

Formulas

discrete time growth:

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

continuous time growth:

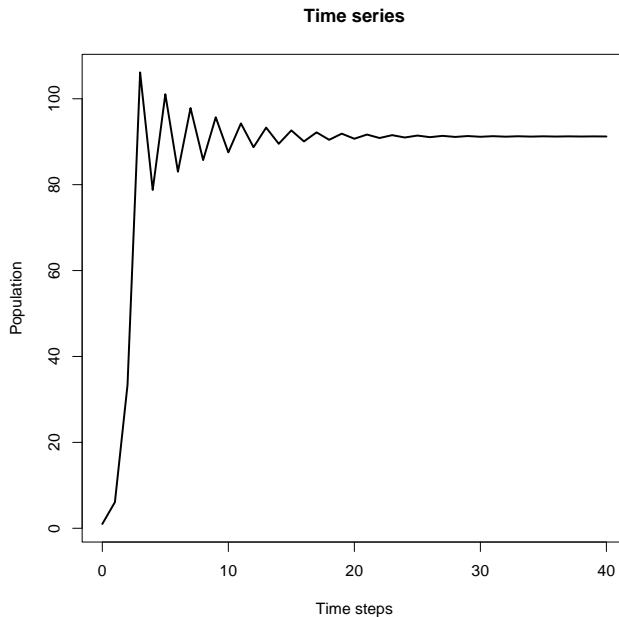
- $N(t) = N(0) \exp(rt)$
- $r = b - d$
- $\mathcal{R} = b/d$

1. When studying insect populations with non-overlapping generations, researchers often use the time when insects are pupating as their census time because

- A. pupae are easy to find and count accurately
- B. counting just before reproduction gives the most detailed information about the population
- C. counting just before reproduction gives the simplest accurate model of the population
- D. counting just after reproduction gives the most detailed information about the population
- E. counting just after reproduction gives the simplest accurate model of the population

2. If a simple model assumes individuals are independent of each other, then _____ death rates should _____ with the size of the population.

- A. per capita; increase
- B. per capita; decrease
- C. total; increase
- D. total; decrease



3. The picture above illustrates a time series that is:
- Converging smoothly to a stable equilibrium
 - Converging with oscillations to a stable equilibrium
 - Converging with oscillations to an unstable equilibrium
 - Oscillating without convergence around an unstable equilibrium
4. An ecologist believes that a population's fecundity decreases when crowded following the equation $f(N) = (N/N_e)^{-k}$. If N is measured in units of indiv/ha, then:
- N_e and k are also in [indiv/ha]
 - N_e is unitless, and k is in [indiv/ha]
 - N_e is in [indiv/ha], and k is unitless
 - N_e and k are both unitless
5. Which of the following processes is necessary for population cycles?
- Regulation
 - Allee effects
 - Stochasticity
 - Predator-prey dynamics
 - Age structure

6. In this class, the professor argued that populations cannot increase or decline exponentially for long, and that high population densities must:

- A. have direct positive effects on their own growth rate
- B. have either indirect or direct positive effects on their own growth rate
- C. have direct negative effects on their own growth rate
- D. have either indirect or direct negative effects on their own growth rate

Use this information for the following two questions. A population of small plants has discrete, overlapping generations. Adults survive each year with a probability of $3/4$ (and thus they have an average lifespan of four years). Each reproducing adult produces an average of 10 seeds *each year*, of which an average of 8% survive to reproduce in the next year. We model this population using a discrete-time model with time step of 1 year, and we count individuals just before reproduction.

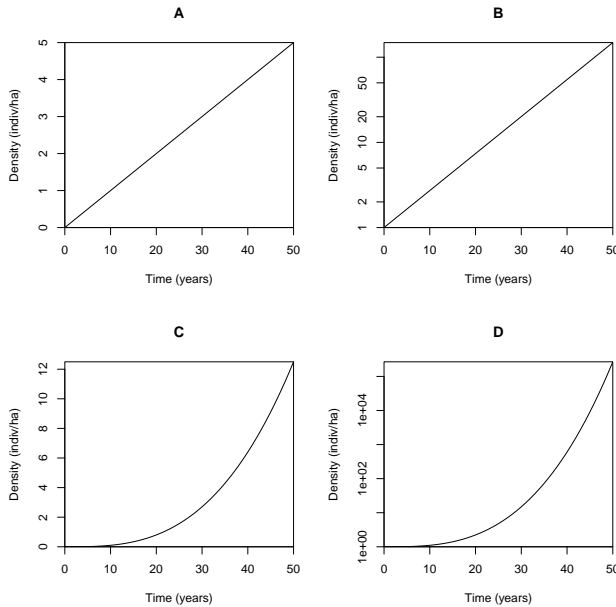
7. What are the values for survival p and fecundity f for this model?

- A. $p = 1/4$ and $f = 10$
- B. $p = 3/4$ and $f = 10$
- C. $p = 1/4$ and $f = 0.8$
- D. $p = 3/4$ and $f = 0.8$

8. The reproductive number \mathcal{R} for this population is:

- A. 1.05
- B. 1.55
- C. 3.2
- D. 10.25
- E. 13.33

9. One of the four pictures below shows a population growing exponentially – which one?



10. Consider a discrete-time, regulated population model with $p = 0$ and $f = f_0 \exp(-N/N_c)$ with $N_c = 50$ indiv/ha and $f_0 = 10$ What is $R(0)$?

