**FINAL EXAM BIOL 3295**

**Fall 2017**

**Instructor: Dr. Amy Hurford**

* You have 2 hours to complete this final exam
* A formula sheet is included on the last page of this question booklet
* Please write all your answers in the blue answer booklets provided
* Please write your name on all your blue answer booklets

Name\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Student ID \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

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| --- | --- | --- |
|  | No. of Marks | Score |
| 1. Defn population/Exponential growth | 10 |  |
| 1. Density dependence/Allee effect | 13 |  |
| 1. Age/stage structure | 10 |  |
| 1. Spatial models/climate change | 7 |  |
| 1. Eco-evolutionary dynamics/life history evolution | 10 |  |
| 1. Game theory/Adaptive dynamics | 10 |  |
| **Total** | **60** |  |

**I. Definition of a population/Exponential growth [10 marks]**

1. Give two reasons why counting the number of ducks on Burton’s Pond would not satisfy the strict definition of a population. [2 marks]
2. Give three assumptions of an exponential growth model. [3 marks]
3. For a continuous time model of exponential growth (see the formula sheet at the end of this question booklet), for what values of *r* does the population increase? [1 mark]
4. For a discrete time model of exponential (geometric) growth (see the formula sheet at the end of this question booklet), for what values of λ does the population increase? [1 mark]
5. For a continuous time exponential growth model, let the birth rate be b = 2 individuals per year and let the mortality rate be 1 individual per year. Assume the initial population size, at t=0, is 10. What will the population size be after 10 years (at time t = 10). [3 marks]

**II. Density dependence/Allee effects [13 marks]**

1. The following data was collected from a laboratory study of *Paramecium*. List a continuous time model of population growth that would be appropriate to fit to this data because the model has similar dynamics to that shown by the data. [1 mark]



1. Give 1 reason to choose the Beverton-Holt model rather than the discrete-time logistic model [1 marks]
2. Draw a graph of the per capita growth rate as a function of population size for:
   1. A continuous time exponential model (solid line) and,
   2. A continuous time logistic model. (dashed line) [2 marks]
3. For a continuous time logistic growth model (see the formula sheet), let N(t)=K. What is the value of dN/dt? Is K an equilibrium for this model? [2 marks]
4. For the discrete time logistic growth model (as given on the formula sheet), let Nt = K. What is the value of Nt+1? Is K an equilibrium for this model? [2 marks]
5. Define an Allee effect and give an example. [2 marks]
6. Sketch a graph of the per capita growth rate versus population size for a model with an Allee effect. Explain how your graph shows the existence of an Allee effect. [3 marks]

**III. Stage-/Age-structured populations [10 marks]**

1. The table below lists parameters that correspond to a stage-structured model for Grizzly bears (*Ursus arctos horribilis*) in Yellowstone National Park. Juvenile bears do not reproduce.

|  |  |  |
| --- | --- | --- |
| Parameter | Description | Value |
| *m* | The average litter size produced per adult bear | 0.318 |
| *sJ* | The probability a juvenile survives from one year to the next, but remains a juvenile | 0.4 |
| *sJA* | The probability the juvenile matures to be an adult | 0.3 |
| *sA* | The probability that the adult survives from year to year | 0.95 |

Data is modified from Harris et al. 2001. Ursus. 22(1): 24-36.

1. Write out the projection matrix for the Yellowstone grizzly bear population. [2 marks]
2. Calculate the eigenvalues for your projection matrix (13a). Based on this result is the population increasing or decreasing? [4 marks]
3. The computer print out for the right eigenvector of the projection matrix from part 13a. is: [-0.42, -0.91]. What information does this eigenvector tell you about the Yellowstone grizzly bear population? [2 marks]
4. A population of Atlantic puffins (*Fratercula arctica*) consists of 50 chicks and 20 adult birds. Researchers are worried that the young chicks are lured away from the ocean by city lights and that the number of chicks is too low for the population to sustain itself. The projection matrix for this population is,

where the rows and columns are organized with chicks first and adults second. Calculate the size of the population at the next time step [2 marks]

**IV. Spatial models/climate change [7 marks]**

1. From the list below, which are assumptions of a reaction diffusion model [5 marks]
2. Dispersal distances are normally distributed
3. Space is modeled as discrete patches
4. Long distance dispersers have higher reproductive rates
5. The net reproductive rate is highest in the center of the spatial domain
6. How far individuals disperse depends on local density
7. What does *p* represent in a metapopulation model? [2 marks]

**V. Eco-evolutionary dynamics/life history evolution [10 marks]**

1. Construct two life history tables that show one phenotype (LH1) that has an earlier age of first reproduction and lower survivorship across all age classes relative to the other phenotype, LH2. [2 marks]
2. Give an example of how ecology can affect evolution. [2 marks]
3. Calculate the lifetime reproduction, R0, for the life table below. [3 marks]

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Age, x | 1 | 2 | 3 | 4 | 5 | 6 |
| Fecundity, mx | 0 | 0 | 0 | 1 | 2 | 0.5 |
| Survivorship, lx | 1 | 0.9 | 0.8 | 0.5 | 0.4 | 0.3 |

1. Give two reasons why decreased fecundity for older individuals (i.e. senescence) has not been eliminated by natural selection [3 marks].
   * 1. **Game theory/adaptive dynamics [10 marks]**
2. Describe what it means for a strategy to be evolutionarily stable strategy? [2 marks]
3. True or false: All evolutionarily stables strategies are also Nash equilibria? [1 mark]
4. An evolutionary invasion analysis finds that a mutant phenotype (bm, pm) can invade if



where *b* is the per capita birth rate at low density, *p* is the year-to-year probability of surviving for the resident trait, and *bm* and *pm* are these same characteristics for the mutant trait. Suppose that *bm* = 2 and *b* = 1 and that there is a trade-off between fecundity and survivorship such that *p*(*x*) = exp(-*x*) where x is the per capita birth rate at low density. Will the mutant trait invade? [4 marks]

1. Is X1 an evolutionarily stable strategy for the payoff matrix below? Explain your reasoning [3 marks]

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Payoff to focal individual | | | | |
|  | Opponent | | | |
| Focal individual |  | X1 | X2 | X3 |
| X1 | 5 | 6 | 7 |
| X2 | 4 | 8 | 12 |
| X3 | 3 | 6 | 7 |