

Use this information for the next four questions. A reintroduced population of wolves, starting with 20 individuals in year 0, is growing continuously at a rate of 5%/year.

The instantaneous growth rate is $r = 0.05/\text{yr}$.

1. The characteristic time of exponential growth/decline for this population is
 - A. 5 years
 - B. **20 years**
 - C. 5 per year
 - D. 20 per year

$$T_c = 1/r$$

2. The doubling time of this population is
 - A. Equal to the characteristic time
 - B. The inverse of the characteristic time
 - C. **Shorter than the characteristic time**
 - D. Longer than the characteristic time
 - E. Not enough information to answer

In one characteristic time, the population would double if it were growing linearly. Since it is growing exponentially, it increases by a factor of $e \approx 2.7$ in one characteristic time. The doubling time must be less than that.

3. If the wolf population continues to grow exponentially, approximately when will it reach 200 individuals?

- A. 20 years
- B. **46 years**
- C. 66 years
- D. 100 years
- E. Never

4. An ecologist wants to model this population with a discrete-time generation-based model, using a time step $\Delta t = 4\text{yr}$. Which of these is closest to the value of λ she should use to match the assumptions above?

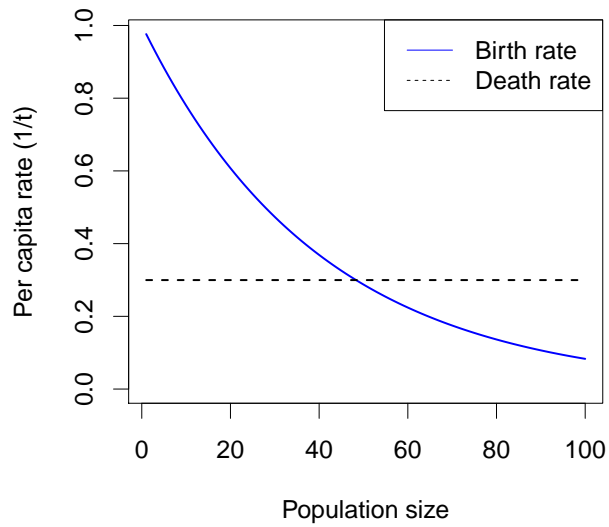
- A. 1.05
- B. 1.20
- C. 1.21
- D. **1.22**
- E. There is not enough information to answer this question

5. Compared to the instantaneous rate 0.05/hr, the instantaneous rate 1.2/day:
- A. **Means exactly the same thing**
 - B. Is not directly comparable, because they refer to different time steps
 - C. Is comparable, and refers to a larger (faster) rate
 - D. Is comparable, and refers to a smaller (slower) rate
6. Which of the following best illustrates resource *depletion* as opposed to simple competition?
- A. Swallows using up all of the available holes in a cliff site for breeding so that no space is left
 - B. Trees in a forest canopy growing so close together that no light gets through to the lower level
 - C. Introduced desert weeds using rainwater so efficiently that trees in the area have no access to water
 - D. **Gypsy moths eating so many oak leaves that the trees die**

