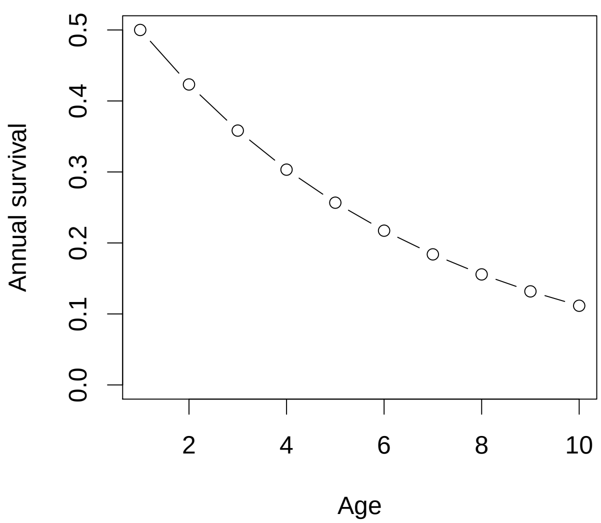
1. A scientist introduces a few thousand unknown bacteria into a large container whose nutrients and conditions may or may not be suitable for growth. She does not expect density dependence to be a factor over the course of the experiment. She should expect the population to show:

A. Linear increase
B. Either linear increase or decrease
C. Exponential increase
D. **Either exponential increase or decrease**
E. Linear or exponential increase or decrease

2. Which of the following traits is *not* typically associated with r strategies?

A. Fast life cycle
B. **Efficient resource use**
C. Relatively small investment per offspring
D. Relatively large investment in dispersal

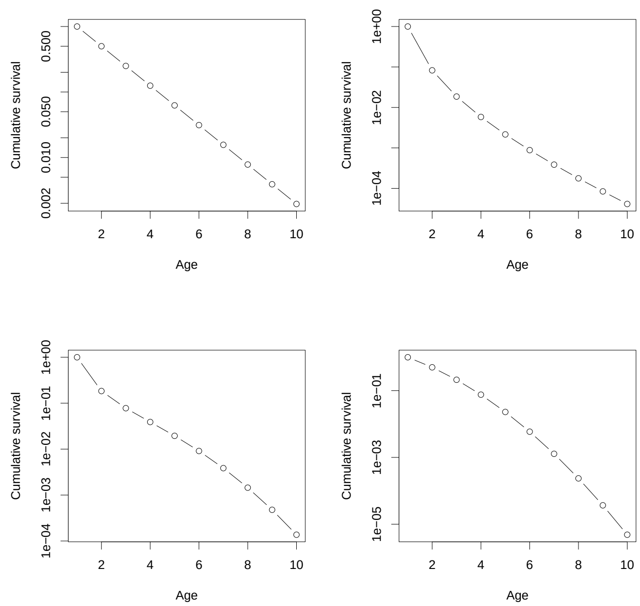


Use the picture above for the following 2 questions.

3. What does this picture of survivorship in an idealized age-structured population indicate about *mortality* in this population?

A. Mortality is constant
B. Mortality is elevated in older individuals
C. **Mortality is elevated in younger individuals**
D. Mortality is elevated in both older and younger individuals

4. The pictures below show *cumulative* survival. Which one corresponds to the picture shown above?



ANS: D

5. When an adult tree dies and falls in a certain pine forest, the seedlings that were already present and struggling for light in the area beneath it compete to grow tallest and take over the space. Eventually one of the seedlings wins and takes over the spot. This is an example of:

A. Contest competition that is a likely explanation for population cycles

B. **Contest competition that is not a likely explanation for population cycles**

C. Scramble competition that is a likely explanation for population cycles

D. Scramble competition that is not a likely explanation for population cycles

6. A population meets the assumptions of the balance argument for sexual allocation. If the population has more females than males at birth, this means:

A. Total investment of resources in producing females is higher than total investment of resources in producing males

B. Total investment of resources in producing males is higher than total investment of resources in producing females

C. Per-offspring investment of resources in producing females is higher than per-offspring investment of resources in producing males

D. **Per-offspring investment of resources in producing males is higher than per-offspring investment of resources in producing females**

7. Values in a life table always describe, for each individual counted __________, the number of individuals they are expected on average to produce that will be counted __________.

A. before reproduction; after reproduction
B. after reproduction; before reproduction one time step later
C. before reproduction; before reproduction one time step later
D. after reproduction; after reproduction one time step later
E. **at any point in the cycle; at the same point one time step later**

8. Many species maximize their long-term average value of λ by:

A. speeding up their life cycle in general
B. slowing down their life cycle in general
C. **speeding up their life cycle when conditions are good**
D. slowing down their life cycle when conditions are good

9. What is $10^{3\,\mathrm{m}}$?

A. 1000 m
B. 1000 m^3
C. **Complete nonsense**
D. The answer depends on context

10. It is hard to estimate the importance of old individuals to population growth in many populations because, in these populations:

A. They have high values of both p and f
B. They have low values of p and high values of f
C. They have high values of both ℓ and f
D. **They have low values of ℓ and high values of f**

11. A population of oak trees is estimated to be at stable age distribution, with a constant life table, with reproductive number $\mathcal{R} = 1.2$. It takes the trees several decades to reach maturity and reproduce. This population is

