vulture_population_matrix.R

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```r
# Matrix Population Models for White-backed Vultures
```

```r
# clean everything first
rm(list=ls())

# load required packages
library(popbio)
```

```
## Warning: package 'popbio' was built under R version 3.2.5
```

```r
library(diagram)
```

```
## Warning: package 'diagram' was built under R version 3.2.5

## Loading required package: shape
```

```r
# fecundity calculation
bp <- 0.85 # breeding propensity
cs <- 1 # clutch size
hs <- 0.75 # hatching success
fs <- 0.6 # fledging success
fecundity <- bp * (cs/2) * hs * fs # divide by 2 to get females only
```

```r
#               KRUGER
```

```r
fsKr <- 0.42 # first year survival
jsKr <- 0.7644702 # juvenile survival Kruger
ssKr <- 0.9256097 # subadult survival Kruger
asKr <- 0.9698704 # adult survival Kruger

# survival this year is multiplied by fecundity next year because in this model
# the birds have to survive the year before they become breeders i.e. from 4 years old to
# breeding age at 5 years old

# for Kruger

ssfKr <- ssKr * fecundity
asfKr <- asKr * fecundity

# create the matrix for Kruger
MKr <- c(0,0,0,0,ssfKr,asfKr,
         fsKr,0,0,0,0,0,
         0,jsKr,0,0,0,0,
         0,0,jsKr,0,0,0,
```

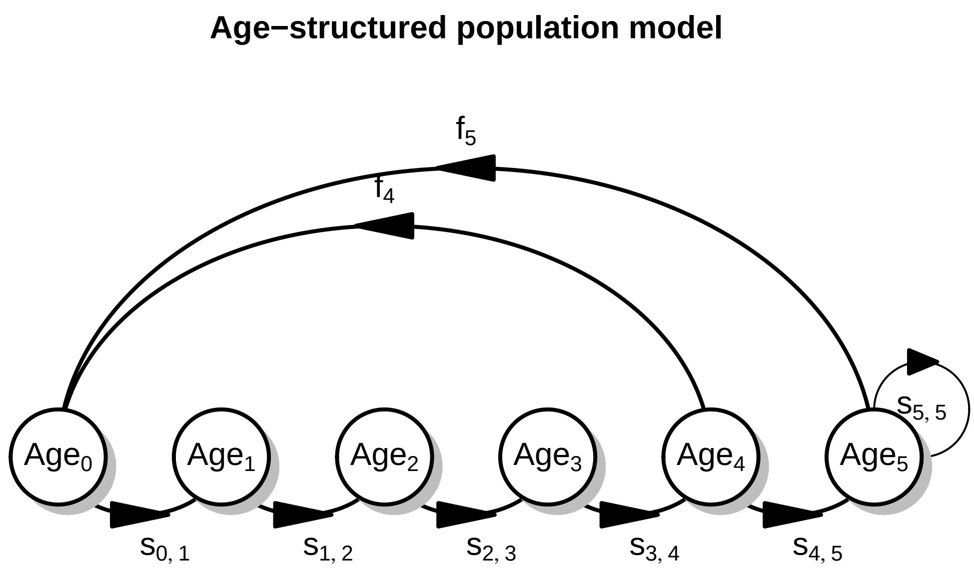
```r
         0,0,0,ssKr,0,0,
         0,0,0,0,ssKr,asKr
)
MKr <- matrix ((MKr), ncol=6, byrow = TRUE)
colnames(MKr) <- c("babies","1yr olds","2yr olds","3yr olds","4yr olds","5yr olds")
MKr
```

```
##      babies  1yr olds  2yr olds  3yr olds  4yr olds  5yr olds
## [1,]   0.00 0.0000000 0.0000000 0.0000000 0.1770229 0.1854877
## [2,]   0.42 0.0000000 0.0000000 0.0000000 0.0000000 0.0000000
## [3,]   0.00 0.7644702 0.0000000 0.0000000 0.0000000 0.0000000
## [4,]   0.00 0.0000000 0.7644702 0.0000000 0.0000000 0.0000000
## [5,]   0.00 0.0000000 0.0000000 0.9256097 0.0000000 0.0000000
## [6,]   0.00 0.0000000 0.0000000 0.0000000 0.9256097 0.9698704
```