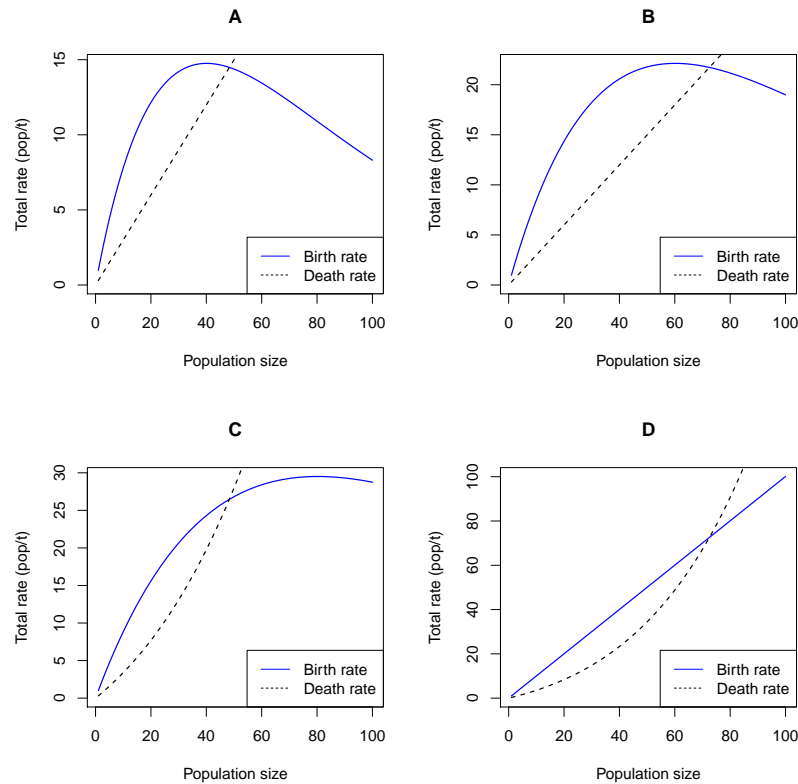
Use this information for the next two questions. A researcher estimates that a moth population has a density of 10 pupae/ha in 2012, and finite rate of growth $\lambda = 1.4$ (associated with a time step of one year). The sex ratio of the population is 2:1 (twice as many females as males at each stage).

7. If λ remains constant, what is the approximate density of pupae she will expect to see in 2020?
- A. 14 pupae/ha
 - B. 27 pupae/ha
 - C. 54 pupae/ha
 - D. 74 pupae/ha
 - E. **148 pupae/ha**
8. 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 yr
 - C. 1.4/yr
 - D. 1.4 yr
 - E. There is not enough information to tell

Use the picture below for the next three questions. It shows the assumptions made for a continuous-time birth-death model.



9. Which of the four pictures below could be generated by the same model as the picture above?



ANS: A

10. The model illustrated above predicts that the population will *decrease* when the population is:

- A. very small or very large
- B. very small (only)
- C. **very large (only)**
- D. between the two equilibria
- E. at the nonzero equilibrium

11. The highest *per capita* net growth rate (r) in this model is seen when the population is:

- A. **Near the zero equilibrium**
- B. between the two equilibria
- C. Near the non-zero equilibrium
- D. very large

12. Which of the following is *not* a possible scenario for density-dependent population regulation?

- A. The birth rate decreases with density and the death rate increases
- B. The birth rate and death rate both increase, but the death rate increases faster
- C. The birth rate and death rate both decrease, but the birth rate decreases faster
- D. **The death rate decreases with density and the birth rate increases**

13. An ecologist believes that a population's fecundity decreases when crowded following the equation $f(N) = (N/N_e)^\alpha$. If N is measured in units of indiv/ha, then:

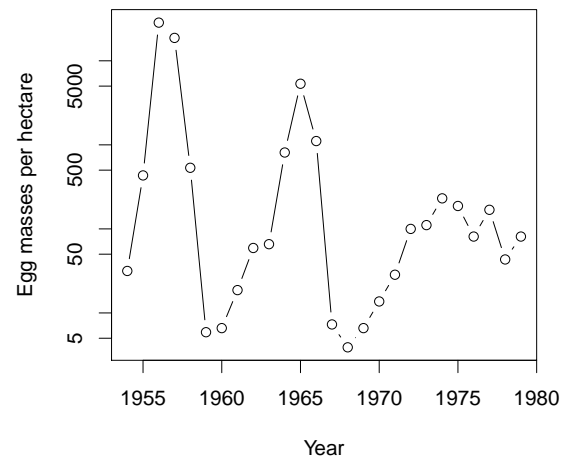
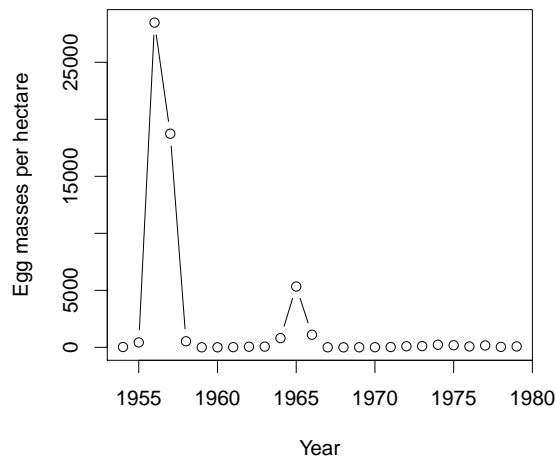
- A. N_e and α are also in [indiv/ha]
- B. N_e is unitless, and α is in [indiv/ha]
- C. **N_e is in [indiv/ha], and α is unitless**
- D. N_e and α are both unitless

