Use the following information for the next two questions. A population of oak trees is estimated to be at stable age distribution, with a constant life table, with reproductive number $\mathcal{R}$= 0.9. It takes the trees several years to reach maturity and reproduce.

1. This population is

A. **declining**
B. stable
C. increasing
D. showing damped oscillations
E. there is not enough information to answer this question

2. What is the *most accurate* statement you can make about the finite rate of growth λ, measured with a time step of one year?

A. We expect $\lambda < 0.9$
B. We expect $\lambda = 0.9$
C. We expect $\lambda < 1$
D. **We expect** $0.9 < \lambda < 1$
E. We expect $0.9 < \lambda$

Since the lifespan is long, we expect λ to be closer to 1 than 0.9. This relates to the theme of slow life cycles producing higher lambda under bad conditions, and so on.

3. Anthrax bacteria can survive for a long time in the soil, even though they are not active, do not feed, and do not reproduce. If each bacterium has a certain small chance of dying each day, regardless of how long it has been inactive in the soil, we expect the population to show what behaviour? *Choose the most precise correct answer.*

A. Linear decrease
B. Linear decrease or increase
C. **Exponential decrease**
D. Exponential decrease or increase

4. Cole's paradox suggests that, from a population biology point of view, it is a mystery why some plants:

A. Reproduce only once
B. **Reproduce many times**
C. Produce a large number of small seeds
D. Produce a small number of large seeds

5. Which of these traits would be *most* typical of a K-strategist?

   A. Has a low individual density at equilibrium
   B. Has a high individual density at equilibrium
   C. Competes poorly in crowded conditions
   D. **Competes well in crowded conditions**

6. Which of these traits would be *most* typical of an r-strategist?

   A. Large final size
   B. **Good dispersal**
   C. Production of a small number of high-quality offspring
   D. Good competitive ability
   E. Iteroparity

7. A simple population model has *structure*, but not *regulation* (individuals are assumed to be independent). Cohorts are not independent. If the model has $\mathcal{R}_0 > 1$, then: The modeled population __________ grow exponentially at first, and __________ grow exponentially as it approaches a stable age distribution (SAD)

   A. will; will
   B. **may not; will**
   C. will; may not
   D. may not; may not

Use this information for the next three questions. A population of phytoplankton reproduces on a strict daily cycle. They survive each day with probability 1/2 (so their average life span is 2 days). Surviving phytoplankton produce an average of 0.8 offspring that will survive to be counted the next day.

8. What is the reproductive number $\mathcal{R}$ for this population?

   A. 0.4
   B. 0.8
   C. 1.3
   D. **1.6**
   E. 2.4

9. What is the finite rate of increase reproductive number λ for this population?

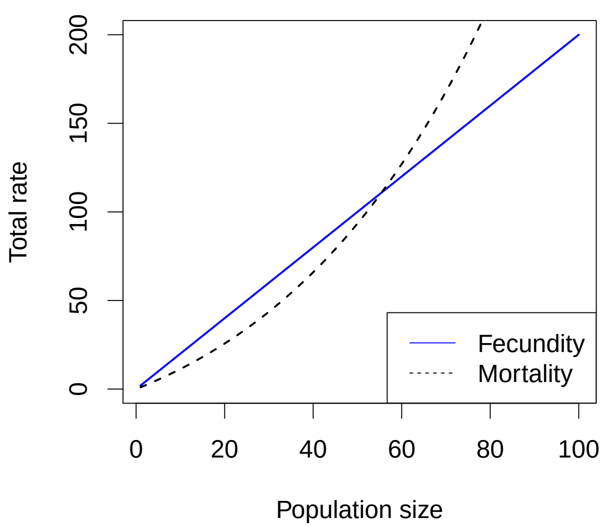
   A. 0.4
   B. 0.8
   C. **1.3**
   D. 1.6
   E. 2.4

10. What can you say about the units of the quantities above?

A. λ is unitless, while $\mathcal{R}$ has units [1/day]
B. $\mathcal{R}$ is unitless, while λ has units [1/day]
C. Both are unitless, but $\mathcal{R}$ is "associated" with the time step of 1 day
D. **Both are unitless, but λ is "associated" with the time step of 1 day**

11. Scientists need to be careful calculating the case fatality proportion of novel coronavirus and other new diseases because

A. It is hard to define what should count as a disease fatality (the numerator)
B. **It is hard to define what should count as a case of disease (the denominator)**
C. People may become immune to the disease through time

