Formulas

discrete time growth:

- $N_T = N_0 \lambda^T$
- $\lambda = f + p$
- $\mathcal{R} = f/(1-p)$

continuous time growth:

- $N(t) = N(0)\exp(rt)$
- $r = b - d$
- $\mathcal{R} = b/d$

structured growth:

- $\ell_x = p_1 \times p_2 \times \ldots p_{x-1}$
- $\mathcal{R} = \sum \ell_x f_x$

1. A researcher estimates that a moth population has a density of 10 pupae/ha in 2016, and finite rate of growth $\lambda = 1.4$ (associated with a time step of one year). The population on average is 2/3 male and 1/3 female. If λ remains constant, what is the approximate density of pupae the researcher will expect to see in 2024?

A. 27 pupae/ha
B. 49 pupae/ha
C. 54 pupae/ha
D. 74 pupae/ha
E. 148 pupae/ha

2. What value of the instantaneous growth rate r corresponds to the finite growth model described in the question above?

A. 0.34/yr
B. 0.34
C. 1.4/yr
D. 1.4
E. There is not enough information to tell

3. When we make an *unstructured*, discrete-time model of a perennial population, we usually census ________ because ________.

A. before reproduction; there are fewer individuals to count
B. after reproduction; there are fewer individuals to count
C. before reproduction; individuals are more likely to be similar to each other
D. after reproduction; individuals are more likely to be similar to each other
E. whenever is most convenient; our model already keeps track of everything we need

4. A biologist hypothesizes that her population is growing faster than exponentially, following the formula $N = N_0 \exp(kt^2)$, where N_0 is the initial population in units of [indiv]/[area], and t has units of [time]. What are the units of k?

A. 1/[time]
B. [indiv]/[time]
C. [area]/[time]
D. [area]/[time]^2
E. 1/[time]^2

5. Which of the following would be the strongest reason to prefer an age-structured model to a stage-structured model?

A. A life cycle that is usually of a predictable time length (like salmon)
B. A life cycle that is not of a predictable time length (like hemlock trees)
C. Large variation in size of reproductive organisms (like codfish)
D. Small variation in size of reproductive organisms (like storks)

6. My favorite lake has no trout, but nearby lakes with similar conditions and similar weather do. I introduce a pair of adult trout to my lake in a year when the trout in the nearby lakes are doing well, but my trout fail to establish a population (they go locally extinct in my lake). This is most likely due to:

A. Allee effects
B. Either Allee effects or environmental stochasticity
C. Either Allee effects or demographic stochasticity
D. Either environmental stochasticity or demographic stochasticity

7. If a simple model assumes individuals are independent of each other, then ________ birth rates should ________ the size of the population.

A. per capita; not be affected by
B. per capita; decrease with
C. total; not be affected by
D. total; decrease with

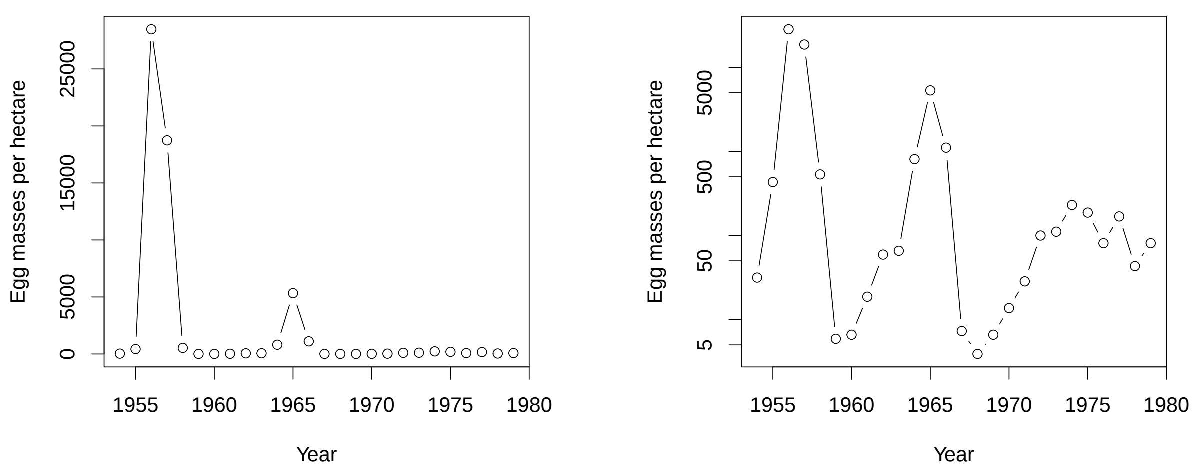
8. The ℓ_x column in a life table identifies

A. The probability of surviving from birth to age x
B. The probability of surviving from age 1 to age x
C. The probability of surviving from age $x - 1$ to age x
D. The probability of surviving from age x to age $x + 1$
E. The cumulative fecundity from age 1 to age x

9. In simple, discrete-time models of a single species competing for resources, we often see population cycles:

A. In models where competition is contest-like
B. In models where competition is scramble-like
C. In models without competition
D. We don't see population cycles in simple discrete-time models

Use the picture below for the next two questions.



