ESM 232 Assignment 7

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Rabbits and Hawks Population Matrix Assignment

```r
source("evolve_pop2.R")

# fertility rates
f1 = 0
f2 = 2/2 # have to divide by two because only women are fertile
f3 = 6/2
f4 = 1/2

# survivability
p01 = 0.8
p12 = 0.85
p23 = 0.65
p34 = 0.1

# initial population parameters
ini = c(0,0,10,0)
nyears = 20
fert_rabbits = c(f1,f2,f3,f4)
surv_rabbits = c(p01,p12,p23,p34)
rabbit_pop=evolve_pop2(fert_rabbits, surv_rabbits, ini, nyears)

head(rabbit_pop)
```

```
## $popbyage
##      [,1] [,2]  [,3]   [,4]    [,5]     [,6]      [,7]      [,8]      [,9]
## [1,]    0 30.0  3.25 24.325 63.8325 32.72325 102.07058 161.91088 163.07027
## [2,]    0  0.0 24.00  2.600 19.4600 51.06600  26.17860  81.65646 129.52871
## [3,]   10  0.0  0.00 20.400  2.2100 16.54100  43.40610  22.25181  69.40799
## [4,]    0  6.5  0.65  0.065 13.2665  2.76315  11.02797  29.31676  17.39535
##          [,10]     [,11]     [,12]     [,13]     [,14]     [,15]     [,16]
## [1,] 346.45036 484.18178 647.94868 1133.9552 1586.6404 2344.0387 3737.2835
## [2,] 130.45622 277.16028 387.34543  518.3589  907.1641 1269.3123 1875.2310
## [3,] 110.09940 110.88778 235.58624  329.2436  440.6051  771.0895 1078.9155
## [4,]  46.85473  76.25008  79.70207  161.1013  230.1185  309.4052  532.1487
##          [,17]    [,18]     [,19]     [,20]
## [1,] 5378.0517 8148.921 12482.258 18371.878
## [2,] 2989.8268 4302.441  6519.137  9985.806
```

```
## [3,] 1593.9463 2541.353  3657.075  5541.266
## [4,]  754.5099 1111.516  1763.031  2553.402
##
## $poptot
##  [1]    10.0000    36.5000    27.9000    47.3900    98.7690   103.0934
##  [7]   182.6832   295.1359   379.4023   633.8607   948.4799  1350.5824
## [13]  2142.6590  3164.5281  4693.8457  7223.5786 10716.3348 16104.2309
## [19] 24421.5004 36452.3518
```

Matrix population model result:

After 20 years and an initial population of 10 adult (age 2-3) rabbits, there are about 36,452 rabbits in the total population, with about 18,372 rabbits in the young (0-1) age class.

Sobel sensitivity analysis

We use Sobel to explore how the intervention of encouraging nesting of hawks that eat rabbits might impact the rabbit population. We also account for uncertainty in our survivability parameters.

```
library(sensitivity)
```

```
## Warning: package 'sensitivity' was built under R version 3.6.2
```

```
## Registered S3 method overwritten by 'sensitivity':
##   method    from
##   print.src dplyr
```

```
##
## Attaching package: 'sensitivity'
```

```
## The following object is masked from 'package:dplyr':
##
##     src
```

```
## The following object is masked from 'package:tidyr':
##
##     extract
```

