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FISH 558

Lab 4 HW

2/6/2024

1. **Age-structured model of a fish population with given parameters using the females**
   1. **Conceptual diagram**

A diagram of a graph

Description automatically generated with medium confidence

Figure : Conceptual diagram illustrating the age-structured model of the fish population in question. Five age classes are illustrated by subscripts 1 through 5. N refers to abundance, f to fecundity, and s to survival for a given age class. Not shown are f1 and s5 since both are equal to 0.

* 1. **Write abundance equations and describe their meaning**

For the later years (i.e. not age 1 fish), the abundance of an age class can be calculated as the abundance of the previous age class the previous year multiplied by that age class’ survival rate. This is different for the age 1 fish, since there is no previous age class. In this case, the abundance of age 1 is the summation of each other age’s fecundity multiplied by its abundance the previous year

* 1. **What is the fecundity for each age?**

Fecundity at age 1 is 0, since the fish are not yet sexually mature at this time. At age 2 it is 0.75, since the fish are half mature and fecundity at full maturity is 1.5. At ages 3, 4, and 5, the fish are fully mature, so fecundity is 1.5.

* 1. **Create and show a Leslie matrix with the proper values**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | **Age 1** | **Age 2** | **Age 3** | **Age 4** | **Age 5** |
| **Age 1** | 0 | 0.75 | 1.5 | 1.5 | 1.5 |
| **Age 2** | 0.4 | 0 | 0 | 0 | 0 |
| **Age 3** | 0 | 0.5 | 0 | 0 | 0 |
| **Age 4** | 0 | 0 | 0.6 | 0 | 0 |
| **Age 5** | 0 | 0 | 0 | 0.6 | 0 |

1. **Simulate the population trajectory for Mud Pond for 15 years**
   1. **What is the population growth rate? Increasing or decreasing by what percent?**

The population growth rate lambda is equal to 0.9627. This means that each year, the population is decreasing by approximately 3.73%. This lambda was calculated using the ratio between the overall abundance in the 15th year and the 14th year.

* 1. **Create a plot of total abundance through time?**

A graph with a line

Description automatically generated

Figure : Plot of total abundance (N, number of individuals) vs time (t, years) according to a 15-year simulated population trajectory for Mud Pond. All age classes are included together.

* 1. **What is the stable age distribution? Provide a graph and specific estimates.**

**A graph with numbers and lines

Description automatically generated**

Figure : Plot of the stable age distribution for the 15-year Mud Pond population simulation. The plot displays the proportion of animals belonging to each age class throughout the 15-year simulation. The red line represents Age 1 individuals and has a stable stage proportion of 0.54. The orange line represents Age2 (stable proportion = 0.22), dotted green represents Age 3 (0.12), dashed green represents Age 4 (0.07) and blue represents Age 5 (0.05). The exact proportion values reported in this caption were taken from pop.projection output.

1. **Conduct an elasticity analysis on the Leslie matrix**
   1. **What is elasticity?**

Elasticity is a quantitative measure of how a proportional change in one value will affect the value of lambda (population growth rate), given that all other values in the matrix are held constant. The elasticity value is the proportional change in lambda when the parameter in question is increased by 1%.

* 1. **Explain which single parameter a manager should focus on to recover the Mud Pond population?**

If we were to target only one single parameter to have the highest impact on population recovery in Mud Pond, it would be most appropriate to focus on the survival of Age 1 individuals, S1. The elasticity value for this parameter is 0.3178, meaning that the relative impact of a 1% increase in Age 1 survival will increase lamba by 31.78%. This is the highest elasticity value (the second-hjighest is Age 2 survival, 0.2149), indicating that this parameter has the largest relative impact.

1. **Simulate the population trajectory for 15 years if age-1 mortality is reduced to 50%. How does it change population dynamics and lambda?**

**A graph with a line

Description automatically generated**

Figure : Plot of total abundance (N, number of individuals) vs time (t, years) according to a 15-year simulated population trajectory for Mud Pond, under conditions where Age-1 mortality has been reduced from 0.6 to 0.5. All age classes are included together.

A comparison between Figure 4 and Figure 2 illuminates the clearest difference between these two simulations: Figure 4 displays a population growth scenario, while Figure 2 shows population decline. As discussed in Question 3, the survival of Age-1 fish was the parameter with the largest relative impact, so it’s perhaps not surprising that the scenario has changed so drastically. The population growth rate lambda, as calculated using the last two years, is 1.034. As explained in Question 2a, under that scenario, lambda was 0.9627. Since the growth rate is greater than 1 for the simulation in Figure 4, growth is expected. Likewise, a growth rate less than 1 leads to the decline shown in Figure 2.

