Structured Population Models

Anoob Prakash & Baxter Worthing

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```
load("COMPADRE_v.4.0.1.RData")
```

Species: *Centaurea horrida*

This is an endagered species according to the IUCN Red List, with two extant population's in Sardinia with about total recorded population size < 12,000. These species posses limited ability to disperse as well as colonize, leading to their limited range. Eventhough it's population is at present stable, it's low population size and limited range puts it under risk of going extinction in case of some drastic changes in the surrounding environment. We would like to see if the species would go extinct in the near future or not. The genus is also of particular interest for the Keller Lab.

```
library(tidyverse)
```

```
## -- Attaching packages --------------------------------------------------------- tidyverse 1.2.1
```

```
## v ggplot2 3.1.0      v purrr   0.2.5
## v tibble  1.4.2      v dplyr   0.7.8
## v tidyr   0.8.2      v stringr 1.3.1
## v readr   1.3.1      v forcats 0.3.0
```

```
## Warning: package 'tidyr' was built under R version 3.5.2
```

```
## Warning: package 'readr' was built under R version 3.5.2
```

```
## Warning: package 'dplyr' was built under R version 3.5.2
```

```
## Warning: package 'forcats' was built under R version 3.5.2
```

```
## -- Conflicts ------------------------------------------------------------- tidyverse_conflicts()
## x dplyr::filter() masks stats::filter()
## x dplyr::lag()    masks stats::lag()
```

```
load("./COMPADRE_v.4.0.1.RData")

grep(compadre$metadata$SpeciesAccepted, pattern = "Centaurea horrida")
```

```
## [1] 1491 1492 1493 1494 1495 1496
```

```
# six entries

#get matrixA from most recent entry

mat1 <- compadre$mat[1496][[1]]$matA
```

this package makes it all much easier

```
#install.packages("demogR")
library(demogR)
```

```
## Warning: package 'demogR' was built under R version 3.5.2
```

first eigenvalue

```r
eigen.analysis(mat1)[1]
```

```
## $lambda1
## [1] 0.8944733
```

stable age distrbution

```r
eigen.analysis(mat1)[5]
```

```
## $stable.age
## [1] 0.11805633 0.16704529 0.02786564 0.27650887 0.41052387
```

elasticities

```r
eigen.analysis(mat1)[4]
```

```
## $elasticities
##               A1          A2           A3           A4          A5
## [1,] 0.000000000 0.000000000 2.076714e-05 0.0005183158 0.003656872
## [2,] 0.004195955 0.018108545 0.000000e+00 0.0000000000 0.000000000
## [3,] 0.000000000 0.004195955 1.260661e-02 0.0040027070 0.000000000
## [4,] 0.000000000 0.000000000 8.177895e-03 0.3007530650 0.026413318
## [5,] 0.000000000 0.000000000 0.000000e+00 0.0300701902 0.587279802
## attr(,"class")
## [1] "leslie.matrix"
```

sensitivities

```r
eigen.analysis(mat1)[3]
```

```
## $sensitivities
##             [,1]       [,2]       [,3]         [,4]       [,5]
## [1,] 0.00000000 0.0000000 0.00099040 0.009827672 0.01459083
## [2,] 0.01576331 0.0223045 0.00000000 0.000000000 0.00000000
## [3,] 0.00000000 0.1247207 0.02080527 0.206449317 0.00000000
## [4,] 0.00000000 0.0000000 0.03379488 0.335344278 0.49787491
## [5,] 0.00000000 0.0000000 0.00000000 0.415816871 0.61734999
## attr(,"class")
## [1] "leslie.matrix"
```

It looks like the survival rate of the oldest individuals (bottom right value) is the most sensitive parameter

Attempt to plot this population through time:

```r
# fuction to find population matrix for given year (t)
modl <- function(L,I,t) {
  N <- L^t %*% I
  return(N)
}

# need an input matrix
# let's say we start with 3 individuals in each class
input <- rep(3,5)

# trying the function

modl(mat1,input,1)
```

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

```
## [1,] 0.8703324
## [2,] 2.8928968
## [3,] 1.7682788
## [4,] 3.1983334
## [5,] 2.7467687
```

```r
# now try to model this population over a longer time scale
# 30 years
tVals <- seq(1,30)