- A. 5
- B. 10
- C. $\exp(-5)$
- D. $10 * \exp(-5)$
- E. $5 * \exp(-10)$

11. The long-term average finite rate of growth λ of a successful species should be:

- A. Very close to 0
- B. Substantially greater than 0, but substantially less than 1
- C. Very close to 1
- D. Substantially greater than 1

12. Plotting how population changes through time *on a log scale* reflects a(n) _____ perspective, because _____ changes through time reflect _____ rates of birth and death

- A. individual; additive; per capita
- B. individual; multiplicative; per capita
- C. population; additive; total
- D. population; multiplicative; total

13. In simple, continuous-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 continuous-time models

Use this information for the next two questions. A microbial population grows in a flask with discrete, non-overlapping generations (i.e., survival to next generation $p = 0$), and finite rate of increase $\lambda = 2$. Its generation time is 1 day. The population takes 20 days to fill 100% of the flask.

14. How much of the flask is filled after 19 days?

- A. 5%
- B. 50%
- C. 67%
- D. 95%
- E. There is not enough information to tell

15. Which of the following *most* accurately describes the instantaneous growth rate r for this population?

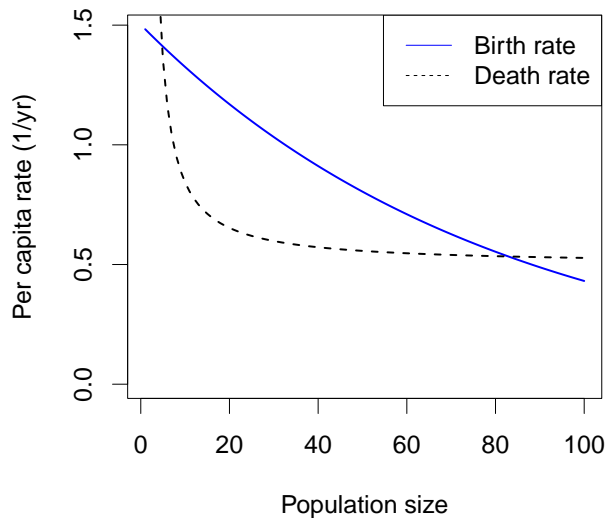
- A. $r < 0$
- B. $r > 0$
- C. $0 < r < 1$
- D. $r > 1$
- E. There is not enough information to tell

16. Which of the following *most* accurately describes the reproductive number \mathcal{R} for this population?

- A. $\mathcal{R} > 1$
- B. $1 < \mathcal{R} < 2$
- C. $\mathcal{R}=2$
- D. $\mathcal{R} > 2$
- E. There is not enough information to tell

17. 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?

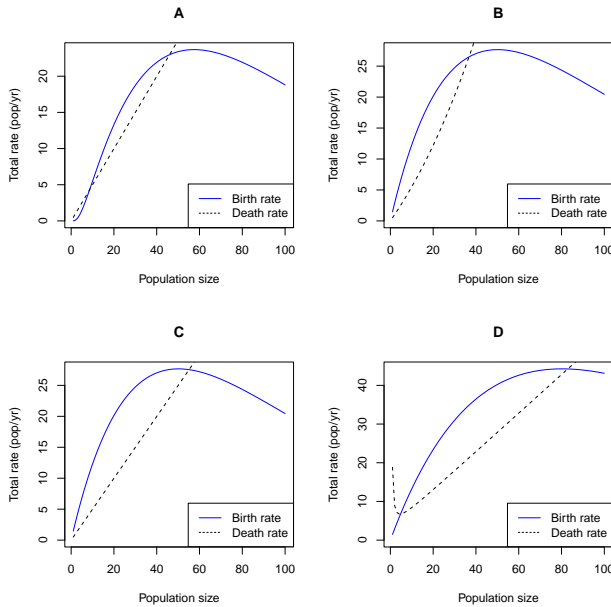
- A. $r(N) = 0$
- B. $0 < r(N) < 1/\text{yr}$
- C. $r(N) = 1/\text{yr}$
- D. $r(N) = 1$



18. The figure above shows _____ in the birth rate and _____ in the death rate

- A. density dependence; density dependence
- B. Allee effects; density dependence
- C. Allee effects; Allee effects
- D. density dependence; Allee effects

19. Which of the four pictures below was generated by the same model as the large picture?



- A. A
- B. B
- C. C
- D. D

20. This population has a(n) _____ equilibrium at 0 individuals and a(n) _____ equilibrium at 80 individuals

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

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. (4 points) A population of sea turtles was observed to decline from 1500 breeding females in the year 2005 to 1000 in 2020. The instantaneous death rate d was estimated at 0.035/year. The sea turtle population has a 1:1 sex ratio. For the purposes of this question, assume the population is changing exponentially, on average.

a) Why does d have units of [1/year] only (no turtles)?

b) What is the instantaneous rate of change r for this population?

c) What is the instantaneous birth rate b ?

d) What is the lifetime reproductive number \mathcal{R} ?

22. Give one plausible reason for density dependence in a population of seed-eating birds