1. **Collaborator?**

None, worked alone

1. **How many hours?**

458 part (questions 1-6): 2 hrs

558 part (question 7): 1 hr

1. **Read a peer-reviewed paper modeling aquatic animal using a Leslie matrix/life cycle model or a variant (e.g. lefkovitch model)**
   1. **Provide a <300 word synopsis, including background, ages/stages in model, any modifcations to standard Leslie matrix model, and conclusion. Citation and link.**

This paper concerned the development of a discrete-time stage-structured model for California newt populations in the Santa Monica Mountains in southern California. This species is disappearing from the Santa Monica Mountains due in part to drought. The researchers were particularly interested in incorporating varying intensities of drought conditions into the model to make predictions about how droughts will affect the persistence of these newts.

The newts were separated into three life stages: egg (E), juvenile (J), and adult (A). The egg stage used by the researchers is actually an amalgam of the newt’s egg and larva life stages, comprising one year spent completely in aquatic habitat. The newts then transition to land, where they spend 6 years in the juvenile life stage before becoming reproductive adults for up to 24 years. Below is a conceptual diagram of their model, followed by the equations.

A diagram of a mathematical equation

Description automatically generated with medium confidence

Figure : Conceptual diagram illustrating the stage-structured model of California newts in the Santa Monica Mountains. A description of the parameters involved follows below.

In Figure 5, the variables E, J, and A refer to the three life stages (egg, juvenile, and adult). The probability of transition between life stages is assigned to T, with TJ representing the probability of transitioning from egg to juvenile, and TA representing the probability of transitioning from juvenile to adult. There are also two probabilities of persistence assigned to P, with PJ representing the probability of a juvenile persisting (i.e. continuing to be a juvenile the following year), and likewise for PA and adults.

The most complex term in this model is the term new eggs recruited. As I will mention in the following question, the nitty-gritty is slightly above my head, but it incorporates adult newt abundance (A), eggs per female (alpha), available habitat (beta), and rainfall (r). The equations for the model are below.

**Reference**

Jones, M.T, Milligan, W.R., Kats, L.B., Vandergon, T.L., Honeycutt, R.L., Fisher, R.N., Davis, C.L., & Lucas, T.A. (2017). A discrete stage-structured model of California newt population dynamics during a period of drought. *Journal of Theoretical Biology, 414(*2017): 245-253.

Link: https://www.sciencedirect.com/science/article/pii/S0022519316303769

* 1. **What was interesting about the paper? What was hard to understand?**

I appreciated seeing one of these models being applied with a specific conservation-related goal. Perhaps it’s personal bias and values speaking, but I’m much more interested in techniques like this when they are describing a natural population of conservation focus, or trying to understand factors behind a decline, rather than describing the status of a stock for extractive purposes. The particular context of trying to project the persistence of a species of concern under drought conditions made it much more interesting to me.

The difficult parts to understand, as mentioned above, were some of the nitty-gritty math components. I understand all of the components involved in the egg production calculation, but I don’t understand how they all fit in to that equation. Additionally, there was a section of the paper focused on limiting the amount of time the newts could spend at a particular life stage (limiting a newt to, say, 6 years as a juvenile) which went over my head.

**Appendix: CODE pasted below**

library(popbio)

library(ggplot2)

# Question 2 ####

#a - run simulation

n.ages = 5

ages=c("Age 1", "Age 2", "Age 3", "Age 4", "Age 5")

f.1 = 0

f.2 = 0.75

f.3 = 1.5

f.4 = 1.5

f.5 = 1.5

s.1 = 0.4

s.2 = 0.5

s.3 = 0.6

s.4 = 0.6

s.5 = 0

leslie = matrix(c(f.1, f.2, f.3, f.4, f.5,

s.1, 0, 0, 0, 0,

0, s.2, 0, 0, 0,

0, 0, s.3, 0, 0,

0, 0, 0, s.4, 0), nrow=n.ages, byrow=T, dimnames = list(ages, ages))

N0=c(100, 65, 42, 20, 11)

n.years=15

project.15<-pop.projection(leslie, N0, n.years)

#b - create plot

years=c(0:(n.years-1))

plot1.df=data.frame(t=years, N=project.15$pop.sizes)

plot1<-ggplot(data=plot1.df, aes(x=t, y=N))+geom\_line()+geom\_point()+theme\_bw()

#c - stable age distribution

stage.vector.plot(project.15$stage.vectors)

# Question 3 ####

eig=eigen.analysis(leslie)

# Question 4 ####

#re-simulate with increased age-1 survival

s.1 = 0.5

leslie.2 = matrix(c(f.1, f.2, f.3, f.4, f.5,

s.1, 0, 0, 0, 0,

0, s.2, 0, 0, 0,

0, 0, s.3, 0, 0,

0, 0, 0, s.4, 0), nrow=n.ages, byrow=T, dimnames = list(ages, ages))

project.15.2<-pop.projection(leslie.2, N0, n.years)

plot2.df=data.frame(t=years, N=project.15.2$pop.sizes)

plot2<-ggplot(data=plot2.df, aes(x=t, y=N))+geom\_line()+geom\_point()+theme\_bw()