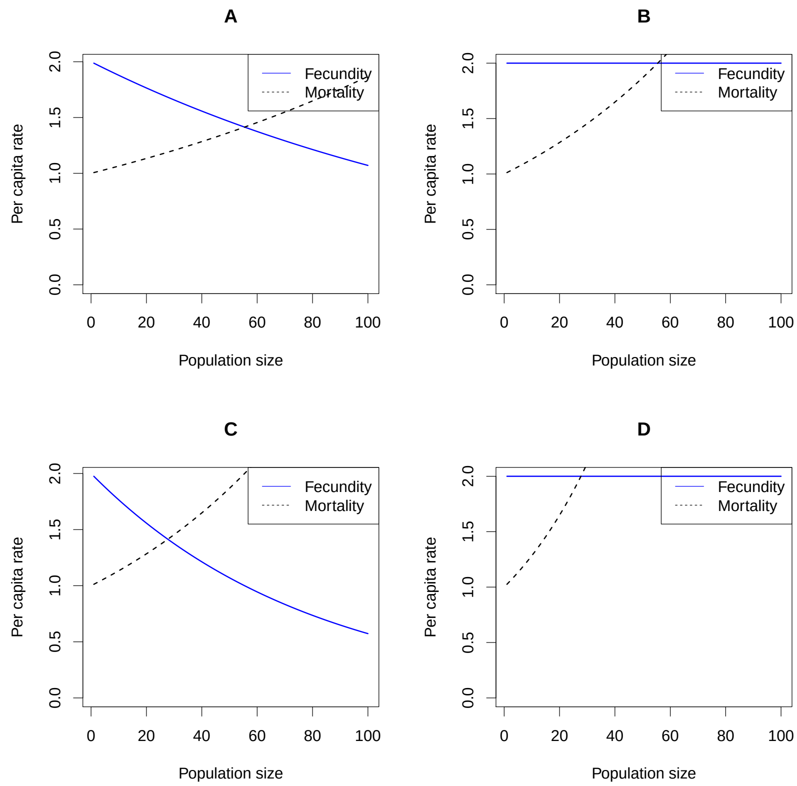


The figure above shows the assumptions made for a discrete-time birth-death model. *Use it for the next 3 questions.*

12. The figure shows:

A. No density dependence
B. Density dependence in fecundity only
C. **Density dependence in mortality only**
D. Density dependence in both mortality and fecundity

13. Which of the four pictures below was generated by the same model as the picture above?



ANS: B

14. A population following this model will:

A. Increase exponentially without limit
B. Decrease exponentially to zero
C. **Approach an intermediate equilibrium**
D. Decrease to zero if started near zero, and increase to an intermediate equilibrium otherwise

15. In logistic growth model, $\frac{dN}{dt} = r_{\max}N(1 - N/K)$, the unit of population density (N) is indiv/km^2 and the unit of time (t) is yr. The units of $r_{\max}$ are __________, and the units of K are __________.

A. yr; indiv.
B. yr; indiv/km^2.
C. 1/yr; indiv.
D. 1/yr**;** indiv/km^2**.**

16. A certain large island does not have any native snakes, despite the fact that snakes are occasionally washed there by storms. Which of the following is *not* a likely explanation for their failure to thrive?

A. Snakes experience Allee effects on the island
B. **Snakes experience density dependence on the island**
C. Snakes have very high death rates on the island
D. Snakes have very low birth rates on the island

17. In which of the following circumstances can an older age class have more individuals than a younger age class? Choose the broadest correct answer

A. Always: Older age classes are always larger than younger age classes
B. Never: Older age classes are never larger than younger age classes
C. **In a decreasing population**
D. In a stable population
E. In an increasing population

18. Individuals in a marigold population produce 40 seeds on average in the first year after it is born, and 60 seeds on average in the second year after it is born, assuming it survives. Seeds survive the first year (and become adults) with probability 0.03, and first-year adults survive to become second-year adults with probability 0.6. Second-year adults always die.

a) (2 points). Explain *briefly* what f_x means, and show how you calculate the values of f_x for this population. You should explain whether you are counting before or after reproduction (either is fine).

We choose to count before reproduction. f_x is the number of offspring we expect to see at next year's census for each individual in group x seen at this year's census.

The first age group we count has already survived for a year. They will produce 40 seeds on average, of which 0.03*40 = 1.2 will survive to be counted the next year. The second group produces 60 seeds on average, of which 0.03*60=1.8 will survive to be counted. So $f_1 = 1.2$ and $f_2 = 1.8$.

b) (2 points). Explain briefly what p_x means, and why you use the values you do *given your decision about when to count.*

p_x is the probability that an individual counted in group x will survive to be counted the next year. Since we are counting before reproduction, individuals we observe have already been alive for one year. We therefore want the probabilities that 1 (or 2) year old adults will survive until the next year. These are 0.6 and 0.

c) (2 points) Fill in the life table and calculate $\mathcal{R}$ for this population.

Life table

x	f_x	p_x	ℓ_x	$\ell_x f_x$
1	1.2	0.6	1.000	1.2
2	1.8	0	0.6	1.08
R				2.28

Counting after reproduction

In this case, f_1 is the probability of a seed surviving, multiplied by the expected number of seeds it will produce: 0.03*40=1.2, and f_2 is the probability of the one-year-old adult surviving multiplied by an expected number of seeds: 0.6*60=36.

The first survival probability is from seed to adult, so p_1 in this case is equal to 0.03. The second survival probability is from adult until *after the last time the plant reproduces*. Conventionally, we write $p_2 = 0$ in this case, but you could also say 0.6, as long as you then write a third row showing $f_3 = 0$.

Life table

x	f_x	p_x	ℓ_x	$\ell_x f_x$
1	1.2	0.03	1.000	1.2
2	36	0	0.03	1.08
R				2.28

19. We learned that tradeoffs are widespread in biology

a) (1 point) Give an example of a tradeoff in nature

Growing fast may lead to faster reproduction but shorter lifetime; having more offspring could lead to less investment per offspring; being able to survive in a wide range of environments could mean less efficiency in favorable environments

b) (1 point) Give a reason why tradeoffs are common under natural selection

If an organism could improve a quantity without any disadvantage, it would probably already have done so. Therefore, most adaptive "choices" available to organisms involve improving one thing but at a cost of being worse at something else.