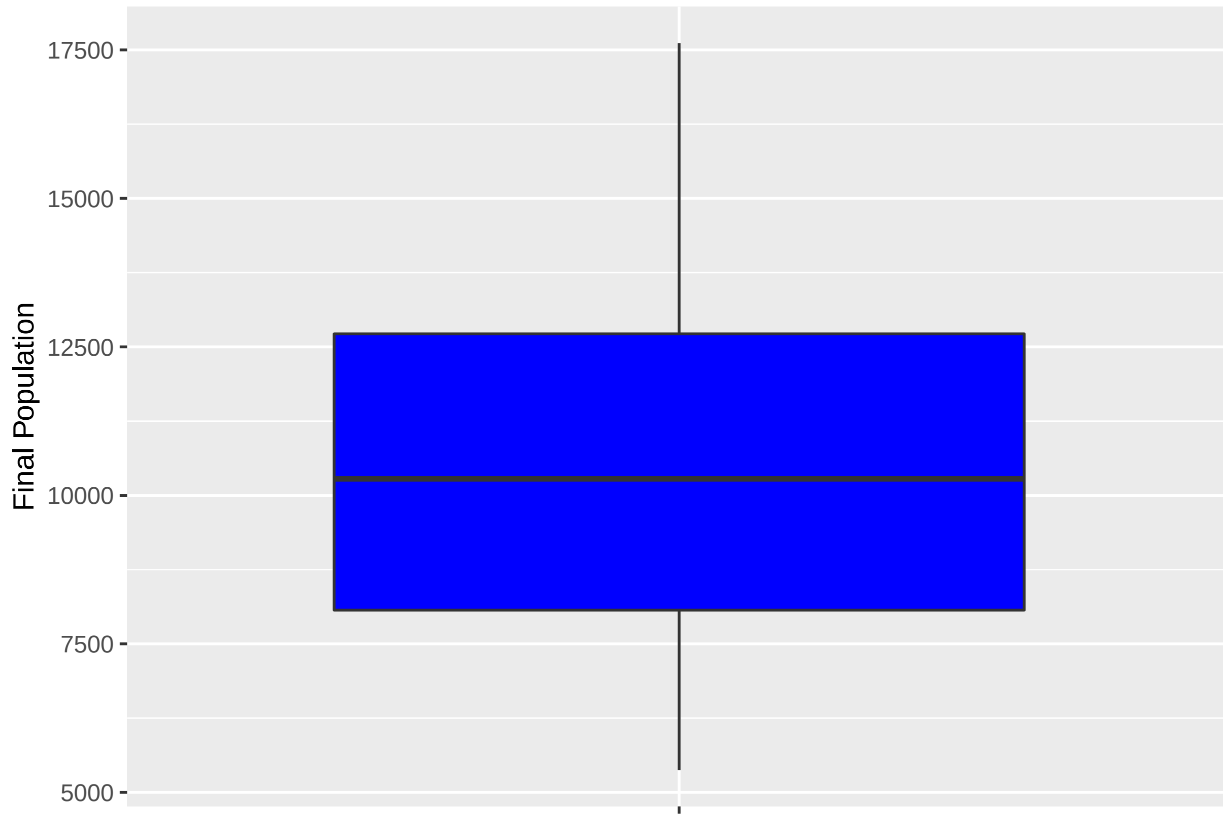
```
# survivability
nsample=200

# create our two samples for Sobel
# first do our survivability
ps1 = cbind.data.frame(p01 = runif(min=0.65, max=0.75, n=nsample),
                       p12 = runif(min=0.75, max=0.8, n=nsample),
                       p23 = runif(min=0.65, max=0.65, n=nsample),
                       p34 = runif(min=0.1, max=0.1, n=nsample))

ps2 = cbind.data.frame(p01=runif(min=0.65, max=0.75, n=nsample),
                       p12 = runif(min=0.75, max=0.8, n=nsample),
                       p23 = runif(min=0.65, max=0.65, n=nsample),
```

```
                        p34 = runif(min=0.1, max=0.1, n=nsample))

# then fertility
fs1 = cbind.data.frame(f1 = 0,
                        f2 = 1,
                        f3 = 3,
                        f4 = 0.5)

# put survivability and fertility together
allp1 = cbind.data.frame(ps1,fs1)
allp2 = cbind.data.frame(ps2,fs1)

# get sobel samples
sens_rabbit=soboljansen(model = NULL, allp1, allp2, nboot = 100)

head(sens_rabbit$X)
```

```
##         p01       p12  p23 p34 f1 f2 f3  f4
## 1 0.7259617 0.7826044 0.65 0.1  0  1  3 0.5
## 2 0.6749311 0.7978959 0.65 0.1  0  1  3 0.5
## 3 0.6586632 0.7849857 0.65 0.1  0  1  3 0.5
## 4 0.7281128 0.7855936 0.65 0.1  0  1  3 0.5
## 5 0.7224200 0.7646907 0.65 0.1  0  1  3 0.5
## 6 0.6738952 0.7612208 0.65 0.1  0  1  3 0.5
```

```
nsim=nrow(sens_rabbit$X)

# run model and save what we care about: final population after 20 years
# this is already output by evolve_pop so we don't need a compute_metric function

ini = c(0,0,10,0)
nyears=20

# as before combine our application of the the dynamics model - for each
# parameter set, with code to extract our metric of interest (final population)
p_wrapper = function(p01, p12, p23, p34, f1,f2,f3,f4,use_func, initialpop, nstep ) {
  fertility=c(f1,f2,f3,f4)
  survivability= c(p01,p12,p23,p34)
  res = use_func(survivability =survivability, fertility = fertility, initialpop=initialpop, nstep=nstep
# now return the final population total
  return(finalpop=res$poptot[nstep])
}

# use pmap here so we can specify rows of our sensitivity analysis parameter object
res = as.data.frame(sens_rabbit$X) %>%
  pmap_dbl(p_wrapper, initialpop=ini, nstep=nyears, use_func=evolve_pop2)

# plot results (variation in final population across all parameter)
# ggplot needs a dataframe - so do a quick conversion with data.frame
ggplot(data.frame(finalpop=res),
       aes(x=finalpop))+
  geom_density()
```


```
# boxplot of variation in total rabbit population
ggplot(data.frame(finalpop=res),
       aes(x="", y=finalpop) )+
  geom_boxplot(fill="blue")+
  theme(axis.title.x = element_blank())+
  labs(y="Final Population")
```