# starting with 90 individuals in each class
input <- rep(90,5)

# iterate model

out <- data_frame(t= tVals,N = tVals)

for (i in 1:length(tVals)) {
out[i,2] <- sum(modl(mat1,input,tVals[i]))
}

# plot population over time

ggplot(out, aes(x=t, y= N)) +
  geom_point()
```
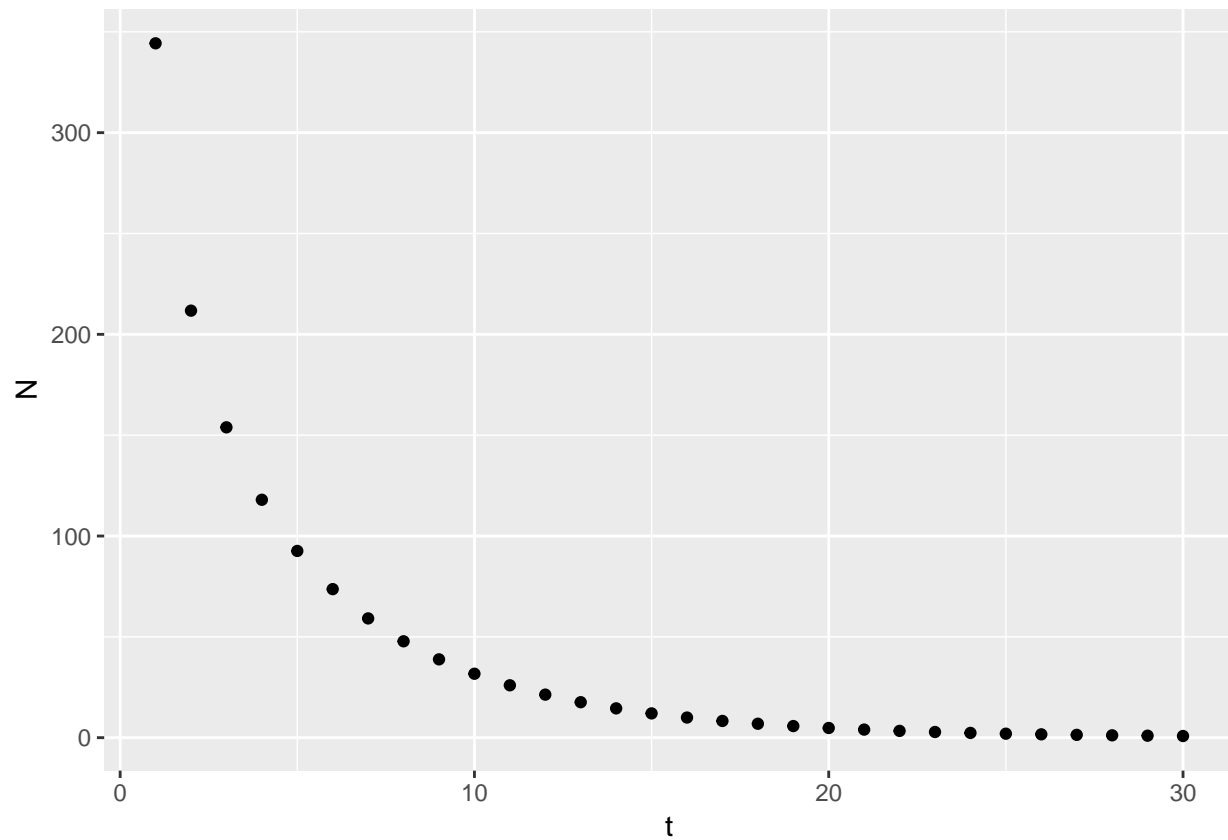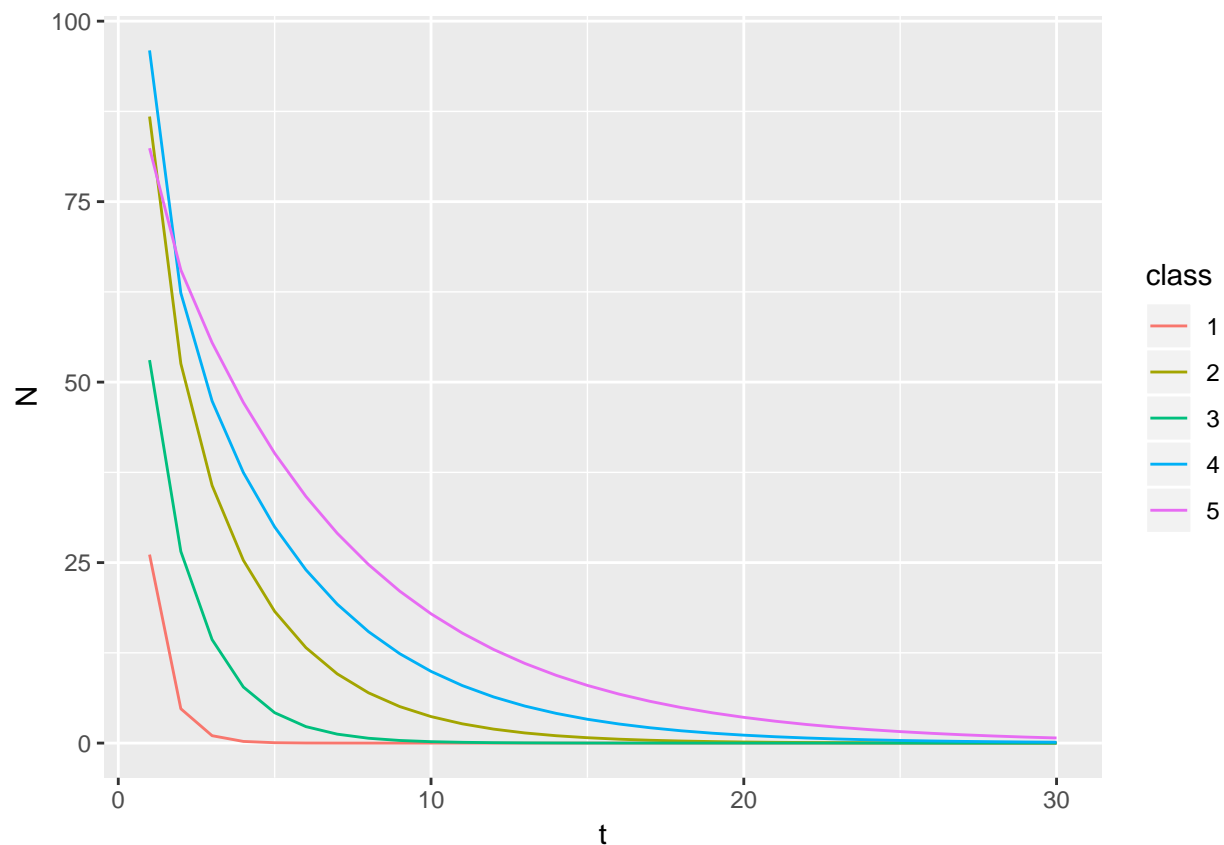

plot each age class over time