```r
# the process looks like the diagram with the nodes representing the age classes
# Create population matrix
#
par(mfrow=c(1,1))

Numgenerations <- 6
DiffMat <- matrix(data = 0, nrow = Numgenerations, ncol = Numgenerations)
AA <- as.data.frame(DiffMat)
AA[[1,5]] <- "f[4]"
AA[[1,6]] <- "f[5]"
#
AA[[2,1]] <- "s[list(0,1)]"
AA[[3,2]] <- "s[list(1,2)]"
AA[[4,3]] <- "s[list(2,3)]"
AA[[5,4]] <- "s[list(3,4)]"
AA[[6,5]] <- "s[list(4,5)]"
AA[[6,6]] <- "s[list(5,5)]"

#
name <- c(expression(Age[0]), expression(Age[1]), expression(Age[2]),
          expression(Age[3]), expression(Age[4]), expression(Age[5]))
#
plotmat(A = AA, pos = 6, curve = 0.7, name = name, lwd = 2,
        arr.len = 0.6, arr.width = 0.25, my = -0.2,
        box.size = 0.05, arr.type = "triangle", dtext = 0.95,
        main = "Age-structured population model",
        relsize=0.97)
```




```
# Population sizes at each age from Kruger

# Murn estimates 904 pairs of breeding adults
# Assume an additional 0.3 immature and non-breeding birds per pair
# Remember, we're only modelling females
additionalPopKr <- 904 * 0.3
totalPopKr <- 904*2 + additionalPopKr # = Murn's estimate
# divide additional population among the 5 non-adult categories
# (Note: do we want some of these included among the adults as adult aged non-breeders?)
additionalPopKr / 5 / 2
```

```
## [1] 27.12
```

```
nKR<-c(27, 27, 27, 27, 27, 904)
nKR<-matrix (nKR, ncol=1)
nKR
```

```
##      [,1]
## [1,]   27
## [2,]   27
## [3,]   27
## [4,]   27
## [5,]   27
## [6,]  904
```

```r
# previous function is wrapped up into pop.projection
popModelKr <- pop.projection(MKr,nKR,iterations=40)

# Calculate population growth rate and other demographic parameters from a projection matrix model
# using matrix algebra
eigen.analysis(MKr, zero=TRUE)
```

```
## $lambda1
## [1] 1.008717
##
## $stable.stage
## [1] 0.13478416 0.05612016 0.04253145 0.03223306 0.02957741 0.70475376
##
## $sensitivities
##           babies   1yr olds   2yr olds   3yr olds    4yr olds  5yr olds
## [1,] 0.00000000 0.00000000 0.00000000 0.00000000 0.007322861 0.1744850
## [2,] 0.08014556 0.00000000 0.00000000 0.00000000 0.000000000 0.0000000
## [3,] 0.00000000 0.04403198 0.00000000 0.00000000 0.000000000 0.0000000
## [4,] 0.00000000 0.00000000 0.04403198 0.00000000 0.000000000 0.0000000
## [5,] 0.00000000 0.00000000 0.00000000 0.03636644 0.000000000 0.0000000
## [6,] 0.00000000 0.00000000 0.00000000 0.00000000 0.034965947 0.8331487
##
## $elasticities
##           babies   1yr olds   2yr olds   3yr olds    4yr olds   5yr olds
## [1,] 0.00000000 0.00000000 0.00000000 0.00000000 0.001285112 0.03208514
## [2,] 0.03337025 0.00000000 0.00000000 0.00000000 0.000000000 0.00000000
## [3,] 0.00000000 0.03337025 0.00000000 0.00000000 0.000000000 0.00000000
## [4,] 0.00000000 0.00000000 0.03337025 0.00000000 0.000000000 0.00000000
## [5,] 0.00000000 0.00000000 0.00000000 0.03337025 0.000000000 0.00000000
## [6,] 0.00000000 0.00000000 0.00000000 0.00000000 0.032085140 0.80106360
##
## $repro.value
## [1] 1.000000 2.401707 3.169047 4.181550 4.556996 4.774902
##
## $damping.ratio
## [1] 2.114052
```

