

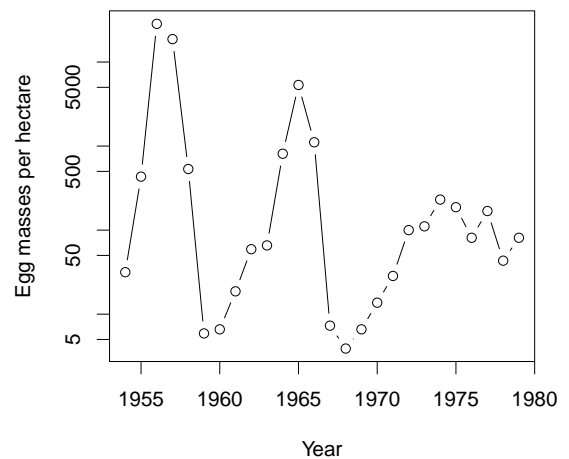
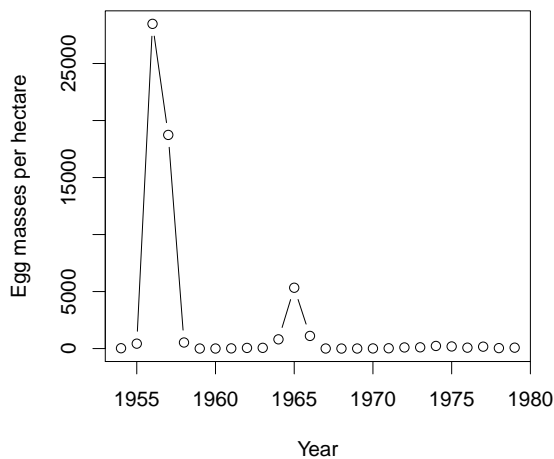
Formulas

discrete time growth:

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

continuous time growth:

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

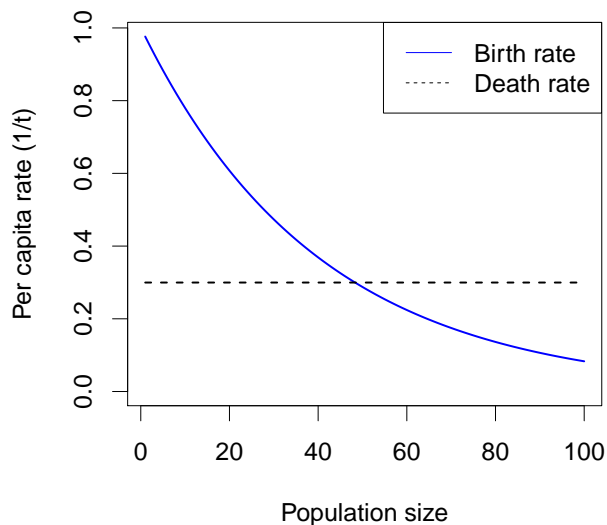


1. The picture above on the _____ shows population on a log scale. Compared to the other picture, it shows _____.

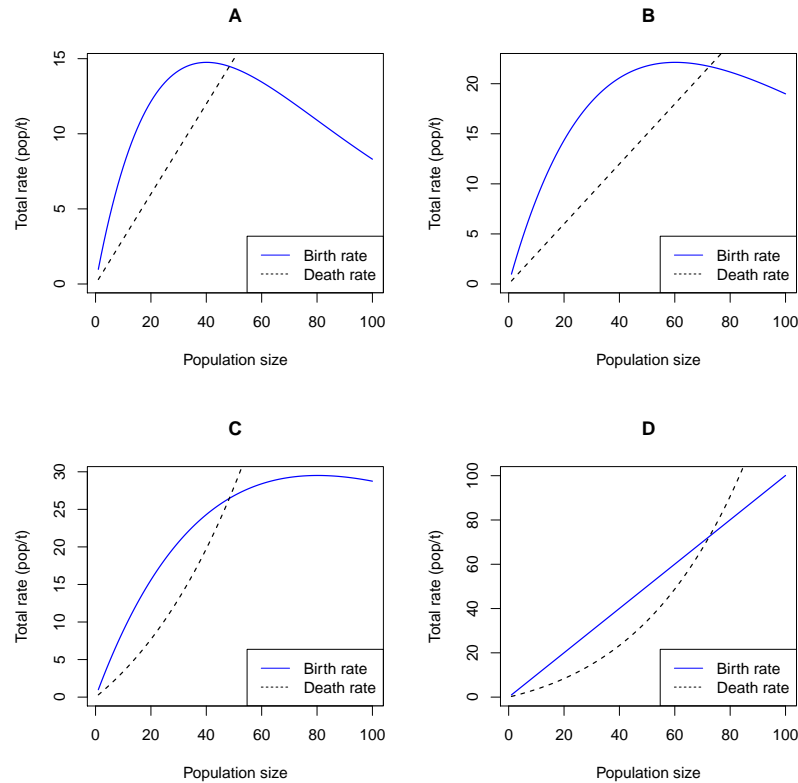
- A. left; individual density instead of total density
- B. left; the same numbers, but from a different perspective
- C. right; individual density instead of total density
- D. right; the same numbers, but from a different perspective

2. 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
3. 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
4. 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

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



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



6. 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

7. 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

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).

8. 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

9. 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

10. 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

11. 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

12. 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

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.

13. 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
14. 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
15. 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
16. 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
17. 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

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

18. (4 points). A pack of marmots invades a previously vacant mountaintop. In 80 years, the population increases from 5 marmots to 1000 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.

- 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 ?

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

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

19. (4 points) 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.

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