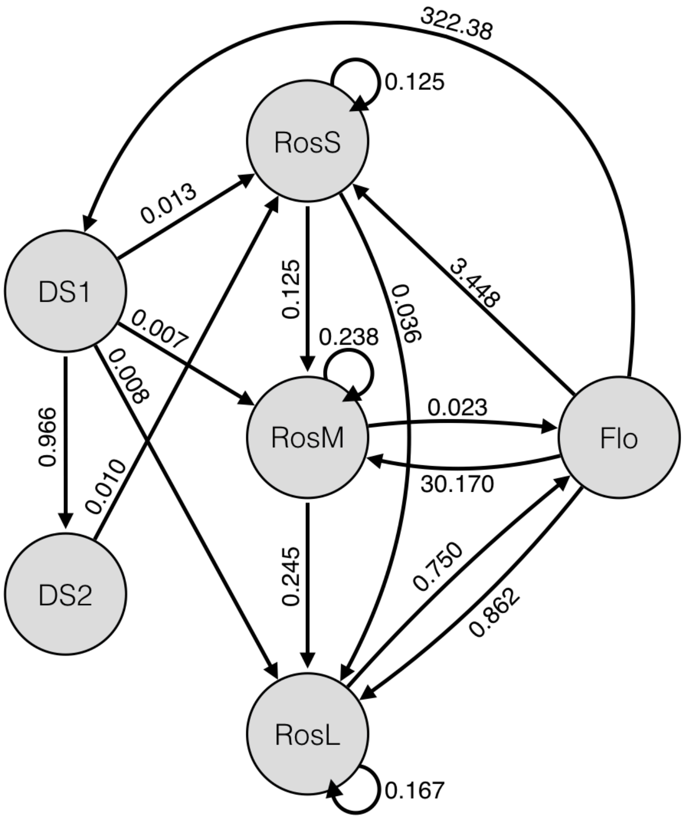
Name: ______**KEY**_________

Structured Population Models—Exercise 1

Natural history and life cycle of teasel (*Dipsacus sylvestris*)

Below is the life cycle diagram for a population of the perennial, monocarpic plant teasel. The life cycle consists of six stages: (i) first-year dormant seeds, (ii) second-year dormant seeds, (iii) small rosettes, (iv) medium rosettes, (v) large rosettes, and (vi) flowering plants. Plants can grow to larger sizes or shrink to smaller size. Plants only reproduce when they are flowering through seeds—there is no vegetative or clonal reproduction. Plants flower only once and die shortly after dispersing their seeds.



a. Convert the life cycle diagram into a stage-structured matrix population model, and calculate the stage-specific survival rates.

U – Survival & growth

Time t (columns); Time t+1 (rows)

	DS1	DS2	RosS	RosM	RosL	Flo
DS1	0	0	0	0	0	0
DS2	0.966	0	0	0	0	0
RosS	0.013	0.010	0.125	0	0	0
RosM	0.007	0	0.125	0.238	0	0
RosL	0.008	0	0.036	0.245	0.167	0
Flo	0	0	0	0.023	0.750	0
Survival	0.994	0.010	0.286	0.506	0.917	0

Key natural history detail: "Plants flower only once and die shortly after dispersing their seeds." Thus all 'Flo' plants must die.

F – Fertility

Time t+1 \ Time t	DS1	DS2	RosS	RosM	RosL	Flo
DS1	0	0	0	0	0	322.380
DS2	0	0	0	0	0	0
RosS	0	0	0	0	0	3.448
RosM	0	0	0	0	0	30.170
RosL	0	0	0	0	0	0.862
Flo	0	0	0	0	0	0

"Plants only reproduce when they are flowering through seeds—there is no vegetative or clonal reproduction." Don't be confused by Flo->RosL being less than 1. It's just rare for a plant to go from seed to large rosette in just 1 year.

C – Clonality

Time t+1 \ Time t	DS1	DS2	RosS	RosM	RosL	Flo
DS1	0	0	0	0	0	0
DS2	0	0	0	0	0	0
RosS	0	0	0	0	0	0
RosM	0	0	0	0	0	0
RosL	0	0	0	0	0	0
Flo	0	0	0	0	0	0

"Plants only reproduce when they are flowering through seeds—there is no vegetative or clonal reproduction."

A – Projection matrix

Time t+1 \ Time t	DS1	DS2	RosS	RosM	RosL	Flo
DS1	0	0	0	0	0	322.380
DS2	0.966	0	0	0	0	0
RosS	0.013	0.010	0.125	0	0	3.448
RosM	0.007	0	0.125	0.238	0	30.170
RosL	0.008	0	0.036	0.245	0.167	0.862
Flo	0	0	0	0.023	0.750	0

Suppose a new population is started (time=0) with 50 first-year dormant seeds and 50 second-year dormant seeds ($N_{DS1}=N_{DS2}=50$).

b. What is the total population size (N) at time=15?

```
library(popbio)
teasel <- matrix(c(0, 0, 0, 0, 0, 322.38,
                  0.966, 0, 0, 0, 0, 0,
                  0.013, 0.010, 0.125, 0, 0, 3.448,
                  0.007, 0, 0.125, 0.238, 0, 30.170,
                  0.008, 0, 0.036, 0.245, 0.167, 0.862,
                  0, 0, 0, 0.023, 0.750, 0), nrow = 6, byrow = TRUE)
pop0 <- matrix(c(50,
                 50,
                 0,
                 0,
                 0,
                 0),
```

```
                nrow = 6, byrow = TRUE)
pop15 <- pop.projection(A = teasel, n = pop0)$stage.vectors[, "15"]
sum(pop15)
```

$N_{t=15}$ = 1,824,897 (a lot of plants, but see section d. below)

c. What is the equilibrium population growth rate (λ)?

```
lambda(teasel)
```

λ = 2.333

d. What is the equilibrium population size structure (w)?

Stage	Proportion
DS1	0.6377
DS2	0.2640
RosS	0.0122
RosM	0.0693
RosL	0.0122
Flo	0.0046

```
stable.stage(teasel)
```

Notice that the population is already quite close to the equilibrium stage structure at t=15 (section b).

```
pop15/sum(pop15)  # this gives the stage structure at t=15 as a proportion
```

That means that >90% of the "plants" that are included in $N_{t=15}$ are seeds in the soil that are hidden from view. Only about 8,000 plants would be flowering, which is a lot, but is a reasonable number for a large agricultural field. Our model doesn't account for spread through seed dispersal, nor do the vital rates change in response to competition.

Assignment:

This matrix model for teasel was constructed in the United States, where teasel is invasive. Propose and evaluate an intervention to reduce the population growth of this species. The intervention strategy can use one or more mechanical, chemical, or biological controls. Please include:

i) A brief description of the intervention.

ii) Matrices (**A=U+F+C**) for a teasel population under the intervention with modified transition rates. The transition rates that are changed by the intervention should be indicated.

iii) A comparison of equilibrium population growth rates, $\lambda_{control}$ and $\lambda_{intervention}$. Do you predict that the intervention will drive the teasel population to extinction?

Submit your assignment as a Word, PDF, or similar file format by email to will.petry@usys.ethz.ch by 17:00 on Monday 1 May.