```r
#                KZN
```

```r
fsKZN <- 0.42 # first year survival
jsKZN <-  0.9813814 # juvenile survival KZN
ssKZN <- 0.6928154 # subadult survival KZN
asKZN <- 0.5082008 # adult survival KZN

# survival this year is multiplied by fecundity next year because in this model
# the birds have to survive the year before they become breeders i.e. from 4 years old to
# breeding age at 5 years old

# for KZN

ssfKZN <- ssKZN * fecundity
asfKZN <- asKZN * fecundity
```

```r
# create the matrix for KZN
MKZN <- c(0,0,0,0,ssfKZN,asfKZN,
          fsKZN,0,0,0,0,0,
          0,jsKZN,0,0,0,0,
          0,0,jsKZN,0,0,0,
          0,0,0,ssKZN,0,0,
          0,0,0,0,ssKZN,asKZN
)
MKZN <- matrix ((MKZN), ncol=6, byrow = TRUE)
colnames(MKZN) <- c("babies","1yr olds","2yr olds","3yr olds","4yr olds","5yr olds")
MKZN
```

```
##      babies  1yr olds  2yr olds  3yr olds  4yr olds  5yr olds
## [1,]   0.00 0.0000000 0.0000000 0.0000000 0.1325009 0.0971934
## [2,]   0.42 0.0000000 0.0000000 0.0000000 0.0000000 0.0000000
## [3,]   0.00 0.9813814 0.0000000 0.0000000 0.0000000 0.0000000
## [4,]   0.00 0.0000000 0.9813814 0.0000000 0.0000000 0.0000000
## [5,]   0.00 0.0000000 0.0000000 0.6928154 0.0000000 0.0000000
## [6,]   0.00 0.0000000 0.0000000 0.0000000 0.6928154 0.5082008
```

```r
# Population sizes at each age from KZN

# Rushworth estimates 319 pairs of breeding adults
# Assume an additional 0.3 immature and non-breeding birds per pair
# Remember, we're only modelling females
additionalPopKZN <- 319 * 0.3
totalPopKZN <- 319*2 + additionalPopKZN # < Rushworth's estimate
# divide additional population among the 5 non-adult categories
# (Note: do we want some of these included among the adults as adult aged non-breeders?)
additionalPopKZN / 5 / 2
```

```
## [1] 9.57
```

```r
# this value is too low to reach the estimated 900 birds, instead we subtract the breeding population
# from the total pop estimate and divide the remainder up among the other 5 age categories
# Rushworth assumes there are between 800 and 900 birds in total in KZN, taking the 900 value
(900-319*2)/5/2
```

```
## [1] 26.2
```

```r
nKZN<-c(26, 26, 26, 26, 26, 319)
nKZN<-matrix (nKZN, ncol=1)
nKZN
```

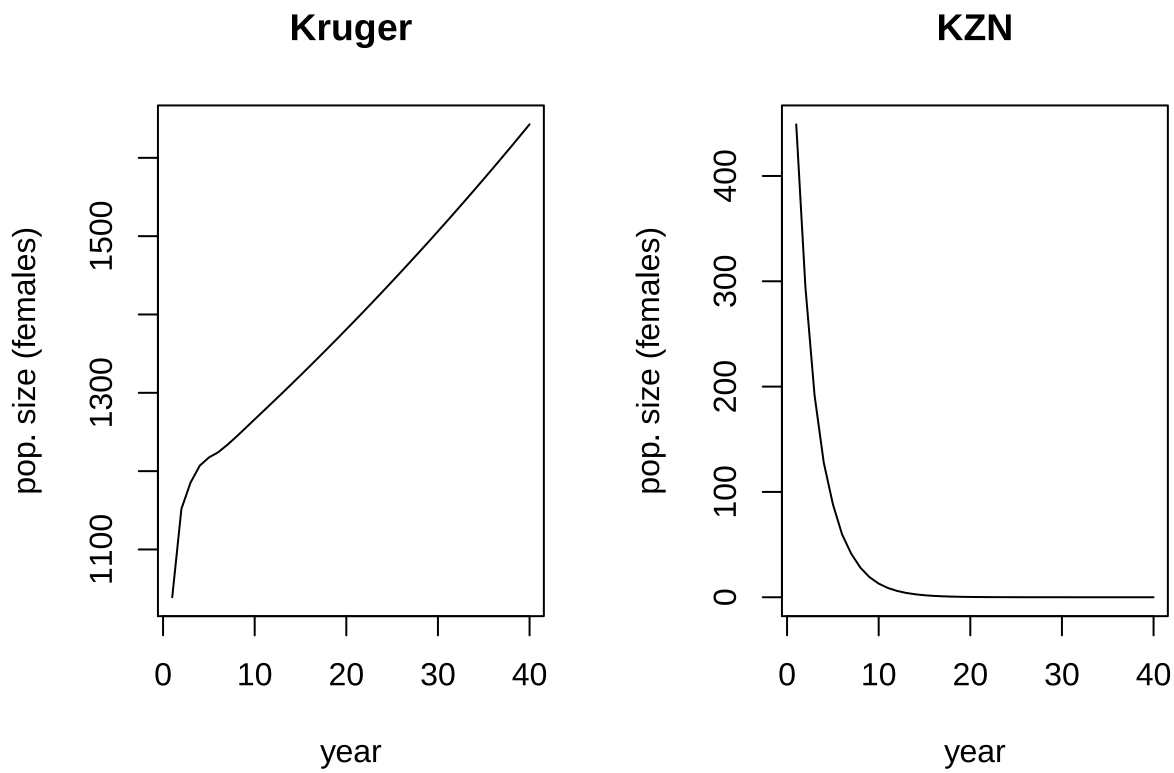
```
##      [,1]
## [1,]   26
## [2,]   26
## [3,]   26
## [4,]   26
## [5,]   26
## [6,]  319
```