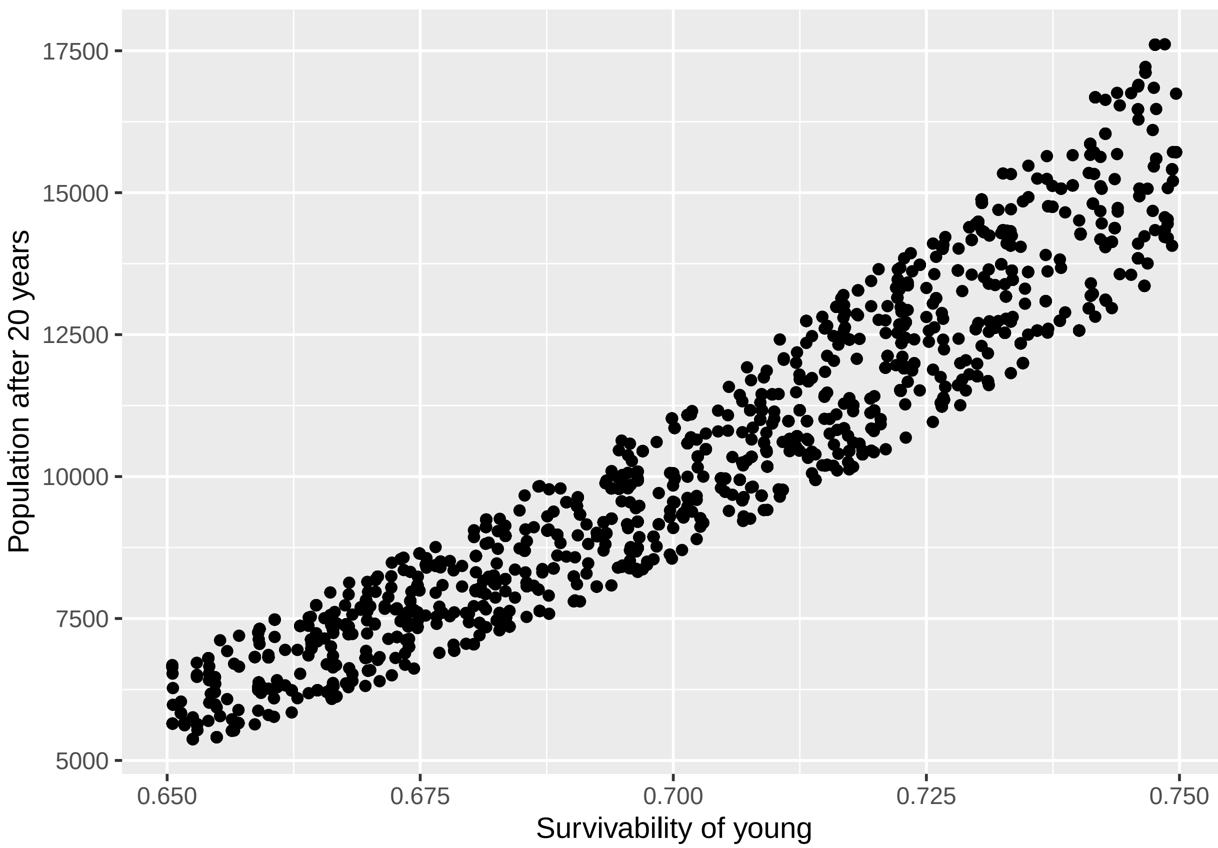

```
# give our results to sensitivity structure
sens_rabbit=tell(sens_rabbit, res)

# look at results
sens_rabbit$S
```

```
##         original          bias std. error  min. c.i.  max. c.i.
## p01  0.92658808 -0.0003154895 0.01158715  0.9077202 0.95376389
## p12 -0.09670074 -0.0097770587 0.10360938 -0.2890134 0.12404084
## p23 -0.12989262 -0.0027962977 0.09670221 -0.3519957 0.08697614
## p34 -0.12989262 -0.0027962977 0.09670221 -0.3519957 0.08697614
## f1  -0.12989262 -0.0027962977 0.09670221 -0.3519957 0.08697614
## f2  -0.12989262 -0.0027962977 0.09670221 -0.3519957 0.08697614
## f3  -0.12989262 -0.0027962977 0.09670221 -0.3519957 0.08697614
## f4  -0.12989262 -0.0027962977 0.09670221 -0.3519957 0.08697614
```