```
size <- length(tVals)*5
out2 <- data_frame(t= 1:size, N = 1:size, class = factor(rep(1:5,length(tVals))))
countr <- 0
for (i in 1:length(tVals)) {
  r1 <- countr + i
  r2 <- (countr + i)+4
out2[r1:r2 , 2] <- modl(mat1,input,tVals[i])
# finally make t column
out2[r1:r2, 1] <- rep(i,5)
countr <- countr + 4
}

ggplot(out2, aes(x=t, y= N, color=class)) +
  geom_line() +
  scale_color_discrete()
```


can we find a survival rate for age class 5 that will get the eigenvalue to 1?

```
r8s <- seq(.8509,1.0000,.0005)
evals <- data_frame(rate = r8s, eigenvalue = 1:length(r8s))
for (i in 1:length(r8s)) {
  mat <- mat1
  mat[5,5] <- r8s[i]
  evals[i,1] <- r8s[i]
  evals[i,2] <- eigen.analysis(mat)[1]
}
```

```r
filter(evals, eigenvalue >= 1)
```

```
## # A tibble: 35 x 2
##      rate eigenvalue
##     <dbl>      <dbl>
##  1 0.983       1.00
##  2 0.983       1.00
##  3 0.984       1.00
##  4 0.984       1.00
##  5 0.985       1.00
##  6 0.985       1.00
##  7 0.986       1.00
##  8 0.986       1.00
##  9 0.987       1.00
## 10 0.987       1.00
## # ... with 25 more rows
```

So, conservationists would need to get the survival rate of the 5th age class up to .983 to even out this population's projected decine

plotting age classes over time with this new survival rate