```r
# pop.projection function
popModelKZN <- pop.projection(MKZN,nKZN,iterations=40)

# Calculate population growth rate and other demographic parameters from a projection matrix model
# using matrix algebra
eigen.analysis(MKZN, zero=TRUE)
```

```
## $lambda1
## [1] 0.6809272
##
## $stable.stage
## [1] 0.09690547 0.05977188 0.08614578 0.12415699 0.12632463 0.50669526
##
## $sensitivities
##         babies   1yr olds   2yr olds  3yr olds   4yr olds  5yr olds
## [1,] 0.000000 0.00000000 0.00000000 0.0000000 0.16413352 0.6583489
## [2,] 0.204131 0.00000000 0.00000000 0.0000000 0.00000000 0.0000000
## [3,] 0.000000 0.08736156 0.00000000 0.0000000 0.00000000 0.0000000
## [4,] 0.000000 0.00000000 0.08736156 0.0000000 0.00000000 0.0000000
## [5,] 0.000000 0.00000000 0.00000000 0.1237487 0.00000000 0.0000000
## [6,] 0.000000 0.00000000 0.00000000 0.0000000 0.09235818 0.3704539
##
## $elasticities
##          babies  1yr olds  2yr olds  3yr olds   4yr olds   5yr olds
## [1,] 0.0000000 0.0000000 0.0000000 0.0000000 0.03193858 0.09397064
## [2,] 0.1259092 0.0000000 0.0000000 0.0000000 0.00000000 0.00000000
## [3,] 0.0000000 0.1259092 0.0000000 0.0000000 0.00000000 0.00000000
## [4,] 0.0000000 0.0000000 0.1259092 0.0000000 0.00000000 0.00000000
## [5,] 0.0000000 0.0000000 0.0000000 0.1259092 0.00000000 0.00000000
## [6,] 0.0000000 0.0000000 0.0000000 0.0000000 0.09397064 0.27648325
##
## $repro.value
## [1] 1.0000000 1.6212552 1.1249009 0.7805076 0.7671146 0.5627015
##
## $damping.ratio
## [1] 1.314004
```

```r
# Plot the data
# create panel plot to show the population trends of both populations side by side
par(mfrow=c(1,2))
plot(popModelKr$pop.sizes, type="l", xlab = "year", ylab = "pop. size (females)", main = "Kruger")
plot(popModelKZN$pop.sizes, type="l", xlab = "year", ylab = "pop. size (females)", main = "KZN")
```


Kruger
pop. size (females)
1100
1300
1500
0
10
20
30
40
year
KZN
pop. size (females)
0
100
200
300
400
0
10
20
30
40
year