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

12. If we are thinking about a simple, continuous-time model, then for a population to be regulated:

A. **The average reproductive number $\mathcal{R}$ must be low at high density and higher at either low or intermediate density**

B. The birth rate b must be low at high density and higher at either low or intermediate density

C. The death rate d must be high at high density and lower at either low or intermediate density

D. All of the above

13. Which of the following is *not* an example of a tradoff?

A. Birds with heavier beaks have higher mortality before reaching maturity

B. **Bushes which produce more defensive chemicals live longer, and produce more viable seeds.**

C. Trees that grow quickly in full sunlight are more likely to die when shaded

D. Rabbits which need less food to survive produce fewer offspring when food is plentiful

14. A population is changing in continuous time, according to the equation $dN/dt = r(N)N$. What are the conditions for this population to be in equilibrium?

A. $r(N) = 0$

B. $0 < r(N) < 1/\,\mathrm{yr}$

C. $r(N) = 1/\,\mathrm{yr}$

D. $r(N) = 1$

ANS: A

15. Which of the following is always true of an age-structured population with a constant life table, at the stable age distribution?

A. If the population is increasing, then there are fewer individuals in younger age classes than older

B. If the population is decreasing, then there are fewer individuals in younger age classes than older

C. **If the population is increasing, then there are more individuals in younger age classes than older**

D. If the population is decreasing, then there are more individuals in younger age classes than older

16. (6 points) Consider a population of hedgehogs that reproduce once a year. The adult sex ratio is 1:1. A reproducing one-year-old female produces on average 4 female offspring. A reproducing 2-year old female produces on average 15 female offspring. 10% of female offspring survive to reproduce in their first year. 60% of females survive from the first to the second year; no-one survives longer.

a) (4 points) Construct a life table and calculate $\mathcal{R}$ for this population. State clearly whether you are calculating before or after reproduction, and show calculations for f_x and p_x

Before reproduction we have no brand-new individuals. To calculate f_x we take the number of female offspring our individuals are about to produce (4 or 15, respectively) and multiply it by survival from birth to reproduction (10%) to complete the annual cycle. Since everything is females per female already, we don't need the sex ratio, so the f_x are (0.4 and 1.5, respectively). The p_x are 0.6 and 0, respectively.

Before reproduction

x	f_x	p_x	ℓ_x	$\ell_x f_x$
1	0.4	0.6	1.000	0.400
2	1.5	0	0.600	0.900
R				1.300

After reproduction we do have brand-new individuals. To calculate f_x we take the survival from birth to reproduction (10%), or post-reproduction to reproduction (60%), and multiply by the number of female offspring our individuals will produce if they survive (4 or 15, respectively) to complete the annual cycle. The f are 0.4 and 9, respectively. The p are 0.10 and 0.6, respectively. It's also OK to say that p_2 is 0, because of the convention of not paying attention to things after they've reproduced for the last time. It is OK to exclude the last row of the life table (as we do), or to include it. If it's included, the correct f_3 is 0, leading to a contribution of 0.

After reproduction

x	f_x	p_x	ℓ_x	$\ell_x f_x$
1	0.4	0.1	1.000	0.400
2	9	0	0.100	0.900
R				1.300

b) (1 point) Write an equation that you could use to calculate λ for this population. Fill in numbers for all values except for λ.

The equation is $\ell_1 f_1 \lambda^{-1} + \ell_2 f_2 \lambda^{-2} = 1$. This comes out as:

$0.4\lambda^{-1} + 0.9\lambda^{-2} = 1$

c) (1 point) Write an expression showing the relationship between λ, $\mathcal{R}$ and 1 (e.g., $\lambda > \mathcal{R} = 1$ or $\lambda < 1 < \mathcal{R}$).

The time step is one year, and the time span of individual reproductive is longer (it always takes at least one year to complete a cycle and make an offspring, and sometimes two). So λ should be closer to 1 than $\mathcal{R}$ (and they should be on the same side). Since $\mathcal{R} > 1$, $R > \lambda > 1$.

17. An annual plant has variable fecundity: each female has an average of 2 successful female offspring in an good year (half of the time) and an average of 0.6 successful female offspring in a bad year (the other half of the time).

a) (1 point) What is the long-run average R for this species?

$\sqrt{2 \times 0.6} = 1.10$

b) (1 point) Now consider a different species ("species 2") that survives for 2 years but that has only half the fecundity per year: 1 successful female offspring per female for 1-year-olds and 0.3 successful female offspring per female for 2-year-olds (there is 100% survival from year 1 to year 2, and no survival after that). Construct the life table.

x	f_x	p_x	ℓ_x	$\ell_x f_x$
1	1	1	1.000	1.000
2	0.3	0	1.000	0.300
R				1.300

c) (1 point) What is R for species 2?

1.3

d) (1 point) What can you say about the stable age distribution for this population? Will there be more 1-year-olds, more 2-year-olds, or the same number?

Since $\mathcal{R} > 1$, we know $\lambda > 1$. Since $\ell_1 = \ell_2 = 1$, we know that $\ell_1\lambda^{-1} > \ell_2\lambda^{-2}$, so there should be more one-year-olds than two-year-olds.