10. Compared to the picture on the left, the picture on the right shows

A. A population with more of a tendency for contest competition
B. A population with more of a tendency for scramble competition
C. More of an individual-level perspective on the same population
D. More of an population-level perspective on the same population

11. The scientists probably chose to count egg masses instead of some other life stage because:

A. They want to observe as many individuals as possible
B. They want to observe individuals as close to the time of reproduction as possible
C. Egg masses are the easiest life stage to count reliably
D. Egg masses are an important food source for birds

12. 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 at a non-zero value?

A. $r(N) = 0$
B. $0 < r(N) < 1/\mathrm{yr}$
C. $r(N) = 1/\mathrm{yr}$
D. $r(N) = 1$

13. A population of small plants has discrete, overlapping generations, with year-to-year survival probability $p = 1/4$ and year-to-year fecundity $f = 1/2$. This population has:

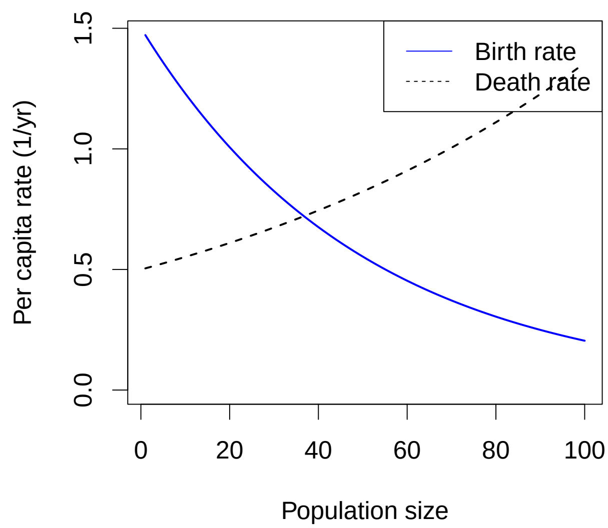
A. $\lambda = 2$ and $\mathcal{R} = 1.25$
B. $\lambda = 1.25$ and $\mathcal{R} = 2$
C. $\lambda = 0.67$ and $\mathcal{R} = 0.75$
D. $\lambda = 0.75$ and $\mathcal{R} = 0.67$

14. An individual's contribution to the reproductive number number $\mathcal{R}$ in age class x is given by the probability of surviving from ________ until age class x multiplied by the expected number of offspring ________.

A. birth; that survive to be counted at the next census
B. the first time the individual is counted; that survive to be counted at the next census
C. birth; produced in the following reproductive season
D. the first time the individual is counted; produced in the following reproductive season

15. The technical meaning of exponential change is:

A. Changing faster and faster
B. Changing at a constant rate
C. Changing at a rate proportional to the size of the thing changing
D. Changing at a rate proportional to time elapsed

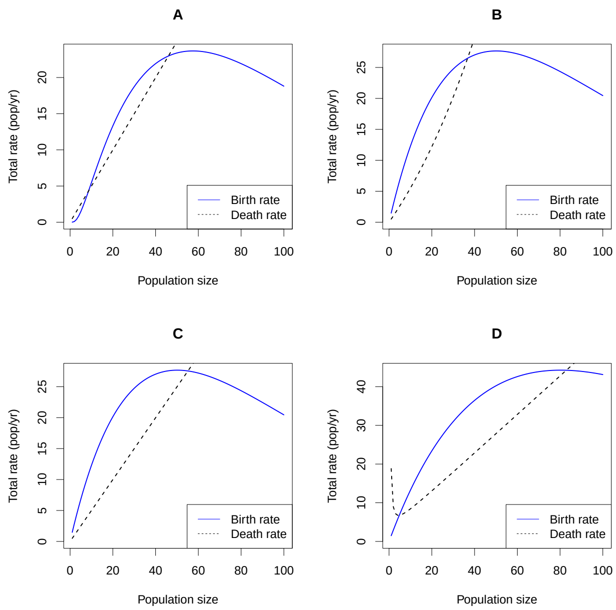


Use the picture above for the next 3 questions.

16. The figure shows:

A. Density dependence in mortality only
B. Density dependence in both mortality and fecundity
C. An Allee effect in mortality only
D. An Allee effect in both mortality and fecundity

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



18. This population has a(n) __________ equilibrium at 0 individuals and a non-zero __________ equilibrium

A. stable; stable
B. stable; unstable
C. unstable; stable
D. unstable; unstable

19. Which of the following is necessary for a population to reach a stable equilibrium?

A. $R(0)$ must be < 1
B. The death rate must be independent of the population size
C. The population growth rate must be positive just above zero
D. The population growth rate must be negative for very large population size
E. The population growth rate must be negative just above zero

20. A pile of radioactive material is decaying *continuously* at an instantaneous rate of 1%/minute. After two minutes, what proportion is left?

A. A little more than 98%
B. Exactly 98%
C. A little less than 98%
D. About 30%
E. None

Short-answer questions

Answer questions *in pen.* *Briefly* show necessary work and equations. Points may be *deducted* for wrong information, even when the correct information is also there.

21. (5 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 9 female offspring. 15% of female offspring survive to reproduce in their first year. 50% of females survive from the first to the second year; no-one survives longer.

a) 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

x	f_x	p_x	ℓ_x	

b) Based on your calculation of $\mathcal{R}$, what can you say about λ for this population?

A. Since $\mathcal{R} > 1$, we expect $\lambda > 1$; because the average life cycle is more than a year, we also expect $\lambda < \mathcal{R}$ (that is, closer to 1 than $\mathcal{R}$ is).