14. Cycling is most likely in a population where competition _____ depletion and acts _____ a delay.

- A. leads to; without
- B. does not lead to; without
- C. **leads to; with**
- D. does not lead to; with

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

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



16. The picture above on the _____ shows population on a log scale. Compared to the other picture, it shows _____.

- A. left; individual density instead of total density
- B. left; the same numbers, but from a different perspective
- C. right; individual density instead of total density
- D. **right; the same numbers, but from a different perspective**

17. Populations are *regulated* (kept under control) when their growth rate tends to _____ when the population _____.

- A. decrease; has been established for a long time
- B. **decrease; becomes larger**
- C. increase; has been established for a long time
- D. increase; becomes larger

18. (4 points). A pack of marmots invades a previously vacant mountaintop. In 150 years, the population increases from 5 marmots to 2000 marmots. The instantaneous birth rate of the population is 0.5/yr. The average sex ratio is 3 females for every 2 males. For the purposes of this question, you can assume the population is growing exponentially, on average.

1 point for each sub-question. Half just for a correct equation. Don't deduct twice for the same mistake. Any units missing should deduct at least half a point. Half a point off unless year units are used consistently (and cancelled for \mathcal{R}). If neither marmots nor individuals are used, you should probably circle, but you don't need to deduct.

- a) Draw a plot showing the size of this population through time. Label and number your axes and say whether you are using log or linear scales
- b) What are the instantaneous growth rate of the population, r , and the instantaneous death rate, d ?

Since $N = N_0 \exp(rt)$, then $r = \log(N/N_0)/t$. $\log(2000\text{marmots}/5\text{marmots})/150\text{yr} = 0.040/\text{yr}$.

Since $r = b - d$, $d = b - r = 0.5/\text{yr} - 0.040/\text{yr} = 0.46$

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

Since $r > 0$, we expect $\mathcal{R} > 1$. $\mathcal{R} = b/d = (0.5/\text{yr})/(0.46/\text{yr}) = 1.09$

- d) If we were to model this population with discrete time steps of 4 years, what would be the finite growth rate λ ?

λ is the amount of increase in time Δt , so $\lambda = \exp(r\Delta t) = \exp((0.040/\text{yr})(4\text{yr})) = 1.22$. *How do you interpret the fact that $\lambda > \mathcal{R}$ in this case?*

The answer is that our time step is longer than the average generation time, so the time-step multiplier is more than the lifetime multiplier.

19. Consider a population of antelopes that experiences an Allee effect and regulation.

- a) Draw a plot of the *total* birth and death rates for the population. Show both lines on the same graph, using different line types to indicate birth and death. Label the lines directly or add a legend to the plot.
- b) Indicate any equilibria on your plot, and say whether they are stable or unstable
- c) Does the graph you've drawn represent a strong or a weak Allee effect? Explain why.

Why don't I have an answer for this?

- d) Give one plausible ecological reason that the Allee effect might occur.

Collective hunting behaviour; difficulty finding mates; inbreeding.

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