 0.513 0.122 488    1  -2.801  0.0053
 Central / Southeast         0.505 0.209 488    1  -1.653  0.0990
 Central / Island Park       0.457 0.189 488    1  -1.890  0.0594
 Southeast / Island Park     0.905 0.179 488    1  -0.503  0.6151

Tests are performed on the log scale
```

Due to an absence of interactions involving area, neither year or day matter.

```r
pairs(emmeans(m, ~area, type = "response", data = ticks), adjust = "none")
```

```
 contrast                    ratio    SE  df null t.ratio p.value
 North / North Central       1.922 0.448 488    1   2.804  0.0053
 North / Central             2.155 0.888 488    1   1.864  0.0629
 North / Southeast           1.089 0.211 488    1   0.440  0.6603
 North / Island Park         0.986 0.197 488    1  -0.071  0.9431
 North Central / Central     1.121 0.485 488    1   0.265  0.7913
 North Central / Southeast   0.567 0.131 488    1  -2.461  0.0142
 North Central / Island Park 0.513 0.122 488    1  -2.801  0.0053
 Central / Southeast         0.505 0.209 488    1  -1.653  0.0990
 Central / Island Park       0.457 0.189 488    1  -1.890  0.0594
 Southeast / Island Park     0.905 0.179 488    1  -0.503  0.6151

Results are averaged over the levels of: year
Tests are performed on the log scale
```

How about *differences* in the expected density (here day and year matter)?

```r
tmp <- emmeans(m, ~area | year, at = list(day = d10), type = "response", data = ticks)
pairs(regrid(tmp, type = "response"), infer = TRUE, adjust = "none")
```

```
year = 2020:
 contrast                    estimate   SE  df lower.CL upper.CL t.ratio p.value
 North - North Central          4.475 1.71 488     1.12    7.831   2.620  0.0091
 North - Central                5.001 2.30 488     0.49    9.512   2.178  0.0299
 North - Southeast              0.762 1.74 488    -2.65    4.173   0.439  0.6610
 North - Island Park           -0.134 1.88 488    -3.83    3.565  -0.071  0.9431
 North Central - Central        0.526 1.93 488    -3.26    4.316   0.273  0.7853
 North Central - Southeast     -3.713 1.59 488    -6.83   -0.594  -2.339  0.0198
 North Central - Island Park   -4.610 1.79 488    -8.12   -1.097  -2.578  0.0102
 Central - Southeast           -4.239 2.21 488    -8.59    0.110  -1.915  0.0560
 Central - Island Park         -5.135 2.35 488    -9.75   -0.519  -2.186  0.0293
 Southeast - Island Park       -0.896 1.79 488    -4.42    2.624  -0.500  0.6172

year = 2021:
 contrast                    estimate   SE  df lower.CL upper.CL t.ratio p.value
 North - North Central          8.613 3.27 488     2.18   15.046   2.631  0.0088
 North - Central                9.625 4.32 488     1.15   18.105   2.230  0.0262
 North - Southeast              1.466 3.35 488    -5.11    8.044   0.438  0.6616
 North - Island Park           -0.259 3.62 488    -7.38    6.860  -0.071  0.9431
 North Central - Central        1.012 3.70 488    -6.26    8.283   0.274  0.7846
 North Central - Southeast     -7.147 3.01 488   -13.06   -1.230  -2.373  0.0180
 North Central - Island Park   -8.872 3.41 488   -15.57   -2.174  -2.602  0.0095
 Central - Southeast           -8.159 4.14 488   -16.30   -0.019  -1.969  0.0495
 Central - Island Park         -9.884 4.40 488   -18.53   -1.234  -2.245  0.0252
 Southeast - Island Park       -1.725 3.45 488    -8.51    5.057  -0.500  0.6175

Confidence level used: 0.95
```