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##### R Code for 'Population Dynamics' #####
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# https://compadre-db.org/Education/article/population-dynamics
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# Compiled on 9 February 2021
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##### Preliminaries #####
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# Use the command install.packages("popdemo") if you haven't already  
# downloaded the package
```

```
library(popdemo) # Activates the package once installed in your library
```

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##### Deterministic models #####
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```
# Add data  
data(Tort)  
Tort
```

```
# Choose a vector  
vec <- runif(8)
```

```
# Project to 50 time intervals  
Tortp <- project(Tort, vec, time = 50, standard.vec = TRUE)  
Tortp
```

```
# Observe population vectors  
vec(Tortp)[1:3,] # Here, we've limited the display to rows 1-3
```

```
# Plot population  
plot(Tortp, log = "y")
```

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##### Asymptotic dynamics #####
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```
# Calculate dominant eigenvalue and eigenvectors  
eigs(Tort, "all")
```

```
# Project to 50 time intervals with vector 'w'  
Tortw <- eigs(Tort, "ss")  
Tortpw <- project(Tort, Tortw, time = 50)
```

```
# Plot population  
plot(Tortp, log = "y")  
lines(0:50, Tortpw, lty = 2) # This line adds to the plot our recently projected population with the stable ratios
```

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##### Transient dynamics #####
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# Plot standardizations
Tortps <- project(Tort, vec, time = 50,
                 standard.A = TRUE, standard.vec = TRUE)

Tortpws <- project(Tort, Tortw, time = 50,
                  standard.A = TRUE, standard.vec = TRUE)

plot(Tortps, log = "y")
lines(Tortpws, lty = 2)

# Calculate damping ratio
dr(Tort)

##### Transient indices #####

# Create sample populations
TortAMP <- c(1, 1, 2, 3, 5, 8, 13, 21) # A population that amplifies
TortATT <- c(21, 13, 8, 5, 3, 2, 1, 1) # A population that attenuates
TortBTH <- c(0, 0, 0, 1, 0, 0, 0, 0) # A population that does both

# Bind them together
Tortvec3 <- cbind(AMP = TortAMP, ATT = TortATT, BTH = TortBTH)
Tortvec3

# Project to 50 time intervals
Tortp3 <- project(Tort, Tortvec3, time = 50,
                 standard.A = TRUE, standard.vec = TRUE)

# Define points
max3 <- apply(Tortvec3[,c(1,3)], 2, maxamp, A = Tort)

max3t <- apply(Tortvec3[,c(1,3)], 2, function(x){
  maxamp(vector = x, A = Tort, return.t = TRUE)$t})

min3 <- apply(Tortvec3[,c(2,3)], 2, maxatt, A = Tort)

min3t <- apply(Tortvec3[,c(2,3)], 2, function(x){
  maxatt(vector = x, A = Tort, return.t = TRUE )$t})

# Plot population
# And finally, let's plot
plot(Tortp3, log = "y"); lines(Tortpws, lty = 2)
points(c(max3t, min3t),
       c(max3, min3),
       pch = 3, col = "red")

```