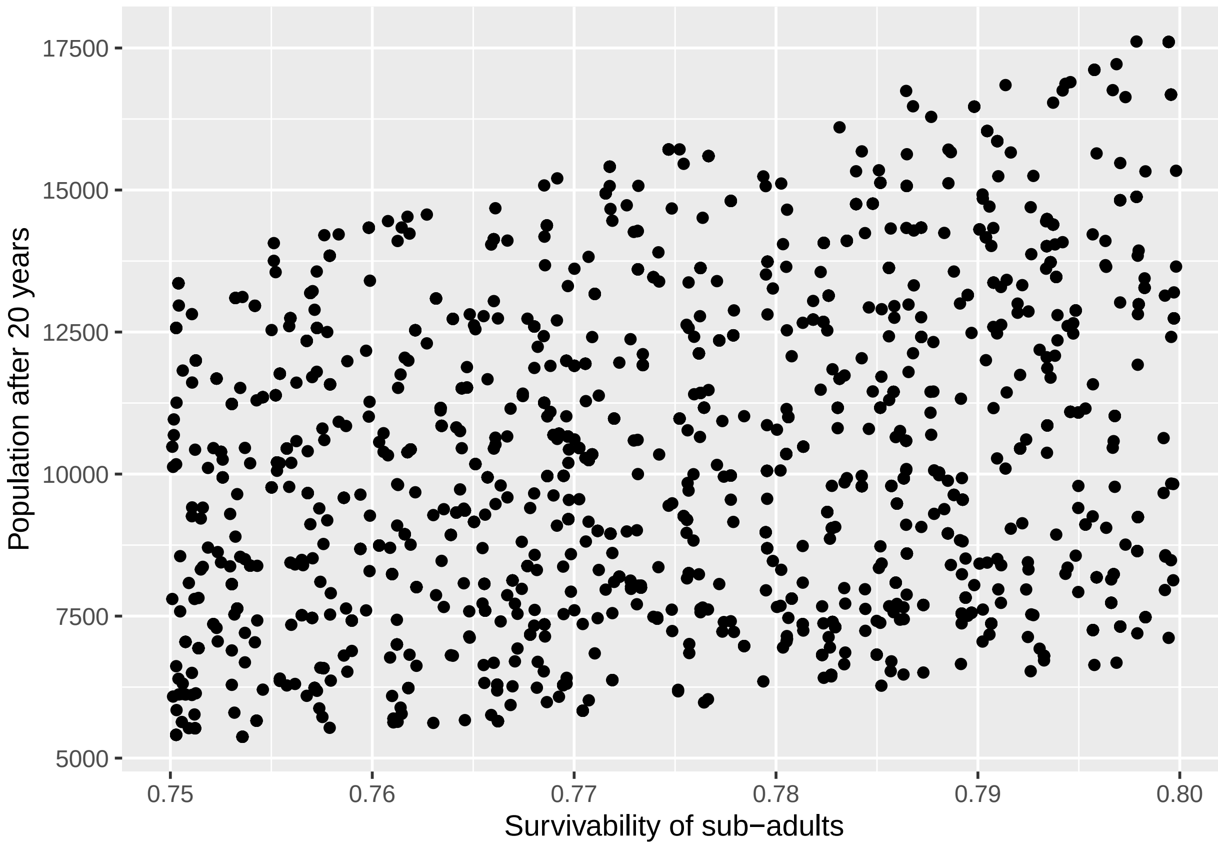
```
sens_rabbit$T
```

```
##        original        bias std. error  min. c.i. max. c.i.
## p01 1.07282049 0.007876005 0.09459102 0.87929335 1.2607356
## p12 0.08286664 0.001374254 0.01344240 0.05062701 0.1026278
## p23 0.00000000 0.000000000 0.00000000 0.00000000 0.0000000
## p34 0.00000000 0.000000000 0.00000000 0.00000000 0.0000000
## f1  0.00000000 0.000000000 0.00000000 0.00000000 0.0000000
## f2  0.00000000 0.000000000 0.00000000 0.00000000 0.0000000
## f3  0.00000000 0.000000000 0.00000000 0.00000000 0.0000000
## f4  0.00000000 0.000000000 0.00000000 0.00000000 0.0000000
```

```r
# Graph how total rabbit population after 20 years varies with survivability of young age and sub-adult
tmp = cbind.data.frame(sens_rabbit$X,
                       pop12=sens_rabbit$y)

# plot of total rabbit population vs. survivability of young
ggplot(tmp, aes(p01, pop12))+
  geom_point()+
  labs(x="Survivability of young",
       y="Population after 20 years")
```




```r
# plot of total rabbit population vs. survivability of sub-adult
ggplot(tmp, aes(p12, pop12))+
  geom_point()+
  labs(x="Survivability of sub-adults",
       y="Population after 20 years")
```


17500
15000
12500
10000
7500
5000
Population after 20 years
0.75
0.76
0.77
0.78
0.79
0.80
Survivability of sub−adults