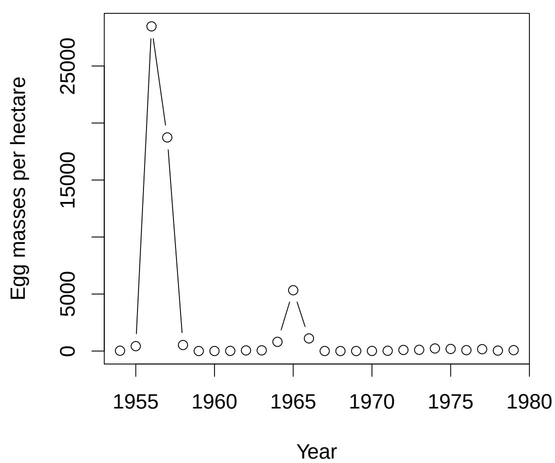
Formulas

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

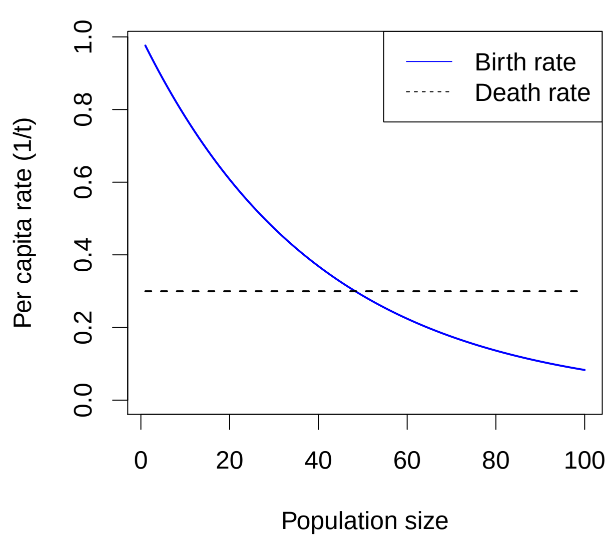
3. Populations are *regulated* (kept under control) when their growth rate tends to __________ when the population __________.

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

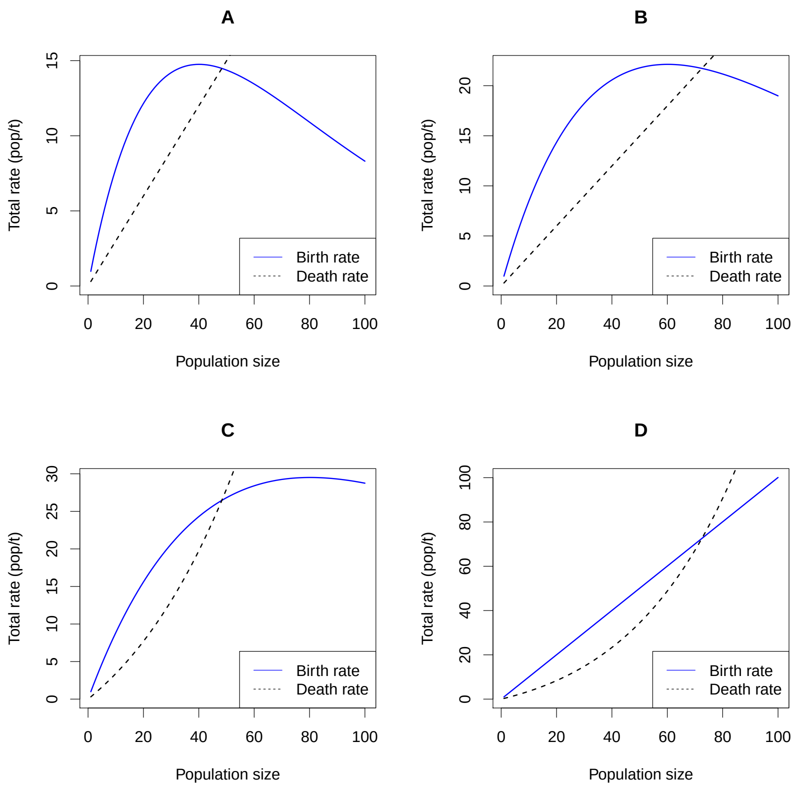
4. Which of the following is *not* a possible scenario for density-dependent population regulation?

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.