```r
# update matrix
mat2 <- mat1
mat2[5,5] <- 0.983


#same as above but now using mat2  rather than mat1

size <- length(tVals)*5
out2 <- data_frame(t= 1:size, N = 1:size, class = factor(rep(1:5,length(tVals))))
countr <- 0
for (i in 1:length(tVals)) {
  r1 <- countr + i
  r2 <- (countr + i)+4
out2[r1:r2 , 2] <- modl(mat2,input,tVals[i])
# finally make t column
out2[r1:r2, 1] <- rep(i,5)
countr <- countr + 4
}

ggplot(out2, aes(x=t, y= N, color=class)) +
  geom_line() +
  scale_color_discrete()
```
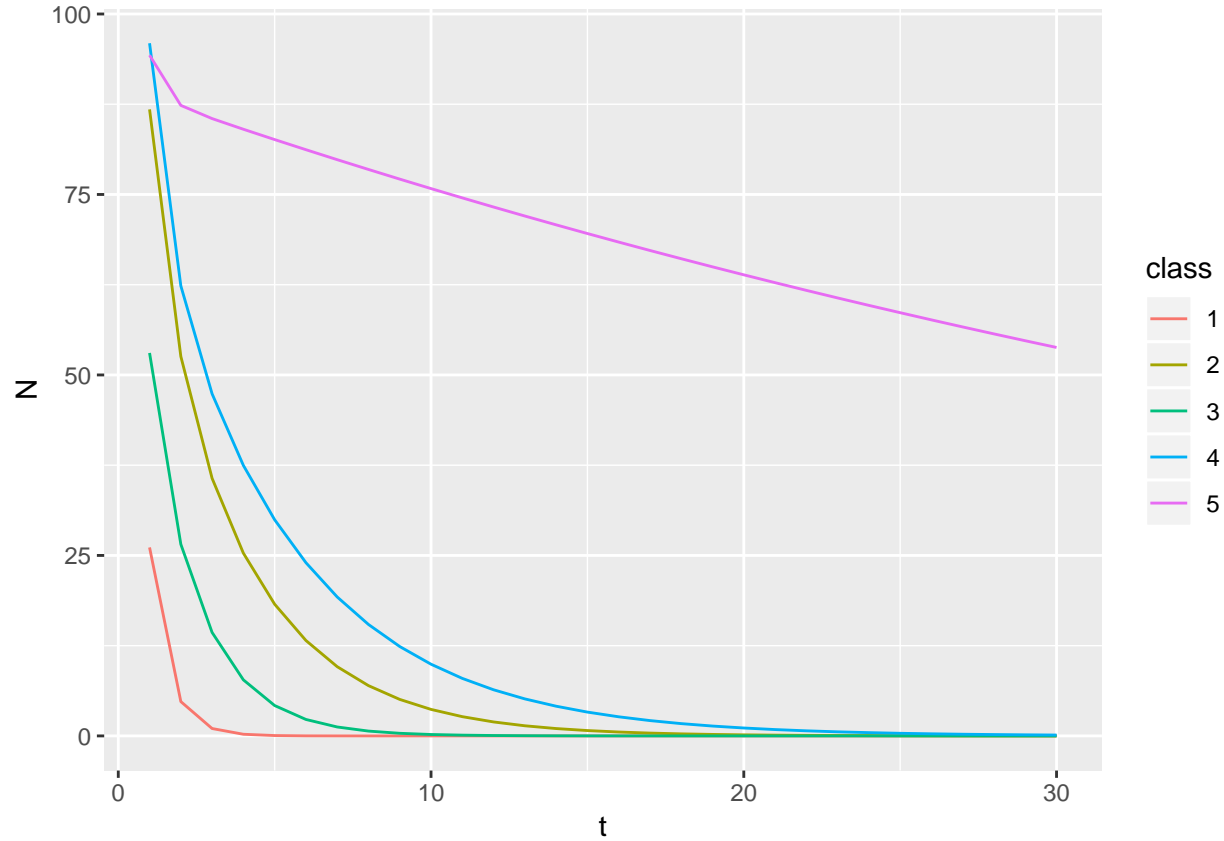
Centaurea horrida is a species that eventhough listed by IUCN as stable at present, have high probability of going extinct due to its limited range and distribution. From the analysis, it is clear that the species is facing exponential decay ($\lambda \leq 1$) over a relatively short time period.

Farris *et al.* (2009) observed that low-intensity agro–sylvo–pastoral activies are beneficial to the conservation of this species along the rocky cliff's (natural habitat) of Sardinia, Italy. In light of our findings, if these efforts were aimed towards the conservation of the most sensitive age class, it would greatly assist in raising its eigen value ≥ 1 (exponential growth).

References

Farris, E., Pisanu, S., Ceccherelli, G., and Filigheddu. R. 2009. Effects of the management regime on the performance of the endangered Mediterranean Centaurea horrida Badarò (Asteraceae). Journal for Nature Conservation, 17(1): 15-24.